

Explaining US employment growth after the great recession: The role of output–employment non-linearities



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ABSTRACT

We investigate the relationship between employment and GDP in the United States. We disentangle trend and cyclical employment components by estimating a non-linear smooth transition error-correction model that simultaneously accounts for long-term relationships between growth and employment and short-run instability over the business cycle. Based on out-of-sample conditional forecasts, we conclude that, since the end of the 2008–09 recession, US employment is on average around 1% below the level implied by the long run output–employment relationship, meaning that about 1.2 million of the trend employment loss cannot be attributed to the identified cyclical factors.

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1. Introduction

One of the central puzzles following the financial crisis and the ensuing Great Recession has been the sluggish growth in employment during the recovery which began in June 2009. It is somewhat surprising that analysts have worried about how employment growth has recently outpaced GDP, according to Okun's law (Okun, 1962), while others have bemoaned the slow pace of employment growth.¹ Underpinning these discussions is a view that there is instability in this relationship between changes in employment and GDP growth.² From mid-2008 through the end of the recession, employment growth was below that predicted by a simple regression of employment growth on GDP growth over the 1987Q1–2007Q4 period; this outcome continuing into the first year of the recovery period. There does seem to be a consistent pattern wherein contractions are associated with employment growth below that implied by the relationship that obtains over both upswings and downswings.

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¹ See, e.g., Sanchez and Thornton (2011), as well as the article "Piecing Together the Job-Picture Puzzle" published in the *Wall Street Journal* in March 12, 2012.

² See, e.g., Knotek (2007), McCarthy et al. (2012) and Owyang and Sekhposyan (2012). Strictly speaking, these papers deal with the unemployment-output relationship, not with the employment-output one. However, as we will explain in Sections 2 and 3, we prefer focusing on employment growth rather than changes in the unemployment rate which is a function of both employment growth and labor force participation rates.

Our analysis is related to the issue of whether structural unemployment³ has risen in the wake of the Great Recession. This issue is of major importance for policy-makers, and biased estimation of natural levels of employment and unemployment can lead to inadequate economic policies. For example, in terms of monetary policy-making, under-estimates of the degree of labor slack can spur overly-tight monetary policy rates by way of standard Taylor equations. Within this context, disentangling structural and cyclical employment components is a key question. We shed light on this issue by identifying the portion of employment that cannot be attributed to statistically defined trend and cycle components.

To investigate whether our variables of interest share a common trend, we estimate the cointegrating relationship between output and employment. We also specify a decomposition of employment between trend and cyclical factors, wherein one could potentially interpret the trend factors as structural in nature—i.e., as factors that affect the structure of the employment–output nexus.⁴ This caveat is necessary because statistically defined trend factors could be structural in origin, but might also conceivably incorporate factors that are not long term in nature, such as enhanced unemployment insurance benefits.⁵ Our specification also incorporates non-linear adjustment dynamics to account for potential instability over the business cycle.

Accordingly, relying on a non-linear error-correction specification over the 1950–2012 period, our main findings can be summarized as follows. First, failing to account for the long-term relationship between GDP and employment (i.e., focusing only on the relationship in first differences), results in an overestimate of employment by a substantial amount during the post-crisis, 2008–2012 period. Second, a standard error-correction model (ECM) is able to reproduce the general evolution of employment, but underpredicts the decline in employment during the recession, and therefore overpredicts employment during the recovery. Third, accounting for the US business cycle by using an innovative non-linear smooth transition error-correction model enables a better reproduction of stylized facts, even without imposing priors on the beginning and end of recessions. Fourth, we still overestimate, albeit by a smaller amount, actual employment on average by 1.05% during the post-recession period. This means that the level of employment averages 1.17 million lower than would have been predicted on the basis of the historical co-movement of employment and GDP.

2. A brief review of the recent literature

Several studies have concluded that the cyclical component cannot account for the entire change in employment. In this respect, [Stock and Watson \(2012\)](#) argue that the slow recovery is mainly explained by a decline in the trend growth of the labor force.

A variety of explanations have been proposed regarding the effect of factors affecting structural employment. [Estevão and Tsounta \(2011\)](#) estimate that about 1.75 percentage point of the increase in unemployment between 2006 and 2010 is due to the growing degree of mismatches between labor market demand and supply given weak housing market conditions. In a multi-country framework, [Chen et al. \(2011\)](#) argue that sectoral shocks specific to the Great Recession—namely in the construction sector and, to a lesser extent, in finance—have contributed to increase the long-duration unemployment rate. Various other explanations include the extension of unemployment benefits and high uncertainty about future economic outlook; however these arguments seem to have less explanatory power (see, e.g., [Daly et al., 2011](#)).

In contrast, others argue that there is little evidence of structural impediments on the labor market, given that modest employment recoveries are commonplace after balance sheets crises. According to this view, the lack of aggregate demand is the main driver of the current high unemployment rate and consequently the job market will return to its pre-recession equilibrium when economic conditions will improve. [Lazear and Spletzer \(2012\)](#) conclude that “neither industrial nor demographic shifts nor a mismatch of skills with job vacancies is behind the increased rates of unemployment”. They recognize that job market mismatches increased during the recession, but argue that those discrepancies diminished at the same pace just after the recession exit.

In a recent work, [Ball et al. \(2013\)](#) defend this point of view and argue that there is no jobless recovery in the US, but only a sluggish economic growth that weighs on the labor market. To support their analysis, they estimate Okun’s law for a sample of 20 advanced countries and show that there is a strong and stable relationship between output and employment. Based on empirical findings, [Rothstein \(2012\)](#) dismisses any structural factors to explain the low labor market activity. [Farber \(2012\)](#) estimates as well mobility rates and does not find any evidence that low geographic mobility, due to a deteriorated housing market, explains the weak labor market.

