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by Mehdi Hosseinkouchack & Maik H. Wolters

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We do not only test the unit root hypothesis at the conditional mean of GDP, but also in the tails of the distribution where the lower tail corresponds to large recessions. The test has more power than conventional unit root tests. We find that positive and negative shocks including large recessionary shocks have permanent effects on output. Therefore, a rebound of GDP to its pre-crisis trend level is unlikely. Current output gap estimates based on deterministic trends are likely to be too negative and inflation forecasts based on these are likely to be too low.

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JEL classification: C22, E32, O40

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December 2, 2012

Abstract

The slow recovery following the 2008/2009 recession has led to renewed interest in the question whether deep recessions lower real GDP permanently or whether we can expect a rebound to earlier trend levels. Using a recent quantile autoregression unit root test we check whether shocks to real GDP have permanent or temporary effects. In contrast to earlier studies this approach takes into account that the transmission of a shock might depend on the sign and the size of the shock. Large recessionary shocks might have a different effect than smaller recessionary or expansionary shocks. We do not only test the unit root hypothesis at the conditional mean of GDP, but also in the tails of the distribution where the lower tail corresponds to large recessions. The test has more power than conventional unit root tests. We find that positive and negative shocks including large recessionary shocks have permanent effects on output. Therefore, a rebound of GDP to its pre-crisis trend level is unlikely. Current output gap estimates based on deterministic trends are likely to be too negative and inflation forecasts based on these are likely to be too low.

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1 Introduction

The financial crisis has triggered two types of GDP forecasts, those in which output returns to its pre-crisis trend, and those in which output is lowered permanently. In early 2009 the Obama Administration predicted strong US GDP growth rates of 3.2% in 2010, 4% in 2011, 4.6% in 2012 and 4.2% in 2013 before GDP growth returns to annual rates of 2.6% afterwards. These numbers imply that actual GDP returns to the long run GDP trend by the end of 2013, as shown in figure 1. In contrast, private sector forecasts as summarized by the Blue Chip consensus forecast predicted lower growth rates of 2.1% in 2010, 2.9% in 2011, 2.9% in 2012, 2.8% in 2013 and 2.7% in the years thereafter.[1] Figure 1 shows that this forecast leads to a permanent impact of the financial crisis on output shifting the whole future path of real GDP downwards without rebounding to the pre-crisis trend.

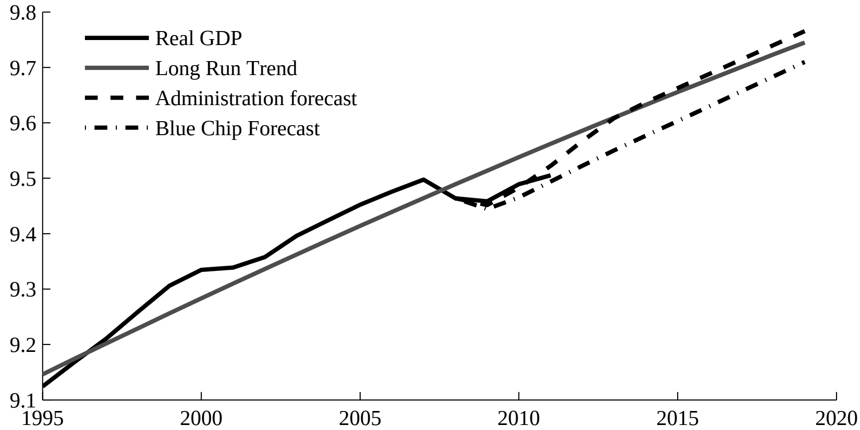

Figure 1: GDP forecasts. Notes: The graph shows yearly observations for US log real GDP, its trend growth rate and forecasts as published by the Office of Administration and the Blue Chip Consensus forecast. The trend growth rate has been computed by regressing the log of quarterly real GDP data from 1947Q1 to 2012Q1 on a constant, a linear and a quadratic trend. The Administration's forecasts and the Blue Chip forecast are given in annual percentage changes. We compute the implied level forecast based on the value of log real GDP in 2008Q4.

