Slow Recoveries: A Structural Interpretation

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Abstract

An analysis of the performance of GDP, employment and other labor market variables following the troughs in postwar U.S. business cycles points to much slower recoveries in the three most recent episodes, but does not reveal any significant change over time in the relation between GDP and employment. This leads us to characterize the last three episodes as *slow* recoveries, as opposed to *jobless* recoveries. We use the estimated New Keynesian model in Galí-Smets-Wouters (2011) to provide a structural interpretation for the slower recoveries since the early nineties.

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1 Introduction

Even though more than two years have gone by since the latest cyclical trough, the unemployment rate in the U.S. economy remains stubbornly high, due to persistently weak job creation.[1] As noted by many commentators, that pattern is not new: a similar pattern can be observed in the aftermath of the two previous recessions, in the early 1990s and early 2000s. The term *jobless recovery* has been used by journalists, academics and policymakers alike to refer to that phenomenon, which contrasts starkly with the strong job creation and robust employment growth observed in previous cyclical recoveries.[2] In the present paper we revisit the evidence on U.S. cyclical recoveries in order to understand better the causes and nature of any observed changes, and the extent to which jobless recoveries may have become "the new normal".

Our paper has two well differentiated parts. In the first part, we provide some basic quantitative evidence on the U.S. postwar recoveries. We start by confirming statistically the existence of a differential pattern in the most recent recoveries. But we emphasize one feature that has not been sufficiently recognized: the three cyclical recoveries since 1990 are characterized by unusually low growth rates of *both* employment and GDP. In fact, we are unable to uncover any evidence of structural change in the relation between those two variables during recoveries. This leads us to relabel the phenomenon we are studying here as *slow recoveries* as opposed to *jobless recoveries*,

[1] The NBER has determined that the trough of the Great Recession occurred in 2009Q2. The latest estimate of the unemployment rate at the time of writing these lines is 8.6% (November 2011).

[2] See, e.g., Bernanke (2003).

the latter being a misnomer in light of our evidence.

In the second part of the paper we use an estimated version of the model developed in Galí, Smets and Wouters (2011) to provide a structural interpretation (through the lens of that model) of the changing speed of recoveries. In particular, we seek to evaluate the role of shocks and structural change as a source of the slower recoveries experienced in recent times. When it comes to shocks, the evidence suggests that relatively favorable (adverse) shocks experienced *during* the pre-90 (post-90) recoveries themselves (rather than shocks that originated during the preceding recessions) are the main factor behind the differential performance. Our main findings stress the change in the sign of the contribution of risk premium and investment shocks as the main reason for the significantly slower recoveries during that recent period. When we take a closer look at the recent episode we uncover a nonnegligible role for adverse wage markup and monetary policy shocks as factors behind the slow recovery. We interpret the latter finding as reflecting the zero lower bound on interest rates and the likely presence of downward wage rigidities.

The remainder of the paper is organized as follows. Section 2 provides the basic evidence on the post-recession performance of the U.S. economy. Section 3 summarizes the main features of the Galí, Smets and Wouters (2011) model. Section 4 discusses the role played by different shocks and their timing, as well as the role of changing parameters, as determinants of the speed of cyclical recoveries. Section 5 takes a closer look at the most recent cyclical episode. Finally, we conclude in Section 6.

2 Postwar U.S. Recoveries: Basic Evidence

Figure 1a displays the cumulative growth of employment over the four quarters following the trough in each of the eleven postwar U.S. recessions, as dated by the NBER. The figure illustrates clearly the slower employment growth characterizing the recoveries since the early 90s.[3] As shown in Table 1, the cumulative growth rate of employment four quarters into the recovery was on average 2.5 percent before the nineties, but -0.1 percent across the three most recent recoveries. Dropping the recent recovery episode makes the latter statistic slightly positive, but does not change the overall picture. A similar pattern can be observed when we look instead at cumulative employment growth rates eight quarters into the recovery, as illustrated in Figure 1b. Note that in the latter figure we have dropped the recovery following the 1980 recession, since the eight-quarter period following its trough overlaps with the 81-82 recession, potentially distorting the evidence.[4] In both cases, we reject comfortably the hypothesis of equality of mean average growth rates across subsample periods at a significance level below one percent.[5]

[3] We conducted a test for a break in the mean based on the maximum t-statistic (with the latter corresponding to the test for equality of means across two populations) across all possible sample splits. The outcome of the test confirms the visual evidence of a break starting in the early 90s. The latter is significant at a level below 1 percent, on the basis of Montecarlo simulations. The same finding applies when we look instead at eight-quarter growth rates (see below).

[4] We dropped the recovery following the 1980 recession throughout the paper whenever we look at eight-quarter periods.

[5] We use a conventional test of equality of means across two populations (see, e.g., Lars and Marx (1981), p.322). Under the assumptions of normality, independence across observations (i.e. recoveries, in our application), and equal variance across samples the t-statistic follows a t-distribution with 9 degrees of freedom (8 in the case of the eight-quarter growth rate due to having one observation less). The significance levels reported in the Table are based on that distribution.

Table 1 reports similar statistics for a number of additional variables.[6] We start by discussing those directly related to the labor market, namely, the labor force, the unemployment rate, hours per worker (workweek) and aggregate hours.

As reported in Table 1, the cumulative growth rate of the labor force during cyclical recoveries has also experienced a decline after 1990, but is substantially smaller than that of employment growth (and significant only at the 10% level and for the 8 quarter horizon). Accordingly, the pattern of employment during recoveries is largely mirrored by that of the unemployment rate. As shown in Table 1, and illustrated graphically in Figures 2a and 2b, the cumulative change in the unemployment rate has been positive on average over the past three recoveries, which contrasts with large cumulative decline in the unemployment rate during the pre-90 recoveries. The difference between the two periods' means is statistically significant. So is the difference in the cumulative growth rate of aggregate hours, which shows a pattern similar to that of employment, given the absence of a large/significant change in the recoveries pattern of hours per worker.

Next we turn to GDP, the central measure of overall economic activity. Figures 3a and 3b show GDP growth rates accumulated over four and eight quarters, respectively, following each postwar U.S. recession. Table 1 reports the corresponding averages for the two subperiods considered. While the mean is shifted upward relative to the corresponding figures for employment,

[6] The data were drawn from the FRED database at the Federal Reserve Bank of St. Louis, with the exception of aggregate hours which correspond to the "unofficial" BLS series used by Francis and Ramey and downloadable from Valerie Ramey's web site. The corresponding mnemonics for the remaining variables are: GDP (GDPC1), civilian employment (CE16OV), labor force (CLF16OV), and the unemployment rate (UNRATE).

we see that an identical pattern emerges, i.e. GDP growth rates have been much lower during the recent recoveries, with a mean of 2.6 percent over four quarters, compared to 7.6 percent in the earlier sample period (5.6 percent vs. 12.5 percent if we look at an eight-quarter horizon). Again, and despite the relatively small number of cyclical episodes, we can easily reject the null of equality of mean recovery growth rates across subsamples also in the case of GDP.

The previous evidence calls into question the widely held view of a "recovery in economic activity coexisting with a sluggish labor market" as a distinctive feature of the aftermath of the three most recent recessions, and which underlies the "jobless recoveries" label. Instead, it appears that *the recovery itself* has been much slower than in earlier episodes.

In fact, there is no evidence of the labor market underperforming relative to the economy as a whole. This observation can be made precise by looking at the evolution of labor productivity after each recession trough. Figures 4a and 4b show the (4 and 8 quarter) cumulative growth rate of GDP per worker after each cyclical trough. If the labor market had lagged GDP in the more recent recovery episodes, the latter would be characterized by a higher productivity growth. But this turns out not to be the case: As shown in Table 1 the average cumulative growth rate of GDP per worker four quarters into the recovery has been 2.7 percent across the three most recent recessions, compared to 4.9 percent before the nineties. This is exactly the opposite from what one would expect under the jobless recovery hypothesis. A similar pattern arises when we look at the eight-quarter horizon statistics: a 4.8 percent average cumulative productivity growth for the recent recoveries, 7 percent in the earlier ones. In both cases the difference in means across sample periods turns out not to be statistically significant, but this is beside the point given that the sign of the difference is opposite from the hypothesized one. A similar pattern can be observed if we take GDP per hour as a measure of labor productivity, as seen in Table 1.