Given this lack of consensus regarding the decomposition of employment between structural and cyclical factors in the wake of the Great Recession, we propose a non-linear econometric model which enables us both to decompose movements in employment into trend and cyclical components, and to account for instability over the business cycle. Indeed, to evaluate the relationship between output and labor market fluctuations, the empirical Okun’s law has been a valuable tool, as pointed

³ By “structural employment”, we refer to unemployment caused by non-cyclical factors, including fundamental shifts in an economy (see Section 2 for more details on factors that may induce such changes).

⁴ To avoid any confusion, let us specify that we use the term “structural” in this paper to refer to factors that affect the structure of the long-run employment–output relationship.

⁵ For instance, [CBO \(2012\)](#) estimates both a long-term natural rate of unemployment, and one accounting for short-run factors. The former is driven by demographics and skill attributes, while the latter is determined in part by extended unemployment insurance benefits. For the sake of completeness, it should also be noticed that regarding hysteresis effects, part of trend employment will depend on long-lasting cyclical effects.

out by [Ball et al. \(2013\)](#) among others. [Knotek \(2007\)](#) as well suggests evidence that Okun's relationship between changes in the unemployment rate and output growth can be a useful forecasting tool, in spite of considerable instability over time and over the business cycle (see also [Owyang and Sekhposyan, 2012](#)). However, this instability in the relationship is not confirmed by [Ball et al. \(2013\)](#), who also reject evidence of non-linearity based on sub-samples investigations.

Nevertheless, focusing on the unemployment rate can lead to spurious results as recent plummet in labor force participation rate ([Erceg and Levin, 2013](#)) has arguably resulted in distortions in the US unemployment rate as a measure of economic slack. Given the uncertainty related to the evolution of the participation rate, as pointed out by [Bengali et al. \(2013\)](#) or [Aaronson and Brave \(2013\)](#), we opt to directly focus on employment levels instead of the unemployment rate.

3. Assessing the output – employment relationship

In this section, we first review some existing basic models available to describe labor market evolutions and GDP growth in the short run. Then we propose a non-linear specification that simultaneously accounts for short and long-run dynamics. This latter model enables decomposition between cyclical and trend components of employment, accounting also for instability over the business cycle.

3.1. Short-term models

Arthur Okun documented the evidence for his eponymous law, the empirical relationship between the unemployment rate and output growth, in 1962. Since then, several versions of Okun's law have been developed. Some are expressed in levels, some in deviations from natural levels (gaps), and some in growth rates. For example, the original Okun's law was expressed in differences such as:

$$\Delta UNR = \alpha + \beta \times \Delta LGDP, \quad (1)$$

where $\Delta LGDP$ is the change in the logarithm of real GDP and ΔUNR is the change in the unemployment rate. The parameter β is sometimes referred to the Okun's coefficient and is expected to be negative, reflecting thus the negative correlation between changes in unemployment and output growth. The ratio $-\alpha/\beta$ is an estimate of the rate of output growth necessary to stabilize the unemployment rate.

Alternatively, the gap version of Okun's law linearly relates the unemployment rate with the output gap, as defined by the difference between the observed GDP and its potential value, such as:

$$UNR = \delta + \lambda \times (LGDP - LGDP^*), \quad (2)$$

where $LGDP^*$ denotes the potential value of log-GDP, which has to be estimated by a given econometric method, and $(LGDP - LGDP^*)$ is the output gap. The parameter δ can be seen as the unemployment rate consistent with full employment. Alternatively, the natural unemployment rate U^* can be estimated exogenously before entering into Eq. (2). In that case, the left-hand side of Eq. (2) becomes $(UNR - UNR^*)$, referred to as the unemployment gap, and λ is set to zero. This gap specification is generally easier to estimate than the differences specification as variables involved are smoother. But the main drawback is that potential GDP and natural unemployment rate are unobserved values and have to be estimated using econometric methods, such as filtering techniques (Hodrick–Prescott or band-pass filters). As there is no consensus on the way to estimate such quantities,⁶ measurement error exacerbates the imprecision in estimating the relationship.

Departures from those original versions of Okun's law given by Eqs. (1) and (2) are motivated by two observations. First, those equations do not include any long-term effect between the two variables as the low-frequency information is eliminated by first differencing or by subtracting potential log-GDP. However, the omission of long-run effects can be costly if long-run relationships in fact exert a strong effect on short-run changes in employment or output. Hence, we incorporate the long-term relationship between employment and output in the framework of error-correction models, as both log-GDP and log-employment series are obviously integrated. We show in the following section how this choice is validated by the results. Using employment data instead of unemployment data also presents the great advantage of sidestepping participation rate that can induce measurement error when relying on the unemployment rate. To be concrete, note that [Stock and Watson \(2012\)](#) conclude that the participation rate decreased from 66% in 2007 to less than 64% in 2012, implying thus a lower unemployment rate for a given level of unemployment in the years 2011–12.

Second, some authors have detected evidence of instability in Okun's law over time. Using standard rolling regressions and estimating the relationship over many different samples, [Knotek \(2007\)](#) underlines a great time variation of the estimated parameters of Okun's law. In particular, he shows that Okun's law is sensitive to the state of the business cycle. Other authors have also investigated the non-linear dynamics of Okun's law, including [Lee \(2000\)](#), [Viren \(2001\)](#) and [Harris and Silverstone \(2001\)](#). According to [Harris and Silverstone \(2001\)](#), four factors may explain the presence of non-linearity in Okun's relationship: capacity constraints, signal extraction, costly adjustment and downward nominal wage rigidity. In addition, [McCarthy et al. \(2012\)](#) underline that Okun's law has not been a consistently reliable tool to forecast the amplitude of decline in the unemployment rate during the last three recessions.

⁶ In particular, [Lee \(2000\)](#) has shown that the estimated Okun's relationship is sensitive to the method used for extracting the cyclical component.