These opposing GDP forecasts led to an intense debate among leading economists (see e.g. CEA, 2009; Krugman, 2009; DeLong, 2009; Mankiw, 2009). The Council of Economic Advisors (CEA) pointed out that "a key fact is that recessions are followed by rebounds. Indeed, if periods of lower-than-normal growth were not followed by periods of higher-than-normal growth, the unemployment rate would never return to normal" (CEA, 2009). For similar reasons also Paul Krugman and Brad DeLong expected a rebound. Greg Mankiw argued instead based on his earlier work (see for example Campbell and Mankiw, 1987) that a negative shock to real GDP would lead to a permanent reduction in the GDP

[1] The Administration's and the Blue Chip forecasts are available in table S-8 in Office of Management and Budget (2009).

trend path.[2,3]

This debate is well-anchored in economic research. If real GDP follows a deterministic trend as implied by the arguments of Krugman and DeLong we should expect a rebound to its pre-crisis trend path. Instead, if real GDP is best modelled as a unit root with drift process—as Mankiw argues—the Great Recession would lower real GDP permanently. There exists a huge literature that applies different unit root tests to distinguish between these competing hypotheses. This literature started with Nelson and Plosser (1982) who challenged the until then accepted hypothesis that output returns to a deterministic log-linear trend in the long run and could be modelled as being trend stationary. They found that GDP is instead best viewed as a unit root process with drift, i.e. as difference stationary, and that shocks to real output have permanent rather than temporary effects. The literature has not converged to a conclusive answer, yet.[4] Some authors have taken into account the possibility that the persistence of the GDP impact of recessionary shocks might differ from that of expansionary shocks. Examples include Hamilton (1989), Perron (1989), Balke and Fomby (1991), Beaudry and Koop (1993), Murray and Nelson (2000) and Kim et al. (2005). Some of these studies find permanent effects of recessions and temporary effects of expansions (e.g. Hamilton, 1989), while others find exactly the opposite (e.g. Beaudry and Koop, 1993).

Our contribution to this line of research is that we test the unit root hypothesis not only at the conditional mean of GDP, but also in the tails of the distribution using a quantile autoregression (QAR) based unit root test. In contrast to least squares estimates we do not only capture the average effect of shocks on GDP, but we can distinguish between GDP realizations that are high or low relative to GDP realizations in previous quarters. In particular recessions may be viewed in the QAR context as data realizations in the lower conditional quantiles. The sum of autoregressive coefficients at the different quantiles shows the persistence of shocks of different sign and magnitude. If recessionary shocks have permanent effects, we would expect the sum of autoregressive coefficients to

[2] A detailed overview about these different views is given in Cushman (2012).

[3] A related discussion has explored whether policy actions have influenced the GDP path after 2008. A crucial point of this discussion is to figure out which path of output can in general be expected after a financial crisis to assess whether the current path of GDP is above or below such a counterfactual scenario. Reinhart and Rogoff (2012) argue that financial crises usually have permanent effects. In contrast, Bordo and Haubrich (2012) take the position that deep recessions are usually followed by quick recoveries so that the current weak recovery might be caused by inappropriate policy. We contribute by exploring whether deep recession have permanent effects, but we do not analyze whether policy actions have been a major factor for the current GDP path neither do we distinguish between recessions that are associated with a financial crisis and those that are not (see e.g. Boysen-Hogrefe et al., 2010, for an analysis of the effect of banking and housing crises on GDP compared to ordinary recessions).

[4] Studies that use long time series of US output going back to 1870 usually reject the unit root hypothesis (Ben-David and Papell, 1995; Cheung and Chinn, 1997; Diebold and Senhadji, 1996). Murray and Nelson (2000) show that results on these long time series can be misleading because heterogeneity of the data can lead to false rejections of the unit root hypothesis. Based on post war data they find evidence that aggregate output is best modelled as a unit root process. Campbell and Mankiw (1987) and more recently Shelley and Wallace (2011) do not find any evidence that GDP is trend-reverting either.

equal one in the lower conditional quantiles.

In contrast to the previous literature, the usage of a QAR-based unit root test has several advantages. First, we allow for the possibility that shocks of different sign and magnitude have a different impact on GDP. For example the impact of large recessionary shocks might differ from that of smaller recessionary and also from that of expansionary shocks. Second, our approach is not restricted to a specific number of regimes like recessions and expansions, but allows generally for differences in the transmission of all kinds of different shocks. Using the QAR-based unit root test we can check whether the inconclusiveness of the existing literature is caused by heterogeneity of shocks which is disregarded by conventional unit root tests at the conditional mean. Third, our approach avoids the estimation of additional parameters and regimes and therefore reduces estimation uncertainty. Existing studies include the estimation of additional parameters by using different regimes or conditioning on additional variables that indicate whether the economy is in expansion or recession. Fourth, the QAR-based unit root test has higher power than conventional unit root tests as shown by Koenker and Xiao (2004). Fifth, the QAR-based unit root is superior to standard unit root tests in case of departure from Gaussian residuals. We test for normality of the residuals and strongly reject it.