Another perspective on the same issue can be obtained by running an "Okun's law regression" of the change in the unemployment rate (Δu_t) on GDP growth (Δy_t) and to test for a change in the associated coefficient in the post-1990 period. Using quarterly U.S. data for the pariod 1948Q1-2011Q4 the estimated equation (with standard errors in brackets) is

$$\Delta u_t = \underset{(0.022)}{0.24}^{***} - \underset{(0.018)}{0.27}^{***} \Delta y_t - \underset{(0.037)}{0.04} \, dum90_t * \Delta y_t$$

where $dum90_t$ is a dummy variable for the post-1990 subsample period. As made clear by the reported estimates there appears to be no trace of a change in the Okun relationship across sample periods, which is consistent with the evidence discussed above.

A possible explanation for the difference in speed of recoveries across periods is that before the 1990s recoveries were more robust because GDP had fallen much more in the preceding recession and there was a more pronounced "snap-back" effect. But the similarity in the average cumulative GDP losses during recessions in the two subperiods (1.85 and 1.92 percent, respectively) do not help support that view.

To summarize: our characterization of changes over time in the pattern of cyclical recoveries points to a substantial reduction in the growth rates of GDP, employment and hours during the three most recent recoveries, relative to the past. As a consequence unemployment has remained very high as late as two years into the recovery, instead of experiencing the fast decline observed in the aftermath of the earlier episodes. In the remainder of the paper we try to shed some light on the reasons for that change, using the model in Galí, Smets and Wouters (2011) as a reference framework.

3 The Slowing of Recoveries through the Lens of an Estimated New Keynesian Model

In this section we use (updated) estimates of the model developed in Galí, Smets and Wouters (2011; henceforth, GSW) to evaluate alternative hypotheses regarding the causes and nature of the recent slow recoveries. The GSW model constitutes an evolution of the well known framework in Smets and Wouters (2003, 2007). Smets and Wouters (2007) show that this framework is able to compete with standard VAR and BVAR models in out-of-sample forecasting. Theory embedded in the structural model is helpful in improving the forecasts of the main US macro variables, including real GDP growth and hours worked, in particular at business cycle frequencies. The SW framework is therefore a good empirical model to examine the causes and nature of the recent slow recoveries.

The main difference with the GSW model lies in the explicit introduction of unemployment, following the approach proposed in Galí (2011a, 2011b), and the use of a utility specification that parameterizes the strength of wealth effects (along the lines of Jaimovich and Rebelo (2009)). Next, we summarize the key ingredients of that approach, emphasizing the reduced form relations they give rise to.

The assumed preferences are such that the household's marginal disutility from having an additional member employed (expressed in terms of consumption) is given in a symmetric equilibrium by $MRS_t = \chi_t Z_t N_t^{\varphi}$, where N_t denotes the employment rate, Z_t is a distributed lag of consumption (thus restricting the short run impact of the latter's changes on the marginal rate of substitution), and $\chi_t \equiv \exp\{\xi_t\}$ is an exogenous labor supply shock.

Thus, and using lower case letters to denote the logs of the original variable, we have:

$$mrs_t = z_t + \varphi n_t + \xi_t \tag{1}$$

On the other hand, and as in Smets and Wouters (2007), the wage inflation equation implied by Calvo staggered wage setting is given by

$$\pi_t^w = \alpha_w + \gamma_w \pi_{t-1}^p + \beta E_t\{\pi_{t+1}^w - \gamma_w \pi_t^p\} - \lambda_w(\mu_{w,t} - \mu_{w,t}^n)$$

where π_t^w is wage inflation, π_t^p is price inflation (with γ_w representing the degree of indexing), $\mu_{w,t}$ is the average wage markup and $\mu_{w,t}^n$ is the natural wage markup (i.e. the one that would obtain under flexible wages). The latter is assumed to vary exogenously. Note that the average wage markup is given by

$$\mu_{w,t} \equiv (w_t - p_t) - mrs_t \tag{2}$$

where $w_t - p_t$ is the average real wage (in logs).

The labor force or participation rate, denoted by l_t (in logs), is pinned down by the individual for whom the relevant marginal rate of substitution is equal to the current average real wage. Thus, we can interpret

$$w_t - p_t = z_t + \varphi l_t + \xi_t \tag{3}$$

as a labor supply equation. Note that the (arbitrarily) smooth response of z_t to any shock (given that it is a distributed lag of consumption), makes it possible to reconcile the sluggish behavior of the average real wage with a (mildly) procyclical labor force. See GSW (2011) for further discussion.[7]

Combining (1), (2), and (3), and letting $u_t \equiv l_t - n_t$ denote the unemployment rate, we can derive a simple relation between the latter and the average wage markup (as in Galí (2011a)):

$$\mu_{w,t} = \varphi u_t$$

The latter relation allows us to rewrite the wage inflation equation in terms of the unemployment rate:

$$\pi_t^w = \alpha_w + \gamma_w \pi_{t-1}^p + \beta E_t\{\pi_{t+1}^w - \gamma_w \pi_t^p\} - \lambda_w \varphi u_t + \lambda_w \mu_{w,t}^n \tag{4}$$

As emphasized in GSW (2011) the error term in (4) captures exclusively shocks to the desired wage markup, and *not* preference shocks (even though the latter have been allowed for in our model). This is in contrast with the representation of the wage equation found in Smets and Wouters (2007) and related papers. That feature, made possible by reformulating the wage equation in terms of the (observable) unemployment rate, allows us to overcome the key identification problem raised by Chari et al. (2009) in their critique of New Keynesian models. Thus, labor supply and wage markup shocks are separately identified in our framework, which allows us to determine their role as a source of fluctuations in any historical episode.

The remaining aspects of the model and estimation are similar (though not identical) to Smets and Wouters (2007).[8] In particular, we use eight data

[7] Christiano, Trabandt and Walentin (2011) propose an alternative approach to modelling unemployment that is also consistent with a procyclical labor force.

[8] See GSW (2011) for a detailed discussion of such differences.

series as observables: GDP, consumption, investment, GDP deflator inflation, the federal funds rate, the unemployment rate and two wage measures (compensation per employee, from the BLS Productivity and Costs Statistics, and average weekly earnings, from the Current Employment Statistics. Furthermore, our model incorporates as many as eight driving forces, which we group in three different categories on the grounds of their implied comovements among output, inflation and the real wage.[9] More specifically, we allow for four "demand" shocks (risk premium, monetary policy, exogenous spending, and investment-specific technology), two "supply" shocks (neutral technology and price markups), and two "labor market" shocks (wage markup and labor supply).

The model is estimated over the sample period 1966Q1-2007Q4 for the reasons discussed in GSW (2011), and then simulated up to 2011Q2.

4 Accounting for Slow Recoveries

We use the estimated model in order to uncover the sources behind the observed GDP patterns during cyclical recoveries. We first look at the role of shocks, their nature and timing, while keeping parameters unchanged. Then we re-estimate the model separately for two subsample periods and carry out counterfactual simulations to assess the role of parameter changes in accounting for the change in the speed of recoveries. The discussion below focuses on the main findings of that analysis, which are reported in Tables 2 through 5. Additional tables with more detailed results can be found in the online appendix.

[9] See GSW (2011) for a discussion.