When dealing with employment instead of unemployment rate, as we do in the present study, a natural approach is to extend the previous Okun's rule by replacing the unemployment rate in the left-hand side of Eq. (1) by the differences in log-employment, denoted by $\Delta LEMP$. This latter approach, that we call *employment version of Okun's law*, will be used in the empirical section of this paper.

3.2. Accounting for long-term dynamics and instability: a non-linear approach

Our aim is to account simultaneously for those two stylized facts described above, namely the existence of a potential long-term relationship between employment and output, and instability effects stemming from the sensitivity of Okun's law to the business cycle. In this respect, we consider a non-linear, smooth transition error-correction model (STEM) whose parameters are allowed to evolve through time. More specifically, we retain the following non-linear specification with two regimes:⁷

$$\Delta LEMP_t = \alpha_0 + \alpha_1 \Delta LEMP_{t-1} + \alpha_2 \Delta LGDP_t + \alpha_3 \Delta LGDP_{t-1} + \alpha_4 (LEMP_{t-1} - \beta_0 - \beta_1 LGDP_{t-1}) + [\alpha'_0 + \alpha'_1 \Delta LEMP_{t-1} + \alpha'_2 \Delta LGDP_t + \alpha'_3 \Delta LGDP_{t-1} + \alpha'_4 (LEMP_{t-1} - \beta_0 - \beta_1 LGDP_{t-1})] \times G(\gamma, c, Z_t) + \varepsilon_t \quad (3)$$

where $LEMP$ denotes private non-farm payroll employment in logarithm, $LGDP$ the logarithm of GDP, ε_t is a Gaussian white noise process, G denotes the transition function, γ is the slope parameter that determines the smoothness of the transition from one regime to the other, c is the threshold parameter, and Z denotes the transition variable.

This non-linear ECM takes the long-term relationship into account, as well as two regimes for the short-term relationship—the long-run relationship remaining invariant to the regime. The economy can evolve in two states, but the transition between those two regimes is smooth: the two regimes are associated with large and small values of the transition variable relative to the threshold value, the switches from one regime to the other being governed by the transition variable Z (here, lagged GDP growth). The smooth transition function, bounded between 0 and 1, takes a logistic form given by:⁸

$$G(\gamma, c, Z_t) = [1 + \exp(-\gamma(Z_t - c))]^{-1} \quad (4)$$

It is noteworthy that when the function $G(\cdot)$ is equal to zero, it turns out that the non-linear STEM equation collapses to a standard linear error-correction model.

Note that Eq. (3) incorporates a contemporaneous impact of GDP growth on employment growth; this specification is consistent with weak exogeneity of GDP with respect to employment. In order to test the validity of this assumption, we assess the statistical significance of the coefficient of GDP growth as a function of the lagged error-correction term, over the 1950Q2–2007Q4 period. The t -statistic on the coefficient is -0.89 , which is far below the critical value of 2.26.⁹ Hence we fail to reject the null hypothesis that GDP is weakly exogenous with respect to employment; a result which is in line with the findings of Basu and Foley (2011) on the US economy. While weak exogeneity is not rejected, it should however be noticed that this is not sufficient to deduce that a significant α_2 coefficient in Eq. (3) implies a causal effect from GDP growth to employment growth. To be valid, this conclusion requires output growth to be also contemporaneously unrelated to shocks to employment growth. In this sense and as for most studies dealing with Okun's law, a significant value for α_2 reflects correlation between GDP growth and employment growth, and not necessarily causality.

Finally, inspection of Eq. (3) highlights the fact that we impose the strong assumption that the *long-run* relationship between employment and GDP is constant over the 1950–2012 period (the employment predicted by this long-run relationship is the *trend* employment which we refer to).

4. Results for the US economy

In this section, we implement the previous non-linear ECM given by Eqs. (3) and (4) until the beginning of the Great Recession, then we use the estimated model in an out-of-sample conditional forecasting approach in order to assess losses in US trend employment.

4.1. In-sample analysis

We estimate the model given by Eqs. (3) and (4) over the period 1950Q1–2007Q4 for US data of log-GDP and log-employment as presented in Fig. 1.¹⁰ This graph clearly highlights a long-term co-movement between both variables as well as evidence of non-stationarity, suggesting thus a cointegrated system.¹¹ Formally, the implementation of Johansen's

⁷ Note that we report only one error-correction model (ECM) equation and not both since our focus is on employment growth.

⁸ See Teräsvirta and Anderson (1992).

⁹ The distribution of the test statistic depends upon the number of stochastic and deterministic regressors. We use the critical values for two variables, and a constant in the error-correction term reported by Ericsson and MacKinnon (2002), Table 2.

¹⁰ As previously mentioned, we do not estimate the equations over our entire sample, as we reserve the 2008Q1–2012Q3 period for out-of-sample forecasts.

¹¹ The non-stationarity of employment and GDP series is also confirmed by the usual unit root tests. Indeed, retaining a specification incorporating both an intercept and a time trend, the ADF test statistics are respectively found to be equal to -2.69 for $LEMP$ and -2.91 for $LGDP$, meaning that the unit-root null hypothesis cannot be rejected at conventional levels.