Using our general approach, we find that positive and negative shocks including large recessionary shocks have permanent effects on real GDP. Real GDP is best described as a unit root process with drift that is relatively homogeneous over its whole conditional distribution. The point estimates in the lower tail of the conditional GDP distribution are extremely close to one. Therefore, the Great Recession—which is an event in the lower tail—has a permanent effect on GDP. A rebound of GDP to its pre-crisis path is unlikely. Following an unexpected change in real output one should change one's forecast of the GDP path permanently. This means that one should predict average growth rates following the shock rather than above average growth rates which would be necessary to generate a rebound of the GDP level to its earlier trend.

Beyond these implications for forecasting the result has implications for macroeconomic modeling and economic policy. Current output gap estimates based on deterministic trends might be too negative. In turn, inflation forecasts based on these might be too low. If policy makers currently use wrong inflation forecasts and output gap estimates then monetary and fiscal policy might be too expansionary aiming at a level of output that is higher than potential output. These actions would ultimately lead to higher inflation and budget deficits without increasing output in a sustainable manner. While in most models only technology shocks can have permanent effects we discuss possible channels through which large recessions can lower output permanently. Including these in structural macroeconomic models would be essential to capture permanent changes of trend GDP that are not caused by technology shocks, but emanate from the financial sector and lead to severe disruptions in the real economy.

The remainder of the paper is structured as follows: section 2 introduces the testing procedure. In section 3 we present and discuss the empirical results. Finally, section 4 concludes.

2 Methodology

Let y_t denote the log of real US GDP and ϵ_t a serially uncorrelated error term. An AR(q) process for log real GDP with drift a and deterministic trend t is given by:

$$y_t = a + bt + \sum_{i=1}^{q} \gamma_i y_{t-i} + \epsilon_t, \quad t = q+1, q+2, ..., n. \tag{1}$$

The sum of the autoregressive coefficients is $\alpha = \sum_{i=1}^{q} \gamma_i$. This is the measure of persistence that we focus on. Rewriting equation (1) as:

$$y_t = \alpha y_{t-1} + a + bt + \sum_{i=1}^{q-1} \phi_i \Delta y_{t-i} + \epsilon_t. \tag{2}$$

one can run the usual unit root test. If $\alpha = 1$ then US GDP has a unit root and, therefore, shocks have permanent effects on GDP. If $\alpha < 1$ then US GDP is trend stationary. In the latter case shocks have only temporary effects only and therefore GDP returns to its deterministic trend after the effects of shocks have faded out. The $q-1$ lags of first-differenced real GDP are included to account for serial correlation.

To get more detailed estimates to analyse persistence not only at the conditional mean, but also in the tails of the conditional distribution of y_t we can estimate equation (2) using quantile autoregression methods. Quantiles are values that divide a distribution such that a given proportion of observations is located below the quantile. The $\tau - th$ conditional quantile is defined as the value $Q_\tau(y_t|y_{t-1}, ..., y_{t-q})$ such that the probability that the output conditional on its recent history will be less than $Q_\tau(y_t|y_{t-1}, ..., y_{t-q})$ is τ and the probability that it will be more than $Q_\tau(y_t|y_{t-1}, ..., y_{t-q})$ is $1 - \tau$.

For example, if output is very high relative to recent output realizations this means that a large positive shock has occurred and that y_t is located above the mean conditional on past observations $y_{t-1}, ..., y_{t-q}$ somewhere in the upper conditional quantiles. If output is lower than in the previous quarters, this means that a negative shock to output has occurred and that output conditional on past observations is located below the mean somewhere in the lower conditional quantiles.

The AR(q) process of real GDP at quantile τ can be written as:

$$Q_\tau\left(y_t|y_{t-1},...,y_{t-q}\right)=\alpha\left(\tau\right)y_{t-1}+a\left(\tau\right)+b\left(\tau\right)t+\sum_{i=1}^{q-1}\phi_i\left(\tau\right)\Delta y_{t-i}. \tag{3}$$

By estimating equation (3) at different quantiles $\tau\in(0,1)$ we get a set of estimates of the persistence measure $\alpha(\tau)$. When estimating (3) our interest lies in the null hypothesis $H_0:\alpha\left(\tau\right)=1$. We can test $\alpha(\tau)=1$ at different values of τ to analyse the persistence of the GDP impact of positive and negative shocks and shocks of different magnitude. For example if large recessionary shocks, i.e. output observations in the low conditional quantiles, lower output permanently, then $\alpha(\tau)=1$ for small values of τ.