4.1 The Role of Shocks

We report a first set of estimates pertaining to the forces behind U.S cyclical recoveries in Table 2. In particular the Table shows the average contribution of the different structural shocks to the cumulative growth of GDP, four and eight quarters after each recession trough. The model is estimated assuming a linear trend in log per capita GDP, and the deviations from this trend are used as a reference variable for the remainder of the exercise.[10] As shown in the first row of the Table, the growth rate of per capita GDP is well above trend in the early period, while the corresponding average growth rate for the post-90 period is just slightly above trend. The difference between the two periods is significant at either the 10 percent (for the four-quarter horizon) or 5 percent (for eight-quarter horizon) levels.

We quantify the role played by different shocks in accounting for the above differences. As discussed above we group the shocks into three categories (demand, supply and labor market) and provide aggregated statistics for each of them. A number of results stand out:

- Supply shocks make a positive contribution to recoveries throughout the sample period, but especially so in the post-90s. That contribution is accounted for by technology shocks, with price markup shocks playing a negligible role. The presence of labor hoarding, unaccounted for in the current version of our model, could be partly responsible for the strong role allocated to technology shocks.

[10] The linear detrending and the normalization by the working age population explain the differences with the growth rates reported in Table 1. Tables with results for employment and unemployment are qualitatively similar and can be found in the online Appendix.

- Labor market shocks make a negative contribution in both subsample periods, but more so in the more recent one. The overall difference is, however, not statistically significant. Both wage markup shocks and labor supply shocks are responsible for this, though the latter only so in the post-90 period (largely accounting for the difference between the two periods).

- Demand shocks make a large positive contribution to the recoveries of the pre-90 period, but negative in the post-90 one. The difference between the two is highly significant, both economically and statistically. This is in itself more than sufficient to explain the difference in recovery growth rates across subsample periods. Investment-specific technology shocks play the largest role in accounting for that difference.

Next we turn our attention to the timing of the shocks responsible for the differences in the speed of recoveries. Table 3 displays the results of a decomposition of GDP growth rates during recoveries based on the *timing* of the shocks: before the onset of the recession ("initial state"), during the recession ("recession shocks") and during the recovery itself ("recovery shocks"). We briefly summarize the main findings:

- The bulk of the difference in recovery growth rates across periods is the result of a very different pattern of shocks *during the recovery itself.* Those shocks were on average largely favorable in the pre-90 period, accounting for much of the GDP growth above trend at both the four-quarter and eight-quarter horizons. On the other hand those shocks have been somewhat adverse during the post-90 period.

- The unwinding of the effects of recession shocks also contributes to GDP growth during cyclical recoveries, but can only account for a small (and statistically insignificant) fraction of the difference across sample periods.

- The observed difference in the pattern of recovery shocks across periods can be traced to demand shocks, whose contribution to recoveries were positive in the pre-90 era, but strongly negative in the post-90 period. This holds true for both four-quarter and eight-quarter horizons.

- Supply shocks experienced during the recoveries have made highly positive contributions to GDP growth rate during those episodes, but cannot account for the slowing of recoveries in the recent period; on the contrary, their positive contribution has risen over time.

- On the other hand, labor supply shocks' during recoveries have made on net a negative contribution to GDP growth during recoveries. This is especially so at the eight-quarter frequency during the most recent period, which may be related to the phenomenon of discouraged job seekers.

We close this section by digging a little deeper and trying to uncover what is the nature of the demand shocks that account for the latter's differential impact during the recoveries. The answer to this question can be found in Table 4, which reports the contribution to GDP growth during recoveries of the different types of demand shocks experienced during those very episodes. All four shocks appear to have made a non-trivial negative contribution during the post-90 era, both at the four-quarter and eight-quarter horizons. In the case of spending and monetary shocks, this was also the case in the pre-90 era. The bulk of difference across periods is thus accounted for by risk premium shocks and investment-specific technology shocks, which made a positive contribution to the speed of recoveries in the pre-90 period, but a negative one in the more recent period. That difference is significant for both shocks and horizons (though not with the same level).

4.2 The Role of Parameters

The decompositions discussed in the previous section were based on the model estimated over the period 1966Q1-2007Q4. Implicitly we assumed that the economic parameters remained stable over that sample period. However, the slower recoveries since the 90s could also be related to changes in the economic structure (i.e. parameter values) as opposed to changes in the patterns of exogenous shocks. In order to evaluate this alternative hypothesis, we re-estimated the model over two sub-samples: 1966Q1-1984Q4 and 1984Q1-2007Q4. The parameter estimates for each of the subsamples (reported in the online appendix) confirm the results in Smets and Wouters (2007). First, we notice important changes in the parameters describing the exogenous processes: the volatility of most of the shocks decreases during the recent period. But we can also observe some important variation in the structural parameters. Most of these changes are related to parameters that are relatively weakly identified and where endogenous rigidities or frictions and persistence in the exogenous drivers are close substitutes. Some examples: the early sample period is characterized by relatively high habits in preferences and a lower persistence in the risk premium, while the opposite occurs during the more recent period. A similar switch happens between endogenous price indexation (high in the early period) and persistence in the price markup (higher in the later period); or between persistence in the exogenous wage markup and wage stickiness. Of course, with our short subsamples and relatively uninformative priors, it is difficult to conclude whether these parameter changes really represent structural changes in the economy or whether they just reflect weak identification.

The previous caveat notwithstanding, if we take the hypothesis of a potential break seriously, the model allows us to carry out two exercises that may shed light on the role of change in structural parameters as a source of the slower recoveries during the recent period. In a first exercise, we use the estimated structural parameters of the late subsample period and impose them on the model estimated for the early subsample. With the resulting model, we can simulate the outcomes of the pre-90s shocks with the post-90 parameters in place.[11] If the estimated changes in the structural parameters play an important role in accounting for the change in the speed of recoveries, we would expect that recoveries in the counterfactual simulation would be significantly slower than the actual ones in the pre-90s data. Table 5 summarizes the results from this exercise. The counterfactual simulation indeed produces a slower recovery but this change is relatively small and not significant. For the four-quarter horizon, the average counterfactual recovery in output measured in deviation from the trend growth path is 2.43 percent against 2.60 percent in the data. This differences increases for the

[11] We only substitute the parameters describing the optimizing behavior of the agents and the policy rule of the central bank. We keep the parameters of the exogenous processes so that they remain consistent with the simulated innovations.

eight-quarter horizon with a cumulated output increase of 4.53 percent in the counterfactual against 4.83 percent in the data. None of these differences are statistically significant. When looking at the contribution of the different shocks, it appears that the parameter changes have divergent implications for the different shocks. Only in the case of labor market shocks and a 4-quarter horizon we uncover a statistically significant difference between the actual average growth rate and the counterfactual, but the sign is the wrong one. We conclude that structural change, as reflected in variations in the model's parameters, is unlikely to have played a major role in explaining the slower recoveries.

In the second exercise, we repeat the decomposition of Tables 2 and 3, but now using the subsample estimated models to identify the shocks and to evaluate their contribution to the slow recovery. If we take the hypothesis of a break in the parameters as the correct hypothesis then the subsample models should yield a more precise identification of the shocks and their transmission mechanism. The outcome of that exercise, summarized in Tables 6 and 7, confirms most of the previously discussed findings with one major exception: The impact of recession shocks on the speed of recoveries now appears to have changed over time. This is especially relevant for the 4-quarter cumulative growth statistic. Thus, while under the full-sample model, the impact of the recessions shocks on output tended to be reversed relatively quickly during the recovery, this stabilization process is much weaker in the model estimated for the more recent period. This change is most apparent in the case of demand shocks experienced during the recessions. When using the full-sample model, but also in the pre-90 subsample model, the economy recovers quickly from the negative demand shocks that hit the economy during the recession. This force is much less present in the model estimated for the more recent sample period. The other side of the coin is that now the adverse demand shocks experienced during the recovery become somewhat less important for explaining the slower recoveries.