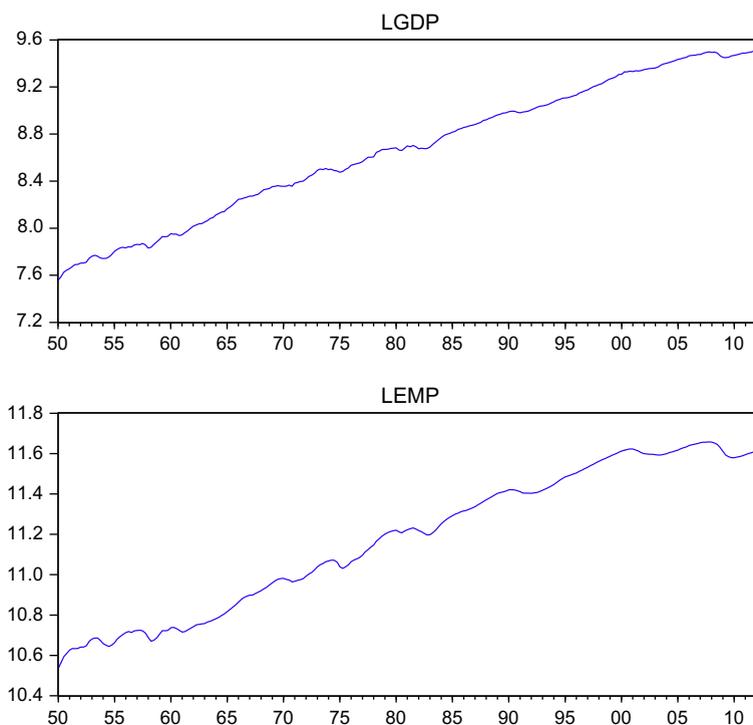


Fig. 1. Log-GDP (top) and log-employment (bottom) over the period 1950Q1–2012Q3. Source: Data are from the Bureau of Economic Analysis (GDP) and Bureau of Labor Statistics (employment). Quarterly GDP data used to estimate the models are seasonally adjusted, expressed in billions of chained 2005 dollars. Employment series corresponds to private non-farm employment, seasonally adjusted. Quarterly employment figures are average of monthly figures.

cointegration test leads to conclude to the existence of a cointegrating relationship between $LEMP$ and $LGDP$. Indeed, using a specification with one lag of first differences for the Johansen's test, we get a value of 24.34 for the trace statistic (24.35 for the maximum eigenvalue statistic), leading us to reject the null hypothesis of no cointegration in favor of the existence of one cointegrating relationship.

First, we estimate the long-term linear relationship through ordinary least-squares over the period 1950Q1–2007Q4.¹² Since we are dealing with a quite long period, it would be relevant to check for the stability of our estimated long-run relationship. To this end, we rely on the Hansen (1992)'s instability test based on the null hypothesis of cointegration against the alternative of no cointegration. Under the alternative hypothesis, evidence of parameter instability is expected. Applying this test over our considered period gives us a Hansen's test statistic of 0.0020 with an associated p -value larger than 0.20. Consequently, the null hypothesis of cointegration cannot be rejected, indicating no evidence of parameter instability. The residuals from the long-term equation are obtained from the following estimated relationship:

$$u_t = LEMP_t - 5.8501 - 0.6155 \times LGDP_t,$$

and are presented in Fig. 2.¹³

Once the estimation of this long-term relationship is realized, we integrate the lagged residuals—i.e., the error-correction term—into our main non-linear Eq. (3). To account for the business cycle in the short-term relationship, we select as transition variable the average GDP growth over 2 quarters, lagged by 2 quarters, i.e.:¹⁴

$$Z_t = 0.5 \times (\Delta LGDP_{t-2} + \Delta LGDP_{t-3})$$

This data-driven choice for the transition variable Z_t means that the non-linear effect tends to appear with a small lag towards the business cycle.

¹² As a robustness check, we have also estimated the cointegrating relationship using the Dynamic OLS (DOLS) procedure, leading to very similar results: $u_t = LEMP_t - 5.8685 - 0.6145 \times LGDP_t$.

¹³ We assess the stationarity of the error-correction term using the KPSS test. The test statistic equals 0.2322, so the null hypothesis of stationarity cannot be rejected at the 5% level, confirming our previous findings.

¹⁴ Note that we have also tried other transition variables, such as changes in the employment rate and other lags for GDP growth rate. Using the average GDP growth over 2 quarters leads to the strongest rejection of the null of linearity, justifying our choice from an econometric viewpoint.

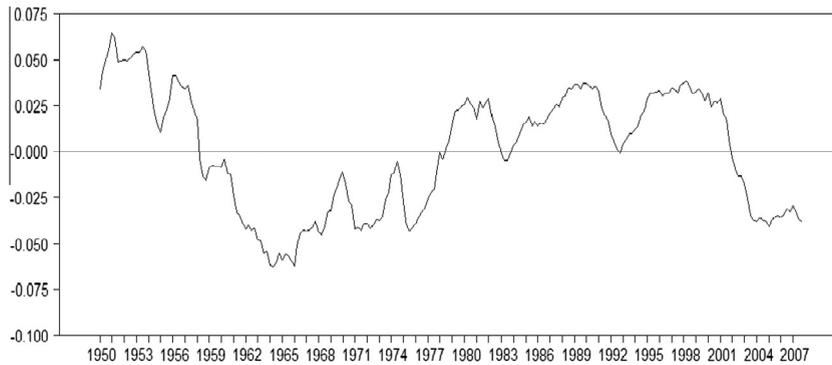


Fig. 2. Deviations from the estimated long-term relationship between log-employment and log-GDP. Source: authors' calculations.

Table 1
Estimates for the non-linear error-correction model.

	Regime 1	Regime 2
Constant	-0.0071***	0.0067***
$\Delta LEMP_{t-1}$	0.2149	0.3741***
$\Delta LGDP_t$	0.6439***	-0.3361***
$\Delta LGDP_{t-1}$	0.1932*	-0.1976
ECT_{t-1}	-0.0193**	0.0070
$\hat{\gamma}$	5.1624	
\hat{c}	0.0001	

In order to obtain the relevant coefficients in Regime 2, add the Regime 2 coefficient to the corresponding Regime 1 coefficient. ECT denotes error-correction term.