Koenker and Xiao (2004) have developed a unit root test based on quantile autoregression. This test allows, in contrast to tests at the conditional mean, for heterogenous effects on output. Their test is, however, restricted to models without deterministic components. In the case of real GDP it is important to include a deterministic trend in the regression. The test has been extended by Galvao (2009) to include deterministic components. In the following paragraphs we describe the technical details of the test.

Let $\widehat{\alpha}\left(\tau\right)$ be the estimator of $\alpha\left(\tau\right)$ which solves

$$\min_{(\alpha(\tau),a(\tau),b(\tau),\phi_1(\tau),...,\phi_{q-1}(\tau))}\sum\nolimits_t\rho_\tau\left(y_t-\alpha\left(\tau\right)y_{t-1}-a\left(\tau\right)+b\left(\tau\right)t-\sum_{i=1}^{q-1}\phi_i\left(\tau\right)\Delta y_{t-i}\right), \tag{4}$$

where $\rho_\tau\left(x\right)=x\left(\tau-I\left(x<0\right)\right)$ is the usual check function as in Koenker and Bassett (1978).

To test $H_0:\alpha\left(\tau\right)=1$ we use the t-stat for $\widehat{\alpha}\left(\tau\right)$ proposed by Koenker and Xiao (2004) which can be written as

$$t_n\left(\tau\right)=\frac{f(\widehat{F^{-1}\left(\tau\right)})}{\sqrt{\tau\left(1-\tau\right)}}\left(Y_{-1}'M_ZY_{-1}\right)^{1/2}\left(\widehat{\alpha}\left(\tau\right)-1\right), \tag{5}$$

where $f\left(u\right)$ and $F\left(u\right)$ are the probability and cumulative density functions of ε_t, Y_{-1} is the vector of lagged log-GDP and M_Z is the projection matrix onto the space orthogonal to $Z=\left(1,t,\Delta y_{t-1},\Delta y_{t-2},...,\Delta y_{t-q+1}\right)$.

As discussed by Galvao (2009), the limiting distribution of $t_n\left(\tau\right)$ can be written as

$$t_n\left(\tau\right)\overset{D}{\to}\delta\left(\int_0^1\underline{W}_1^2\left(r\right)dr\right)^{-1/2}\int_0^1\underline{W}_1\left(r\right)dW_1\left(r\right)+\sqrt{1-\delta^2}N\left(0,1\right),$$

where $\overset{D}{\to}$ signifies convergence in distribution, $W_1\left(r\right)$ is a Brownian motion, $\underline{W}_1\left(r\right)=W_1\left(r\right)-\left[\int_0^1\left(4-6s\right)W_1\left(s\right)ds-r\int_0^1\left(6-12s\right)W_1\left(s\right)ds\right]$ and $N\left(0,1\right)$ is a standard normal random variable independent from the first component of the limiting distribution. Let

$\psi_\tau(x) = \tau - I(x<0)$ and $\varepsilon_{t\tau}$ be the residuals from the regression equation (3), then the weighting parameter, δ, is

$$\delta = \frac{\sigma_{\varepsilon\psi}}{\sigma_\varepsilon\sqrt{\tau(1-\tau)}},$$

where σ_ε is the long variance of ε_t and $\sigma_{\varepsilon\psi}$ is the long-run covariance of ε_t and $\psi_\tau(\varepsilon_{t\tau})$. We follow the suggestions of Koenker and Xiao (2004) and Galvao (2009) to estimate the nuisance parameters.[5] To provide an estimate for $f\left(F^{-1}(\tau)\right)$ we follow the rule given in Koenker and Xiao (2004), i.e.

$$f(\widehat{F^{-1}(\tau)}) = \frac{2h_n}{\overline{y}_{\tau+h_n} - \overline{y}_{\tau-h_n}},$$

where we choose h_n using the discussions made in Qu (2008), and $\overline{y}_{\tau^*}$ is the average of the fitted values from (4) for the τ^*-th quantile.[6]

Besides allowing for asymmetric effects of shocks on GDP an important advantage of QAR-based unit root tests over standard unit root tests is that they have more power. This is shown by Koenker and Xiao (2004). To understand this power gain a comparison with Hansen (1995) is helpful. He shows that including more covariates can lead to substantial power gains when compared to univariate unit root tests. This result that including more relevant information results in large power gains is quite intuitive. Interestingly the limiting distribution of the t-statistic of Koenker and Xiao (2004) and Galvao (2009) resemble the limiting distribution of tests discussed in Hansen (1995). Hence QAR autoregression could be seen as a tool for systematically resorting to the framework of Hansen (1995) without including additional covariates.