5 A Closer Look at the Great Recession and its Aftermath

In this section we concentrate on the recovery after the Great Recession. Figures 5a and 5b illustrate the role of the different exogenous forces driving output and the unemployment rate, respectively, during the period 2007Q1-2011Q2, and based on the model estimated over the full sample. The following observations are worth making:

- The Great Recession is mostly explained by negative risk premium and investment shocks, whose adverse effects clearly kick in when GDP starts declining significantly, in 2008Q3. Monetary policy shocks partially offset the negative demand developments during the early phase of the recession, but its contribution turns negative from 2009Q2 onwards, possibly reflecting the zero lower bound constraint on the nominal short-term interest rate (which the model estimates interpret as an "exogenous" deviation from the historical rule).

- The very limited recovery of output after 2009Q2 coexists with persistently negative demand developments and is almost entirely driven by positive productivity shocks. The contribution of the latter is larger than during any of the previous recoveries in our sample.

- The negative contribution of demand forces to the slowness of the recovery is accounted for by the four demand shocks, with investment playing a somewhat larger role. In addition to the demand shocks, the model attributes a substantial role to adverse wage markup shocks as a factor behind the slow recovery. In other words, wages seem to have adjusted less than economic conditions would warrant, given historical estimates of the wage equation. We interpret that evidence as reflecting the likely presence of downward wage rigidities, in an environment with low inflation and high unemployment.

- A similar picture emerges when we look at the performance of the unemployment rate. While the initial increase in unemployment during the Great Recession is largely due to contractionary risk premium shocks, its persistently high level well into the recovery is mostly accounted by adverse exogenous wage markup shocks (about 3 percentage points) and by the combined negative influence of the four demand shocks. Note that, in contrast with the picture for output, productivity developments have very limited effects on unemployment.

6 Concluding Remarks

Our analysis of the performance of employment, GDP and other labor market variables following the troughs of postwar U.S. business cycles points to much slower recoveries in the three most recent episodes, but does not reveal any significant change over time in the relation between GDP and employment.

This leads us to characterize the last three episodes as *slow* recoveries, as opposed to *jobless* recoveries.

We have sought to interpret that evidence through the lens of an estimated version of the New Keynesian model developed in Galí-Smets-Wouters (2011). Our findings suggest that the slower recoveries are not due to structural change in the U.S. economy. Instead we uncover a dramatic change in the sign of demand shocks experienced during the recovery itself and, according to some estimates, during the preceding recession as well. If our interpretation is correct, there is no fundamental reason why recoveries should remain slow in the future, especially if there is room for expansionary fiscal and monetary policies that may counteract any adverse demand developments.

APPENDIX

In this appendix, we summarize the key log-linear equations of the estimated model. For a more detailed presentation, we refer to the discussion in Smets and Wouters (2003) and Galí-Smets-Wouters (2011).

- Consumption Euler equation:

$$\widehat{c}_t = c_1 \widehat{c}_{t-1} + (1 - c_1) E_t\{\widehat{c}_{t+1}\} - c_2(\widehat{r}_t - E_t\{\widehat{\pi}_{t+1}\} + \widehat{\varepsilon}_t^b)$$

with $c_1 \equiv (h/\tau)/(1 + h/\tau)$, $c_2 \equiv (1 - h/\tau)/(1 + h/\tau)$ where h is the external habit parameter and $\tau \equiv \Pi_x$ is the trend growth rate. $\widehat{r}_t$ is the nominal interest rate and $\widehat{\varepsilon}_t^b$ is the exogenous AR(1) risk premium process.

- Investment Euler equation:

$$\widehat{i}_t = i_1 \widehat{i}_{t-1} + (1 - i_1) E_t\{\widehat{i}_{t+1}\} + i_2 \widehat{q}_t + \widehat{\varepsilon}_t^q$$

with $i_1 = 1/(1+\beta)$, $i_2 = i_1/(\tau^2 \Psi)$ where β is the household's discount factor, and Ψ is the elasticity of the capital adjustment cost function. $\widehat{q}_t$ is the value of installed capital and $\widehat{\varepsilon}_t^q$ is the exogenous AR(1) process for the investment specific technology.

- Value of the capital stock:

$$\widehat{q}_t = -(\widehat{r}_t - E_t\{\widehat{\pi}_{t+1}\} + \widehat{\varepsilon}_t^b) + q_1 E_t\{r_{t+1}^k\} + (1 - q_1) E_t\{\widehat{q}_{t+1}\}$$

with $q_1 = r^k/(r^k + (1 - \delta))$ where $\widehat{r}_t^k$ is the capital rental rate and δ the depreciation rate.

- Goods market clearing

$$\begin{aligned} \widehat{y}_t &= c_y \widehat{c}_t + i_y \widehat{i}_t + \widehat{\varepsilon}_t^g + v_y \widehat{v}_t \\ &= \mathcal{M}_p(\alpha \widehat{k}_t + (1 - \alpha)\widehat{n}_t + \widehat{\varepsilon}_t^a) \end{aligned}$$

with $c_y \equiv (C/Y)$, $i_y \equiv (I/Y)$, and $v_y \equiv R^k K/Y$. Parameter $\mathcal{M}_p$ denotes the degree of returns to scale which is assumed to correspond to the price markup in steady state. $\widehat{\varepsilon}_t^g$ and $\widehat{\varepsilon}_t^a$ are the AR(1) processes representing respectively exogenous demand components and the neutral-technology process.

- Price-setting under the Calvo model with indexation:

$$\widehat{\pi}_t^p - \gamma_p \widehat{\pi}_{t-1}^p = \beta \left(E_t\{\widehat{\pi}_{t+1}^p\} - \gamma_p \widehat{\pi}_t^p \right) - \pi_2(\widehat{\mu}_{p,t} - \widehat{\mu}_{p,t}^n)$$

with $\pi_1 = (1-\beta\theta_p)(1-\theta_p)/[\theta_p(1+(\mathcal{M}_p-1)\varsigma_p)]$, where θ_p and γ_p respectively denote the Calvo price stickiness and the price indexation parameters, ς_p is the curvature of the Kimball aggregator.

- Average and natural price markups

$$\widehat{\mu}_{p,t} = -(1-\alpha)\widehat{\omega}_t - \alpha \widehat{r}_t^k + \widehat{\varepsilon}_t^a$$

$$\widehat{\mu}_{p,t}^n = 100 * \widehat{\varepsilon}_t^p$$

where $\omega_t \equiv w_t - p_t$ is the real wage

- Wage-setting under the Calvo model with indexation:

$$\widehat{\pi}_t^w - \gamma_w \widehat{\pi}_{t-1}^p = \beta(E_t\{\widehat{\pi}_{t+1}^w\} - \gamma_w \widehat{\pi}_t^p) - \lambda_w(\widehat{\mu}_{w,t} - \widehat{\mu}_{w,t}^n)$$

with $\lambda_w \equiv (1-\beta\theta_w)(1-\theta_w)/[\theta_w(1+\epsilon_w\varphi)]$.

- Average and natural wage markups and unemployment

$$\begin{aligned} \widehat{\mu}_{w,t} &= \widehat{\omega}_t - (\widehat{z}_t + \widehat{\varepsilon}_t^\chi + \varphi \widehat{n}_t) \\ &= \varphi \widehat{u}_t \end{aligned}$$

$$\begin{aligned}\widehat{\mu}^n_{w,t} &= 100 * \widehat{\varepsilon}^w_t \\ &= \varphi \widehat{u}^n_t\end{aligned}$$

$$\widehat{z}_t = (1-\upsilon)\widehat{z}_{t-1} + \upsilon[(1/(1-h/\gamma))\widehat{c}_t - ((h/\gamma)/(1-h/\gamma))\widehat{c}_{t-1}]$$

where the exogenous labor supply shock $\widehat{\varepsilon}^\chi_t$ is assumed to follow a highly persistent AR(1) process with autoregressive coefficient fixed at $\rho_\chi = 0.999$.