*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

The estimation of the non-linear specification follows the methodology proposed by Teräsvirta (1994). We start by testing for the null hypothesis of linearity using the test introduced by Luukkonen et al. (1988). Once the null of linearity has been rejected, we select the specification of the transition function using the test sequence presented in Teräsvirta (1994).¹⁵ We then estimate the non-linear ECM, leading to the results presented in Table 1.¹⁶

The estimated value \hat{c} of the threshold c is close to zero, delimiting thus periods of expansion and periods of recession, as shown by the transition function displayed in Fig. 3.¹⁷ The transition function clearly highlights the existence of two regimes in the short-term relationship between employment and output, which are strongly related to the business cycle phases, though slightly lagged. There is one regular regime that occurs most of the time, with an unconditional probability of 89%, while the second regime is more exceptional and appears only 11% of the time (i.e., when the transition function exceeds the natural threshold of 0.50). Turning to the other parameter of the transition function, namely γ , its quite small value indicates that the transition from one regime to the other is rather smooth than abrupt.

It is noteworthy that the second regime always begins at the end of recessions, generally one quarter before the end. The average duration of this recession regime is slightly greater than 3 quarters. In fact during this specific period of time, the persistence of the growth rate of employment tends to increase, as the first-order autoregressive estimate jumps to 0.589 from 0.215 in the regular regime. In addition, the contemporaneous elasticity dips from 0.644 to 0.308 and the lagged elasticity dies out. Thus, in this second regime, the link between employment growth and output growth is weakened. One explanation may be due to the fact that GDP growth tends to strongly bounce-back after recessions before returning to a “normal” expansion regime.¹⁸ Yet, during this bounce-back period, employment growth does not follow at the same pace, leading to a loosening in the relationship with output growth and an increase in its persistence.

¹⁵ We refer for example to van Dijk et al. (2002) for details on smooth transition models.

¹⁶ Note that the estimated model has successfully passed the usual misspecification tests: test of no residual autocorrelation (Teräsvirta, 1998), LM-test for no remaining non-linearity (Eitrheim and Teräsvirta, 1996) and ARCH-LM test.

¹⁷ Recall that c corresponds to the threshold value associated with the transition variable Z_t . The estimated threshold being very close to zero, this means that the first regime is associated with negative values of Z_t , while the second regime is associated with positive values. Z_t being defined as an average GDP growth, a negative value refers to a recession, and a positive one to an expansionary state.

¹⁸ Evidence of such behavior is documented in the papers of Morley and Piger (2012) and Bec et al. (2014a).

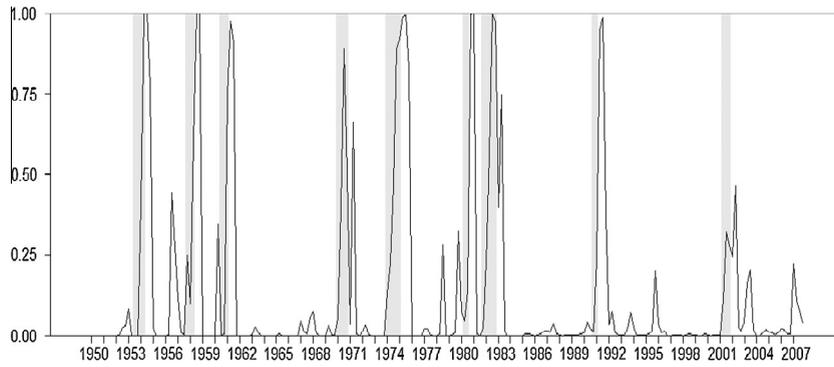


Fig. 3. Estimated transition function and US recessions until 2007Q4. Sources: authors' calculations, and NBER for the dating of recessions. The gray bands represent US recessions.

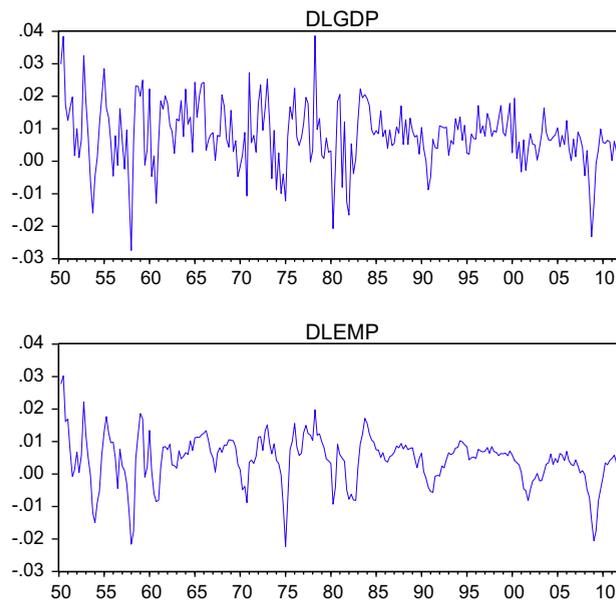


Fig. 4. Log-GDP in differences over 1 quarter (top) and log-employment in differences over 1 quarter (bottom). Source: authors' calculations based on data extracted from BEA and BLS.

In order to compare those latter results stemming from our model, we consider two benchmark models estimated over the same period: (i) a standard ECM given by Eq. (3) with function $G(\cdot)$ being equal to zero, and (ii) an Okun's law expressed in differences as given by Eq. (1). Series in log-differences over one quarter are presented in Fig. 4.

Regarding the specification of the linear ECM, we impose for the short-term dynamics a similar structure to the one given in Eq. (3). Results of parameter estimation are given in Table 2.

Table 2
Estimates for the linear error-correction model.

	Estimates
Constant	-0.0013***
$\Delta LEMP_{t-1}$	0.5402***
$\Delta LGDP_t$	0.3733***
$\Delta LGDP_{t-1}$	0.0358
ECT_{t-1}	-0.0133**

ECT denotes error-correction term.