3 Empirical results

We use quarterly post WWII data on log US real GDP from 1947Q1 to 2012Q1. We do not include earlier observations to exclude the possibility that the results are distorted by the heterogeneity of the data (see Murray and Nelson, 2000, for a detailed analysis of the heterogeneity issue). We estimate the parameters in equation (3) by solving equation (4). We choose the lag length based on the MAIC criterion suggested by Ng and Perron (2001). We find a lag length of $q = 9$.[7] We use the same lag length for all considered quantiles τ.

[5] In particular, to estimate σ_ε and $\sigma_{\varepsilon\psi}$ we use a kernel estimation, with the following kernel from Andrews (1991):

$$k(h) = \begin{cases} \frac{25M^2}{12\pi^2h^2}\left(\frac{\sin(6\pi h/5M)}{6\pi h/5M} - \cos(6\pi h/5M)\right) & h>0 \\ 1 & h=0 \end{cases},$$

where M is the window size that we choose to be $n^{1/3}$.

[6] Alternatively, one could estimate $f\left(F^{-1}(\tau)\right)$ nonparametrically using the mean regression residuals.

[7] The results are robust to using a different lag length. For example Schwert's rule (Schwert, 1989) of thumb, i.e. $q = [4*(T/100)^{0.25}]$, yields $q = 5$ and delivers very similar parameter estimates.

3.1 Estimation results

Figure 2 shows the estimates of $\alpha(\tau)$ for $\tau = 0.05, 0.10, ..., 0.95$ together with 95% bootstrapped confidence bands. As this graph shows, the persistence parameter estimates are close to one for all the quantiles considered. The point estimate is slightly above one at the 0.10 quantile, coincides with one at the 0.80 quantile and is slightly below one in the center of the conditional distribution and at the upper tail. Overall the parameter estimates are relatively homogenous over the conditional GDP distribution. For comparison we show estimates at the conditional mean (horizontal dashed line), $\widehat{\alpha}$, using equation (2). This estimate is very close to the quantile estimates $\widehat{\alpha}(\tau)$ for all τ's considered. The confidence band includes unity for all quantiles considered.

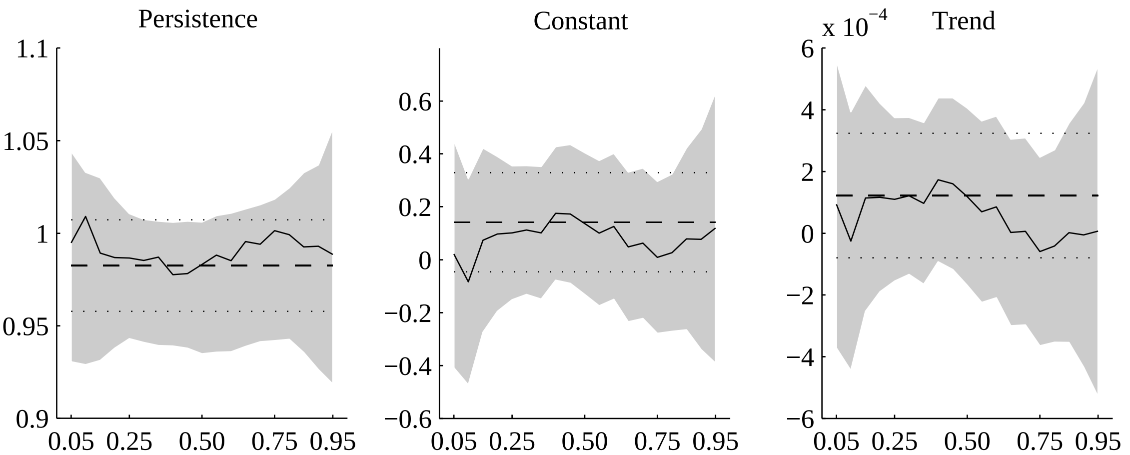

Figure 2: Quantile regression estimates. Notes: The graphs show estimates of the persistence parameter $\alpha(\tau)$ and the deterministic parameters $a(\tau)$ and $b(\tau)$ at different quantiles $\tau \in \{0.05, 0.1, ..., 0.95\}$. The grey areas indicate 95% bootstrapped confidence bands for the quantile autoregression estimates. The horizontal dashed line shows estimated parameters from a simple mean regression with 95% confidence bands (dotted) for comparison.