- Labor force:

$$\widehat{l}_t = \widehat{n}_t + \widehat{u}_t$$

- Capital accumulation equation:

$$\widehat{\overline{k}}_t = \kappa_1 \widehat{\overline{k}}_{t-1} + (1-\kappa_1)\widehat{i}_t + \kappa_2 \widehat{\varepsilon}^q_t$$

with $\kappa_1 \equiv 1 - (I/\overline{K})$, $\kappa_2 = (I/\overline{K})(1+\beta)\tau^2\Psi$. Capital services used in production are defined as: $\widehat{k}_t = \widehat{v}_t + \widehat{\overline{k}}_{t-1}$

- Optimal capital utilisation condition:

$$\widehat{v}_t = ((1-\psi)/\psi)\widehat{r}^k_t$$

with ψ is the elasticity of the capital utilization cost function.

- Optimal input choice

$$\widehat{k}_t = \widehat{\omega}_t - \widehat{r}^k_t + \widehat{n}_t$$

- Monetary policy rule:

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r)(r_\pi \widehat{\pi}^p_t + r_y(\widehat{ygap}_t) + r_{\Delta y}\Delta(\widehat{ygap}_t) + \widehat{\varepsilon}^r_t$$

with $ygap_t \equiv \widehat{y}_t - \widehat{y}_t^{flex}$, is the difference between actual output and the output in the flexible price and wage economy in absence of distorting price and wage markup shocks.

Two parameters are not identified by the estimation procedure and are therefore calibrated: $\delta = 0.025$, $\varsigma_p = 10$. Note also that the trend growth rate in real "average weekly earnings" is allowed to differ from the common trend.

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Table 1. The Changing Speed of Recoveries						
	Four-quarter growth			*Eight-quarter growth*		
	Pre-90	Post-90	Change	Pre-90	Post-90	Change
Employment	2.53	−0.10	−2.63***	5.18	0.76	−4.42***
Labor force	1.12	0.44	−0.68	3.12	0.99	−2.11*
Unemployment	−1.34	0.50	1.84**	−1.86	0.20	2.06**
Workweek	0.61	−0.23	−0.84	0.38	0.50	0.12
Hours	3.16	−0.32	−3.48**	6.51	1.26	−5.25***
GDP	7.63	2.62	−5.01**	12.52	5.62	−6.90**
GDP per Worker	4.97	2.72	−2.25	7.01	4.83	−2.18
GDP per Hour	4.33	2.95	−1.38*	4.83	4.81	−0.02

Note: Mean cumulative growth rates for all variables except the unemployment rate for which the mean cumulative change is reported. Asterisks indicates a rejection of equality of means across periods at a 10% (∗), 5% (∗∗) or 1% (∗ ∗ ∗) significance levels (one-sided t-test).

Table 2
GDP Growth in Cyclical Recoveries:
A Structural Decomposition

	Four-quarter growth			*Eight-quarter growth*		
	Pre-90	Post-90	Change	Pre-90	Post-90	Change
Total	**2.50**	**0.26**	**−2.24***	**4.63**	**0.63**	**−4.00****
Demand Shocks	**1.70**	**−1.02**	**−2.72*****	**2.63**	**−1.26**	**−3.89*****
Risk premium	0.91	0.53	−0.38	0.61	0.54	−0.07
Spending	0.21	−0.48	−0.69	−0.01	−1.01	−1.00
Investment	0.81	−0.64	−1.45***	1.05	−0.80	−1.85***
Monetary	−0.24	−0.42	−0.18	0.97	0.02	−0.95**
Supply Shocks	**1.47**	**2.77**	**1.30**	**2.57**	**4.75**	**2.19**
Technology	1.48	2.71	1.23	1.95	4.82	2.87
Price Markup	−0.01	0.05	0.07	0.62	−0.07	−0.69**
Labor Market Shocks	**−0.51**	**−1.48**	**−0.97**	**−0.24**	**−2.85**	**−2.61**
Labor supply	0.09	−0.93	−1.02*	0.35	−1.75	−2.10*
Wage Markup	−0.61	−0.55	0.06	−0.60	−1.10	−0.50
Initial State	**−0.16**	**−0.01**	**0.15**	**−0.33**	**−0.02**	**0.31**

Note: Asterisks indicates a rejection of equality of means across periods at a 10% (∗), 5% (∗∗) or 1% (∗ ∗ ∗) significance levels (one-sided t-test).

Table 3
GDP Growth in Cyclical Recoveries:
Decomposition by Timing of Shocks

	Four-quarter growth			*Eight-quarter growth*		
	Pre-90	Post-90	Change	Pre-90	Post-90	Change
Total	**2.50**	**0.26**	**−2.24****	**4.63**	**0.63**	**−4.00****
Initial state	−0.75	−0.39	0.36	−0.60	−0.45	0.16
Demand	−0.38	−0.35	0.03	−0.07	−0.47	−0.41**
Supply	−0.16	0.15	0.30	−0.20	0.40	0.60
Labor	−0.06	−0.17	−0.11**	−0.01	−0.36	−0.34**
Recession shocks	1.02	0.85	−0.16	1.77	1.47	−0.30
Demand	1.26	1.00	−0.26	1.70	1.91	0.21
Supply	−0.01	0.35	0.36	0.38	0.32	−0.06
Labor	−0.23	−0.49	−0.26	−0.31	−0.77	−0.46
Recovery shocks	2.24	−0.20	−2.44***	3.46	−0.39	−3.85**
Demand	0.82	−1.66	−2.48**	0.99	−2.69	−3.69**
Supply	1.63	2.27	0.64	2.39	4.03	2.12
Labor	−0.22	−0.81	−0.60	0.08	−1.73	−1.81

Note: Asterisks indicates a rejection of equality of means across periods at a 10% (∗), 5% (∗∗) or 1% (∗ ∗ ∗) significance levels (one-sided t-test).

Table 4
GDP Growth in Cyclical Recoveries:
The Role of Demand Shocks during Recoveries

	Four-quarter growth			*Eight-quarter growth*		
	Pre-90	Post-90	Change	Pre-90	Post-90	Change
Total	**0.82**	**−1.66**	**−2.48****	**0.99**	**−2.69**	**−3.69****
Risk premium	0.58	−0.56	−1.14*	0.10	−0.93	−1.03**
Spending	−0.13	−0.37	−0.23	−0.58	−0.85	−0.27
Investment	0.92	−0.43	−1.35***	1.03	−0.83	−1.86**
Monetary	−0.56	−0.31	0.28	0.44	−0.09	−0.53

Note: Asterisks indicates a rejection of equality of means across periods at a 10% (∗), 5% (∗∗) or 1% (∗ ∗ ∗) significance levels (one-sided t-test).

Table 5
GDP Growth in Cyclical Recoveries:
Impact of Parameter Changes

	Four-quarter growth			*Eight-quarter growth*		
	Estimated	Counterfactual	Change	Estimated	Counterfactual	Change
Total	**2.60**	**2.43**	**−0.17**	**4.83**	**4.53**	**−0.29**
Demand	**1.73**	1.**04**	**−0.68**	**2.87**	**2.98**	**0.12**
Supply	**1.59**	**1.59**	**0.00**	**2.54**	**1.74**	**−0.80**
Labor Market	**−0.61**	**−0.11**	**0.51****	**−0.33**	**0.04**	**0.36**

Table 6
GDP Growth in Cyclical Recoveries:
Structural Decomposition based on Subsample Estimates

	Four-quarter growth			*Eight-quarter growth*		
	Pre-90	Post-90	Change	Pre-90	Post-90	Change
Total	**2.60**	**0.24**	**−2.35****	**4.83**	**0.60**	**−4.23*****
Demand Shocks	**1.73**	**−1.66**	**−3.39*****	**2.87**	**−2.33**	**−5.20*****
Risk premium	1.21	-0.43	−1.54**	1.59	−1.25	−2.84**
Spending	0.04	−0.20	−0.24	−0.28	−0.39	−0.11
Investment	0.85	−0.49	−1.34***	1.10	−0.40	−1.50***
Monetary	−0.37	−0.53	−0.16	0.45	−0.29	−0.74
Supply Shocks	**1.59**	**2.60**	**1.01**	**2.54**	**4.24**	**1.70**
Technology	1.68	2.39	0.71	2.34	3.97	1.63
Price Markup	−0.09	0.21	0.29	0.20	0.27	0.07
Labor Shocks	**−0.61**	**−0.73**	**−0.12**	**−0.33**	**−1.37**	**−1.04**
Labor supply	-0.05	−0.77	−0.72*	0.09	−1.42	−1.51*
Wage Markup	−0.56	0.04	0.60***	−0.42	0.05	0.47*
Initial State	**−0.11**	**0.03**	**0.14**	**−0.25**	**0.06**	**0.31***

Note: Asterisks indicates a rejection of equality of means across periods at a 10% (∗), 5% (∗∗) or 1% (∗ ∗ ∗) significance levels (one-sided t-test).