*** Significant at the 1% level.

** Significant at the 5% level.

It is noteworthy that those estimates are rather close to the sum of the corresponding parameters in Regime 1 and Regime 2 (Table 1). The lagged log-difference GDP is not significant at conventional levels.

The estimated equation in differences (the employment version of Okun's law) is given by:

$$\Delta \widehat{LEMP}_t = 0.0003 + 0.5400 \times \Delta LGDP_t.$$

The estimated parameter associated with GDP is significant at the 5% level, but residuals appear to be serially correlated according to usual whitening tests. In order to improve the goodness-of-fit, we include short-term dynamics into the regression model. The estimated model is the following:

$$\Delta \widehat{LEMP}_t = -0.0012 + 0.3846 \times \Delta LGDP_t + 0.5729 \times \Delta LEMP_{t-1}.$$

All estimated parameters are significant at the 5% level, and we do not reject the null of serially uncorrelated residuals. The model specification strategy relies on a step-wise ascending approach. According to this strategy, including more lags in the previous equation is not useful, as they are not statistically significant at usual levels.

4.2. Conditional forecasts

We now compare the previous models on the basis of conditional dynamic forecasts of the variable *LEMP* over the period 2008Q1–2012Q3. This means that we forecast employment based on the knowledge of the *ex post* path for *LGDP*. Those conditional forecasts are dynamic in the sense that, for each step, we use the previously forecasted employment value instead of the observed value.

We start by comparing the three linear models, namely the model in differences, the model in differences with dynamics and the ECM. Conditional forecasts are presented in Fig. 5.

Both models in differences largely miss the drop in employment during the Great Recession. In particular, conditional forecasts stemming from the equations in differences exceed the pre-recession values of employment by the end of 2010. Those results are not consistent with reality and point to a failure in the employment version of Okun's law. If we incorporate dynamics in the equation in differences, conditional forecasts are shifted downwards due to the presence of lagged differences of employment. At the end of 2012, conditional forecasts are close to observed values of employment, meaning that, at this date, the level of employment would be consistent with its historical equilibrium. Yet, this hardly makes this model convincing in explaining employment dynamics during the Great Recession.

When taking the long-term relationship into account, conditional forecasts partly reproduce the dip in employment due to the large decrease in the level of GDP during this specific period of time. However, there is still a wide gap between observed values of employment and conditional forecasts stemming from the ECM. In addition, this gap tends to persist after the end of the recession.

Let us now turn to the comparison of the ECM and the non-linear ECM based on those conditional forecasts. Fig. 6 presents the observed employment (dark line), as well as conditional forecasts from a standard (linear) ECM (blue line) and from the non-linear ECM (green line).

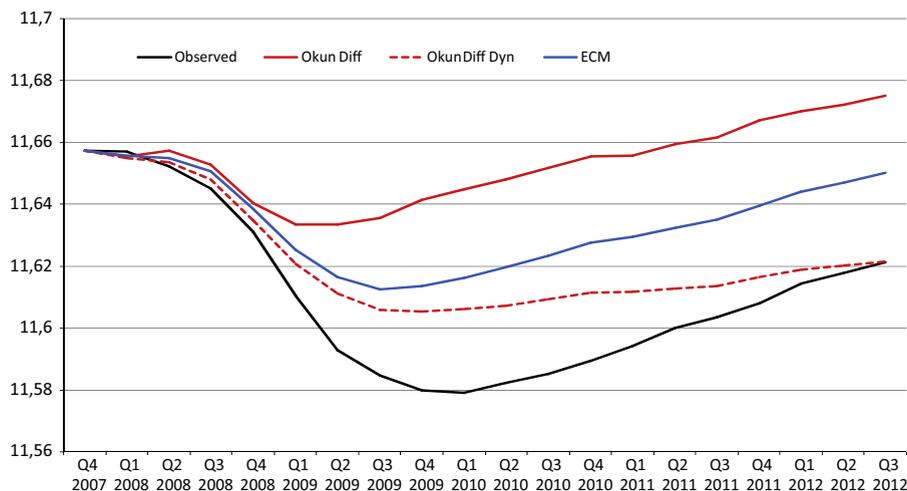


Fig. 5. Conditional forecasts of log-employment stemming from linear models. Note: Conditional forecasts stemming from the model in differences (red), the model in differences with dynamics (dotted red) and the ECM (blue). Observed values are presented in the dark line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

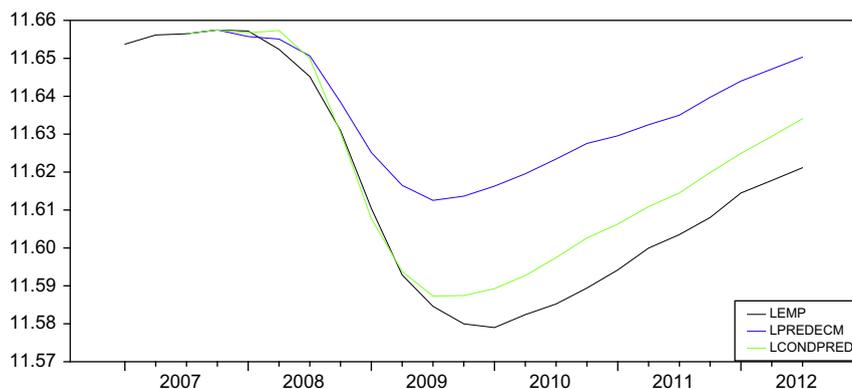


Fig. 6. Conditional forecasts of log-employment stemming from linear and non-linear error-correction models. Note: Conditional forecasts stemming from the linear ECM (blue) and the non-linear ECM (green). Observed values are presented in the dark line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Both ECMs are able to reproduce the main movements in employment during and after the recession. However, there is a persistent gap between the observed employment (dark line) and the conditional forecasts from both models (blue and green lines), meaning that employment is currently well below what it should be according to the models. When comparing both ECMs, taking the non-linear business cycle into account through the non-linear ECM (green line) leads to an important reduction in the gap. The contribution of the non-linear cycle to the employment is quite high (the average difference between the blue and green lines is around 2.6% in 2010) but tends to diminish (the green line slightly tends to the blue line), the average difference being only of 1.6% during the first three quarters of 2012.