Persistence is highest at the lower tail of the conditional GDP distribution. The most negative shocks to real GDP like the 2008/2009 recession, thus, lower output permanently. However, also the parameter estimates at the other parts of the conditional GDP distribution are only slightly lower than one indicating that not only large recessionary, but all shocks to GDP have a highly persistent impact. This result is in line with for example Balke and Fomby (1991) who find that infrequent recessionary shocks have permanent effects on output, but that also the impact of all other shocks is of substantial persistence. The parameter estimates for the trend are not significantly different from zero over the whole conditional distribution which is in line with not rejecting the unit root hypothesis. The estimated constant is slightly larger than zero for most parts of the conditional distribution—though insignificant on the 5% level—which is necessary to explain that the GDP time series grows over time, i.e. it follows a unit root with drift process.

To test the null of $\alpha(\tau) = 1$ for $\tau = 0.05, 0.10, ..., 0.95$ more formally, we use the t-statistic based on equation (5). Table 1 shows the t-statistics and the critical values that we have computed.

Table 1: Unit root test results

Quantile	$\alpha(\tau)$	t-statistic	critical value
0.05	0.9966	-0.1100	-2.7597
0.10	1.0119	0.3607	-2.8892
0.15	0.9843	-0.6545	-3.1436
0.20	0.9746	-1.2205	-3.0921
0.25	0.9789	-1.0349	-2.9465
0.30	0.9813	-1.1360	-3.0358
0.35	0.9786	-1.3969	-3.0565
0.40	0.9735	-1.7068	-3.1363
0.45	0.9764	-1.5998	-3.0797
0.50	0.9744	-1.6665	-2.9879
0.55	0.9846	-0.8976	-2.8879
0.60	0.9832	-1.1604	-2.8955
0.65	0.9936	-0.4492	-2.9639
0.70	0.9810	-1.2869	-2.8090
0.75	1.0011	0.0694	-2.7623
0.80	0.9934	-0.3714	-2.7985
0.85	0.9892	-0.5264	-2.6454
0.90	0.9930	-0.2564	-2.4777
0.95	0.9885	-0.2907	-2.3100

Notes: The table shows point estimates, t-statistics and critical values for the 5 percent significance level. If the t-statistic is smaller than the critical value then we reject the null hypothesis of $\alpha(\tau) = 1$ at the 5 percent level.

We find that $H_0 : \alpha(\tau) = 1$ cannot be rejected at the 5% significance level over the whole conditional GDP distribution. The test confirms that all types of shocks to GDP lead to permanent effects on real GDP. This result is in line with for example Campbell and Mankiw (1987) who find that an unexpected change in real output should change one's forecast permanently.

3.2 Robustness

Balke and Fomby (1991) show that a process generated by infrequent large permanent shocks and a process with a breaking linear time trend are observationally equivalent. Therefore, we check whether the result wrongly show evidence for permanent shocks if instead a break in a deterministic trend has taken place. To do so we follow Perron (1989) who extended the ADF test to allow for a structural break in the level and/or the slope of y_t at a known date ξ.

$$y_t = \alpha y_{t-1} + a + bt + \sum_{i=1}^{q-1} \phi_i \Delta y_{t-i} + \delta t S(\xi)_t + \gamma I(\xi)_t + \epsilon_t, \tag{6}$$