Table 7
GDP Growth in Cyclical Recoveries:
Decomposition by Timing of Shocks based on Subsample Estimates

	Four-quarter growth			*Eight-quarter growth*		
	Pre-90	Post-90	Change	Pre-90	Post-90	Change
Total	**2.60**	**0.24**	**−2.35***	**4.83**	**0.60**	**−4.23****
Initial state	−0.73	−0.01	0.72*	−0.69	0.15	0.84
Demand	−0.49	−0.37	0.12	−0.37	−0.59	−0.22
Supply	−0.11	0.40	0.52	−0.17	0.85	1.02
Labor	−0.03	−0.07	−0.05	0.11	−0.16	−0.27**
Recession shocks	1.37	0.15	−1.22***	2.11	0.98	−1.14
Demand	1.65	0.01	−1.64***	2.04	0.85	−1.20*
Supply	0.03	0.22	0.19	0.45	0.23	−0.21
Labor	−0.32	−0.08	0.24***	−0.37	−0.10	0.28***
Recovery shocks	1.96	0.10	−1.86***	3.40	−0.53	−3.93***
Demand	0.56	−1.30	−1.86***	1.19	−2.59	−3.78***
Supply	1.67	1.98	0.31	2.26	3.17	0.90
Labor	−0.27	−0.58	−0.31	−0.06	−1.11	−1.05