Our findings lead us to conclude that there has been indeed an effect of the Great Recession on the long-term private employment. Specifically, on average, since the exit of the recession (2009Q2), we find that employment is 1.05% below predicted levels (according to the non-linear ECM), meaning that about 1.17 million of jobs have been lost due to non-cyclical reasons. This interpretation is in line with the recent literature on this topic, as pointed out for example by [Chen et al. \(2011\)](#) or [Stock and Watson \(2012\)](#).¹⁹

4.3. Robustness checks

As robustness checks, we compute confidence intervals for conditional forecasts and evaluate the sensitivity of our results to alternative measures of employment.

4.3.1. Confidence intervals

To assess the quality of conditional forecasts, we compute confidence intervals based on a re-sampling bootstrap approach. As previously mentioned, the residuals ($\hat{\varepsilon}_t$) stemming from Eq. (3) over the sample period 1950–2007 are shown to be non-correlated for low order lags. In addition, they are not far from being normally distributed, according to the Jarque–Bera test of Normality, evaluated at the 1% level.²⁰ Thus, we choose to implement a bootstrap re-sampling approach based on those residuals in order to estimate confidence bounds around conditional forecasts $\Delta LEMP_t$ over the period from 2008Q1 to 2012Q3. As new residuals based on the difference between observed and conditional forecasts become available, we integrate them in the re-sampling approach. The number of bootstrap replications is fixed at 1000.

As shown in Fig. 7, the 95% confidence interval is quite narrow, due to the low standard deviation of residuals (equal to 0.0029), and illustrates the reliability of our forecasts.²¹ Starting from the exit of recession, the realized employment stays clearly below the lower bound of the confidence interval until the end of the sample.

4.3.2. Robustness to the employment series

We now assess the sensitivity of our findings to the choice of the employment series. To this end, we focus on total non-farm payroll employment (LEMPTOT) instead of only private non-farm payroll employment. First, we estimate the long-term linear relationship over the period 1950Q1–2007Q4, leading to the following residual series:

¹⁹ Ignoring estimation and specification error, the forecast gap is attributable to factors that have a longer duration than those associated with ordinary business cycle frequencies. These could include structural factors of an economic nature, such as temporarily elevated unemployment benefits, or the extended effects of the balance sheet recession; for the former, see [CBO \(2014\)](#), and for the latter, see [Jordà et al. \(2011\)](#).

²⁰ The null of Normality is accepted at the 1% level but rejected at the 5% level (p-value of 0.013).

²¹ Note that we have assumed that parameters in Eq. (3) are known. Obviously, as in any other empirical application, parameters need to be estimated, which leads to an additional uncertainty in predicted values. To our knowledge, there is no available clear procedure when dealing with a STECM, in spite of papers relying on other types of non-linear models (see for example [Li, 2011](#), or [Bec et al., 2014b](#), in the case of univariate threshold models).

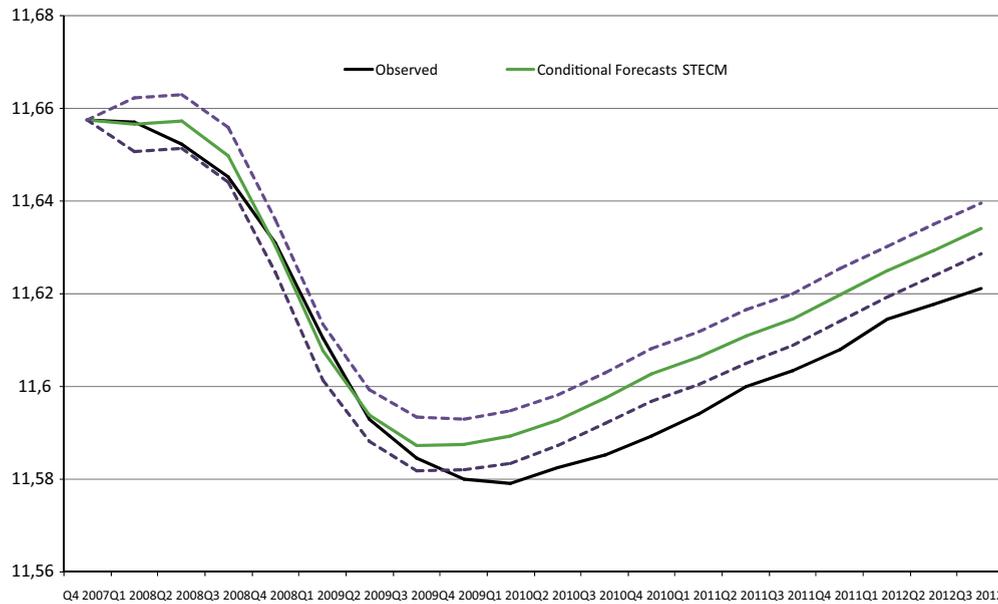


Fig. 7. Confidence interval at 95% for conditional forecasts based on the STECM. Note: Conditional forecasts stemming from the non-linear ECM (green) with corresponding bootstrapped 95% confidence interval. Observed values are presented in the dark line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 3

Estimates for linear and non-linear ECMs for total payroll employment.

	Linear ECM	Non-linear STECM	
		Regime 1	Regime 2
Constant	0.0006**	-0.0055***	0.0055**
$\Delta LEMP_{t-1}$	0.5763	0.2640	0.3763***
$\Delta LGDP_t$	0.3206***	0.6502***	-0.4094***
ECT_{t-1}	-0.0104	-0.0131	0.0057
$\hat{\gamma}$		2.5041	
\hat{c}		-0.0015	

In order to obtain the relevant coefficients in Regime 2, add the Regime 2 coefficient to the corresponding Regime 1 coefficient.