The dummy variables S and I are zero through year ξ and one afterwards. If y_t follows a unit root process, then the dummy variable I accounts for a break in the level. If y_t is trend stationary the step dummy S accounts for a break in the trend leading to a permanent shift of the deterministic trend. Assuming that a break happens at the third quarter of 2007, the time of break relative to sample size would be 0.93. Let λ be the fraction of time of break relative to sample size. As Perron (1989) shows the t-statistic of $\widehat{\alpha}$ in equation (6) depends on λ, and consequently provides five percent level critical values for the t-statistic of $\widehat{\alpha}$ for $\lambda = 0.1, 0, 0.2, ..., 0.9$. Conducting a simulation study we obtain the corresponding critical values of -3.0704 for $\lambda = 0.95$.[8] With this calculation, we are able to interpolate critical values for $\lambda \in [0.1, 0.95]$. For the log-GDP series having a break at $\lambda = 0.93$ (i.e. at the third quarter of 2007), we find a critical value of -3.6860 for the t-statistic of $\widehat{\alpha}$ equation (6). The t-statistic is -3.0704, which is larger than the critical value and leads to a failure in rejecting the null of a unit root. We also included a break in 1973 (i.e. $\lambda = 0.41$) to account for a slow down of productivity and average GDP growth rates since then (see for example Perron, 1989). In this case we find a t-statistic of -2.6047 for $\widehat{\alpha}$ in equation (6). Correspondingly, when $\lambda = 0.41$ the five percent critical value would be -4.2220 for the null of $\alpha = 1$. This leads again to a failure in rejecting the null of a unit root showing that our results are indeed valid and robust to including trend breaks in 2007 and 1973.

In addition to these robustness checks, we also tested for normality of the error residuals from a regression at the conditional mean. Monte Carlo studies performed by Galvao (2009), among others, clearly show the superiority of QAR-based unit root tests when departing from Gaussian residuals. The residuals do not exhibit any significant serial correlation hence we can use standard normality tests. The Kurtosis of the residuals is 4.9189 and the Skewness is 0.1079. These two already indicate possible deviation from normality. We run three different tests of the null of normality. All three tests strongly reject Gaussianity of the residuals. The Jarque-Bera test has a p-value smaller than 0.001, the Lilliefors test finds a p-value of 0.008 and the Shapiro-Wilk test finds a p-value smaller than 0.001. Based on these results a QAR-based unit root tests is advantageous even if one would be only interested in the average effect of shocks on GDP.

[8] We considered a simulation length of 10,000 and time series with length of 1000 for equation (6) setting $\phi_i = 0$ for all i's.

3.3 Discussing the implications of our results

Our results have implications for current potential output estimates, output gap estimates, inflation forecasts derived from the output-gap estimates and monetary and fiscal policy. The upper graph in figure 3 shows potential output estimates by the Congressional Budget Office (CBO) and an estimated deterministic trend of real GDP.[9] We show two version of the CBO estimates. One has been produced in 2007 and the other one is from 2012. Evidently, the CBO has revised the potential output estimates downwards recently, but they are still largely above recent real GDP numbers. The 2012 potential output estimate coincides with estimates of a deterministic trend. The lower part of figure 3 shows the implied output gap estimates, i.e. percentage deviations of real GDP from potential output. The output gap estimates of the CBO imply a persistently negative output gap similar to the one based on deterministically detrending the data. As GDP has grown at modest rates after the financial crisis, it has not converted back to its pre-crisis trend.

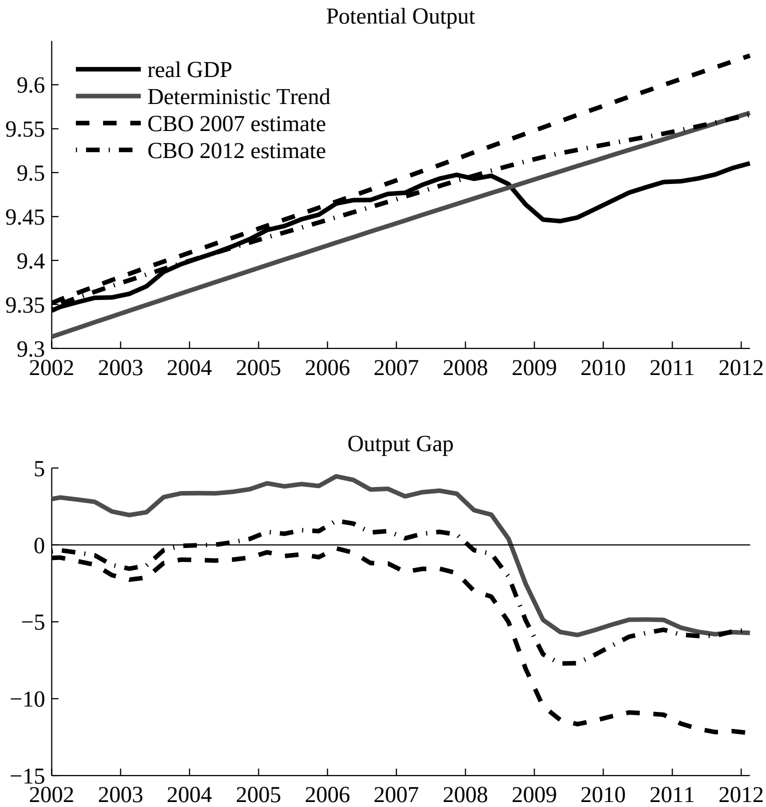

Figure 3: Potential output and output gap estimates. Notes: The vertical scale in the upper graph is in natural logarithms of GDP measured in billions of 2005 US dollars. The 2007 potential output estimates are shifted so that the level in 1995:Q1 is equal to the value in the 2012 vintage. The lower graph shows the percentage difference between real GDP and the potential output estimates.