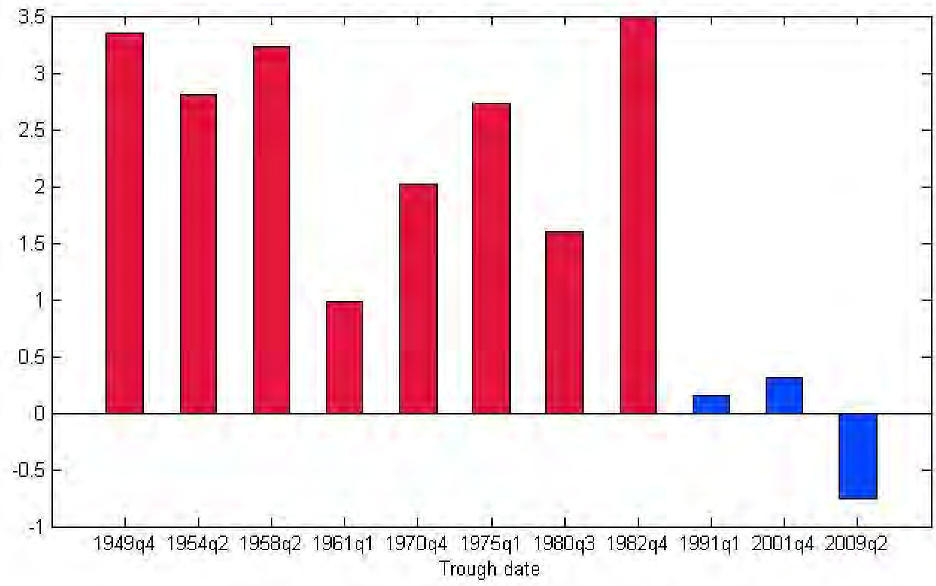

Figure 1a. Cumulative Growth (4 quarters after trough): Employment

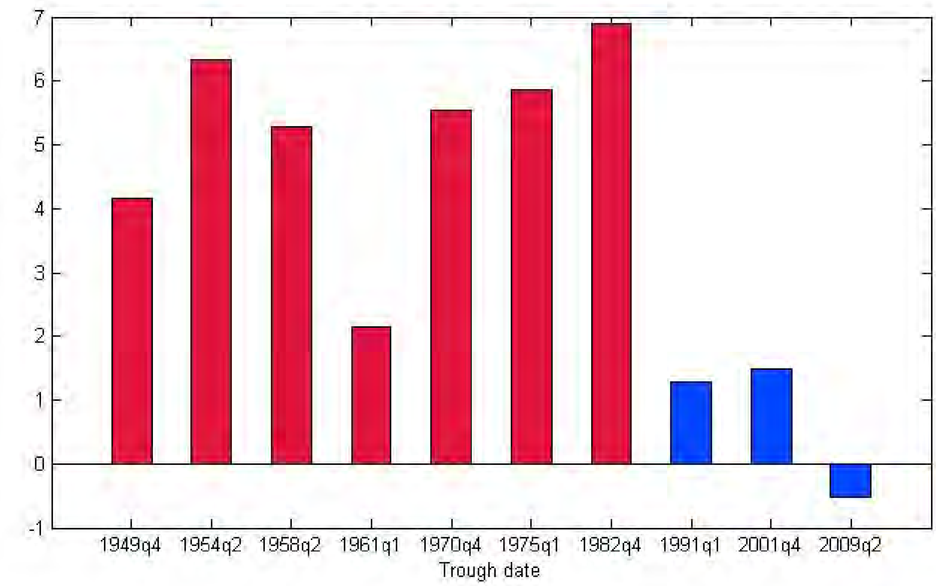

Figure 1b. Cumulative Growth (8 quarters after trough): Employment

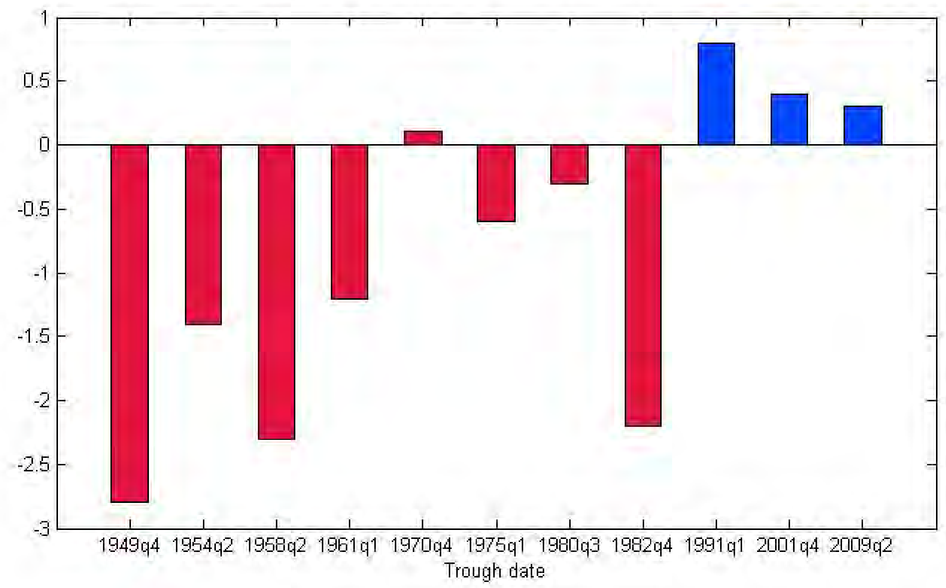

Figure 2a. Cumulative change (4 quarters after trough): Unemployment rate

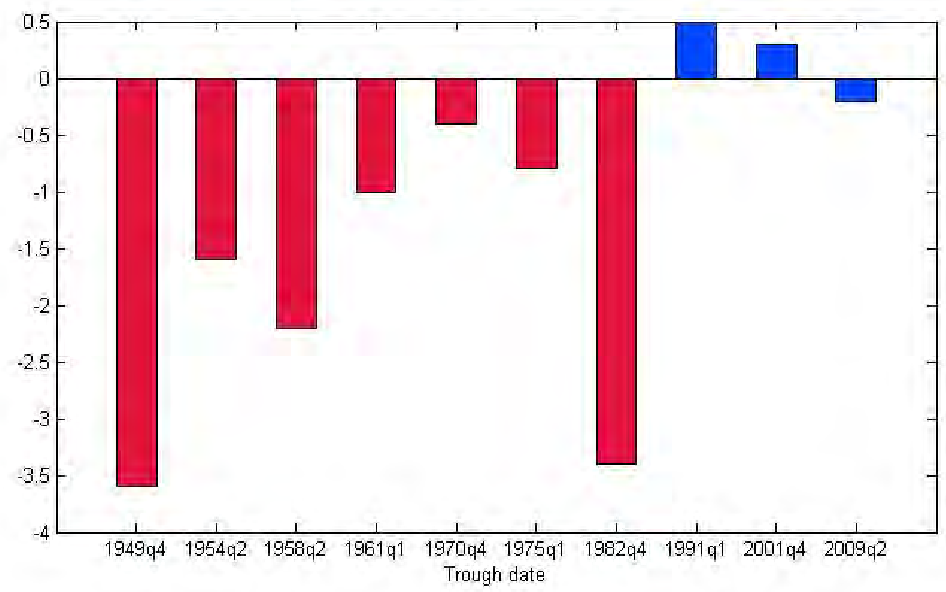

Figure 2b. Cumulative change (8 quarters after trough): Unemployment rate

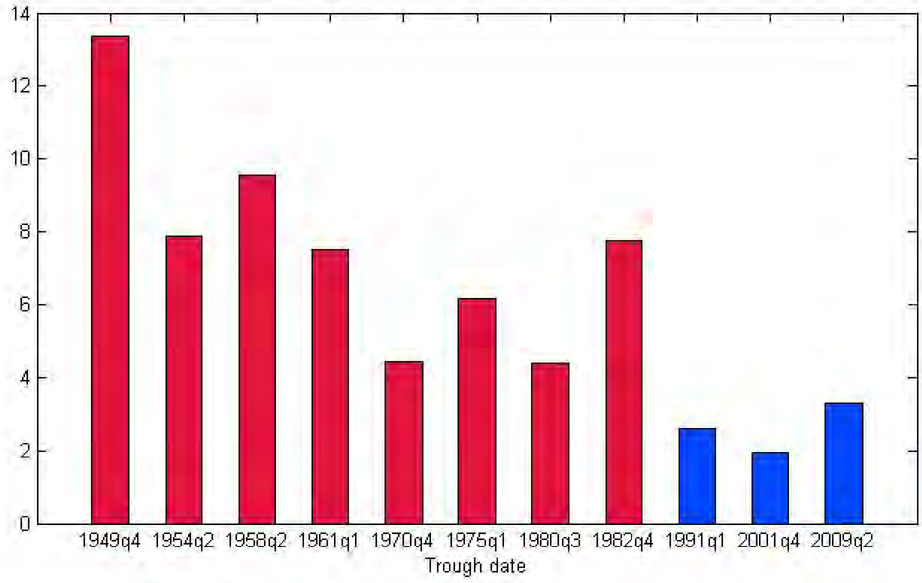

Figure 3a. Cumulative growth (4 quarters after trough): GDP