ECT denotes error-correction term.

*** Significant at the 1% level.

** Significant at the 5% level.

$$u_t = LEMPTOT_t - 5.9296 - 0.6273 \times LGDP_t.$$

As shown, the long-run elasticity is very close to the one obtained with private employment (0.6155). We then estimate a linear ECM over the same period, as well as the STECM given by Eq. (3).²² Parameter estimates of both models are given in Table 3; they are consistent with those obtained when dealing with private employment—the main exception being the speed of adjustment to the long-term target which is lower here and even non-significant.²³ The estimated threshold value is now negative, but remains very close to zero. The interpretation of the two regimes is thus very similar to that corresponding to the results in Table 1: the first regime corresponds to recessions characterized by negative output growth rates up to -0.15%, while the second regime is associated with, say, “weak recessionary” (output growth rates between -0.15% and 0%) and expansionary (positive growth rates) states. The transition function also describes very precisely the business cycles, though the probabilities do not reach one in this framework. This likely reflects the fact that public employment is counter-cyclical during these specific periods (see Fig. 8).

²² Note that the STECM is estimated without any lagged GDP given that the null of linearity was more strongly rejected when not including lagged GDP. As for the estimation with private employment, the lagged GDP is non-significant in the linear specification.

²³ To investigate whether the insignificant ECM parameter estimates come from the fact that employment is the source of the common trend or from the absence of cointegration between total non-farm payroll employment and output, we have to look at the second ECM equation. In the latter, the value of the ECM term is very close to zero and not significant, in line with the lack of cointegration between the two series.

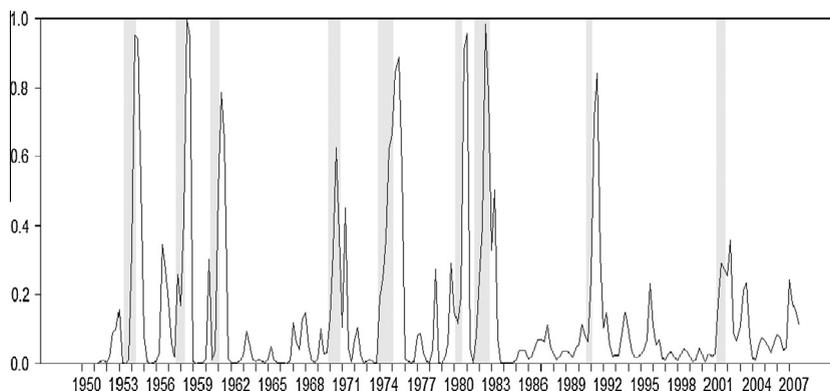


Fig. 8. Estimated transition function for the total employment and US recessions until 2007Q4. Sources: authors' calculations, and NBER for the dating of recessions. The gray bands represent US recessions.

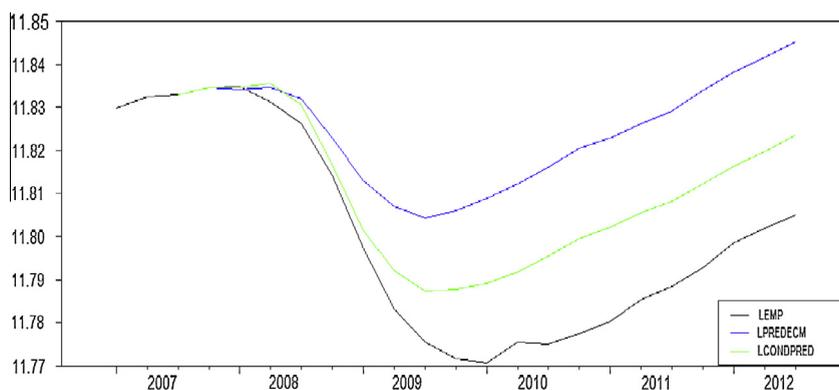


Fig. 9. Conditional forecasts from linear and non-linear ECMs for total payroll employment. Note: Conditional forecasts stemming from the linear ECM (blue) and the non-linear ECM (green). Observed values are presented in the dark line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Based on those estimates, we compute dynamic conditional forecasts for both linear and non-linear ECMs. Results are presented in Fig. 9. Confirming our intuition, total employment is much less sensitive to the business cycle. This result is expected because total employment also includes government employment which tends to be less pro-cyclical. Average losses of employment since the exit of the recession amount to 3.9% with the ECM and 1.8% with the STECM. Based on this latter model, this corresponds respectively to an average loss of 2.4 millions of jobs. If we assume that our estimation of the private employment loss at around 1 million is correct, it means that the long-run loss of government jobs is likely to be close to 1.4 million on average since the exit of the recession.

5. Conclusion

Addressing the issue of whether the Great Recession led to structural changes in the US economy is of crucial importance. Within this context, this paper aims at investigating the links between employment and GDP in the United States. From a statistical perspective, we disentangle trend and cyclical components in US employment based on an innovative non-linear error correction model that accounts for both a (constant) long-term relationship between output and employment and short-run non-linearities in dynamics over the business cycle. Based on this estimated non-linear specification, a conditional forecasting analysis shows that the level of US private sector employment is on average around 1% below the level implied by the long-run output–employment relationship, meaning that around 1.2 million of the trend employment loss cannot be attributed to the identified cyclical factors.²⁴ To the extent that trend employment depends on structural factors, eliminating this shortfall will depend upon the implementation of measures that improve the workings of the labor market, as well as eliminating other government policies that raise the natural rate of unemployment.

²⁴ The misprediction incorporates both estimated trend factors and prediction error due to model uncertainty.

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