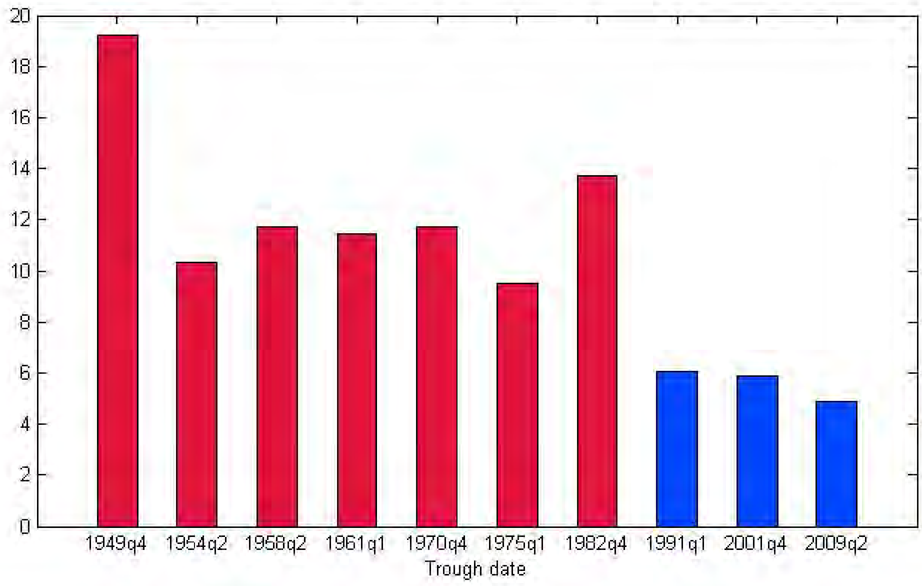

Figure 3b. Cumulative growth (8 quarters after trough): GDP

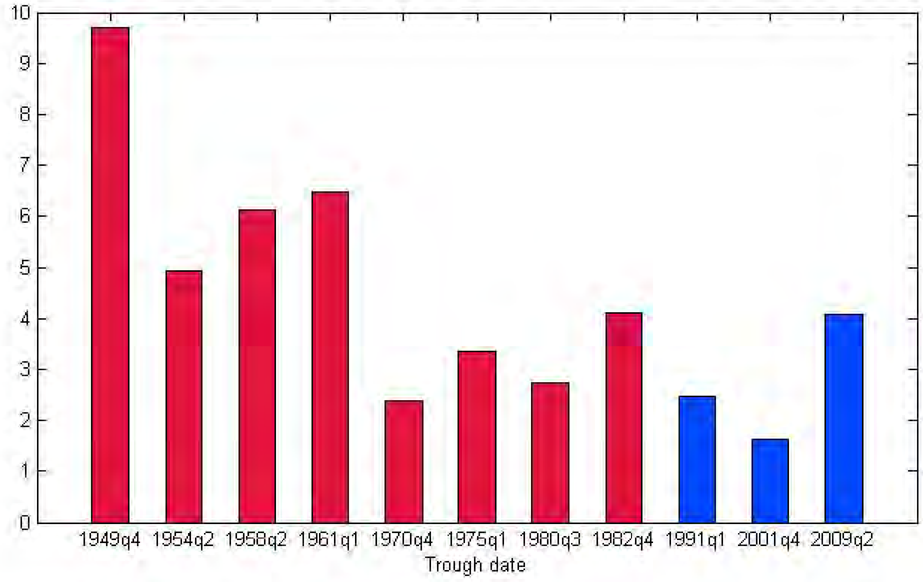

Figure 4a. Cumulative growth (4 quarters after trough): GDP per Worker

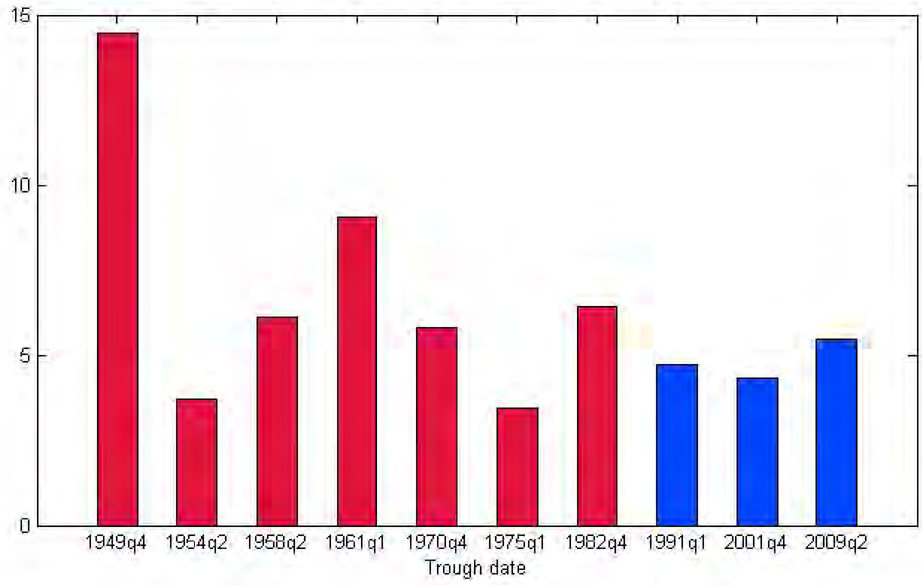

Figure 4b. Cumulative growth (8 quarters after trough): GDP per Worker

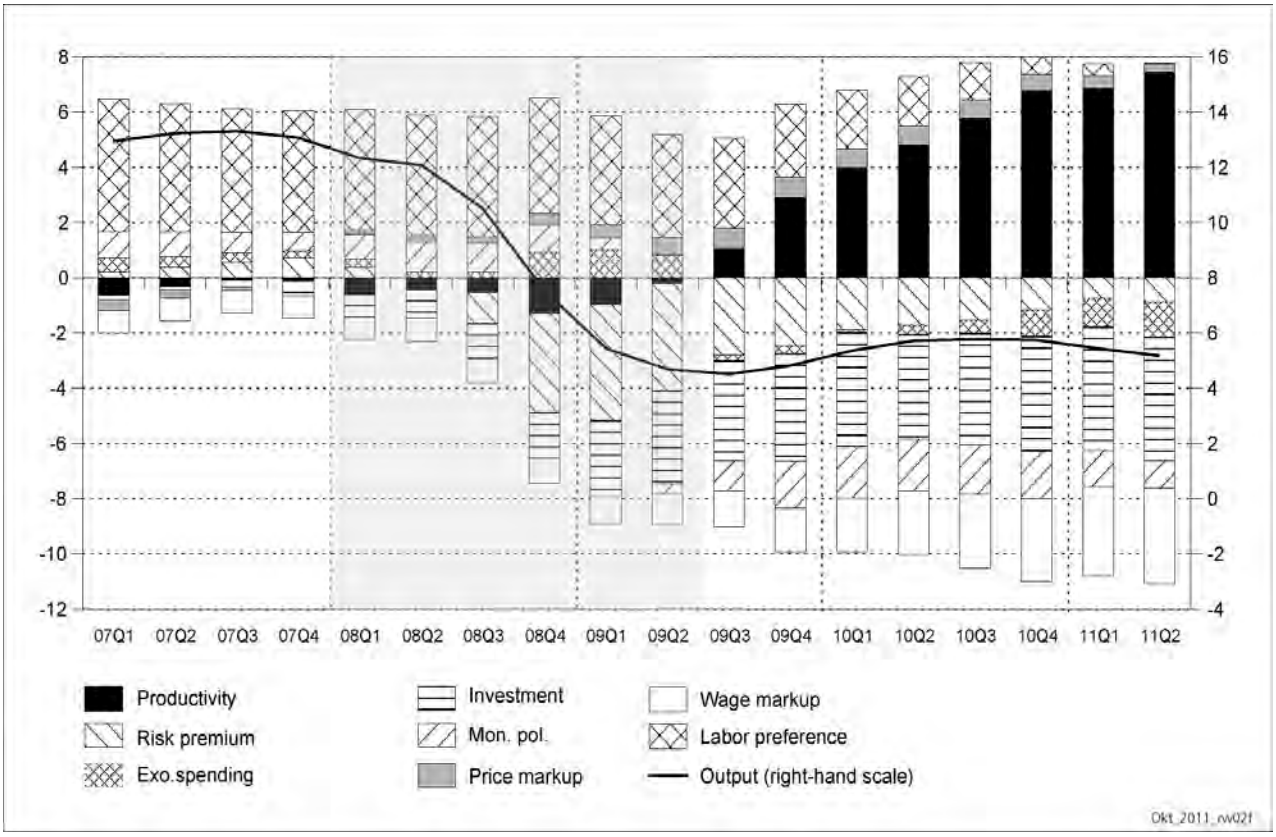

Figure 5a. The Great Recession and its Aftermath: GDP

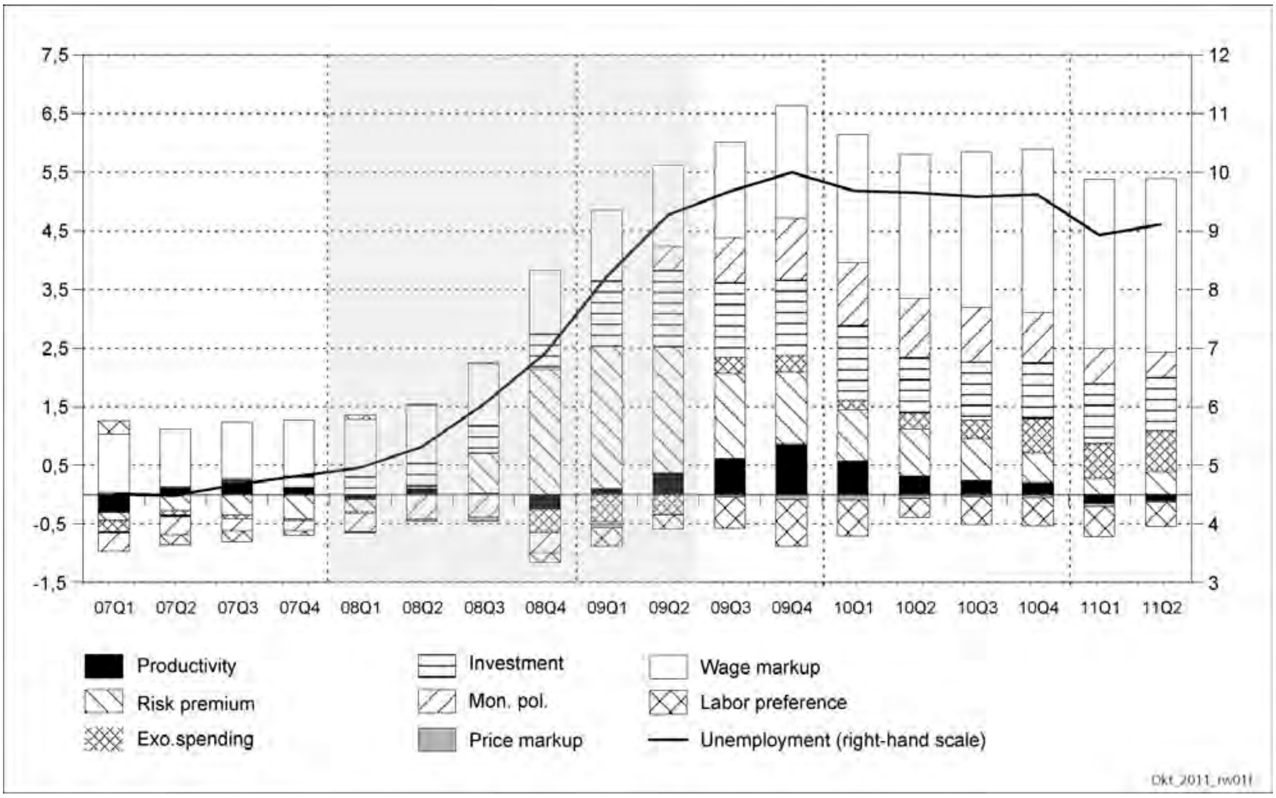

Figure 5b. The Great Recession and its Aftermath: Unemployment rate