[9] As in figure 1 we regress the log of quarterly real GDP data from 1947Q1 to 2012Q1 on a constant, a linear and a quadratic trend.

The Federal Open Market Committee (FOMC) issued statements following its 2012 January and March meetings indicating that it "currently anticipates that economic conditions—including low rates of resource utilization and a subdued outlook for inflation over the medium run—are likely to warrant exceptionally low levels for the federal funds rate at least through late 2014." Also Yellen (2012) argues that the unemployment rate stands well above its long run level and that this keeps inflation down. These arguments are in line with the potential output and output gap estimates shown in figure 3.

Our analysis shows instead that these potential output and output gap estimates are misleading as they are based on the assumption that potential GDP and the long run unemployment rate have not been changed substantially by the financial crisis. We find instead that the Great Recession has most likely lowered GDP permanently leading to a much smaller output gap than figure 3 suggests. Real GDP might be much closer to a new lower path of potential GDP. Furthermore, the very modest increase in inflation in 2011 and 2012 is at odds with a large negative output gap, because a large and negative output gap rather suggests a decrease in inflation (see also Gavin, 2012). Highly expansionary monetary policy like recent extensions of quantitative easing to increase output might be misguided if potential output has decreased and might ultimately result in higher inflation rates rather than a strong decrease in the unemployment rate.

A reason why policy makers argue in favour of a rebound of GDP to its pre-crisis trend path might be that in modern macroeconomic models as used by policy institutions only technology shocks can lead to permanent changes in long run GDP and the natural unemployment rate. At least for the 2008/2009 crisis it is hard to believe that technology shocks are the main driving factor that have led to a lower GDP path. If technology shocks were not the reasons for the permanent reduction of GDP following the 2008/2009 crisis, then there must exist other shocks and transmission channels that have permanent effects on GDP and are not yet included in standard macroeconomic models.

Bullard (2012) has analysed possible channels through which the recent financial crisis has lowered output permanently. He argues that the financial crisis was a one-time permanent shock to wealth and in particular to housing wealth. The perceived value of US real estate fell by 30% during the crisis and is not expected to return to pre-crisis levels anytime soon. Therefore, this wealth is permanently gone. This loss might lower consumption and output permanently and lead to significant disruptions in the US labor market. Williamson (2012) discusses the argument by Bullard. In his opinion it is not the wealth loss that lowers output permanently, but the loss of collateral. He argues that houses serve as collateral for mortgage debt which can be repackaged in mortgage-backed securities. These serve as collateral in financial arrangements and can support multiple credit arrangements. With the burst of the housing bubble part of this collateral is gone which leads to permanent negative effect on GDP. These arguments indicate that while the recession was not caused by a permanent technology shock, the decrease in GDP is likely to be permanent leading to an increase in the long run unemployment rate. The possibility that wealth or collateral losses cause a permanent change in GDP and potential GDP is not included in modern macroeconomic models as used by policy institutions, yet, which makes it difficult to formalize these intuitive arguments. This might also be a reason for the widespread belief that recessions that are not caused by permanent technology shocks must lead to a rebound of GDP after the recession is over.

4 Conclusion

We have analysed the question whether large recession lower output permanently using a recent quantile autoregression based unit root test. This test allows for heterogenous effects of shocks of different size and magnitude. We find that all types of shocks to GDP can have permanent effects. Especially, large recessionary shocks tend to have a highly persistent negative impact on GDP. In the context of the 2008/2009 financial crisis, our results imply that the path of US real GDP has been shifted to a lower level compared to its pre-crisis trend path. A rebound of real GDP to its pre-crisis trend appears unlikely. Our results rather suggest that GDP will follow a path similar to the one predicted by the Blue Chip Consensus forecast as shown in figure 1. Potential GDP has decreased permanently so that output gap estimates based on a deterministic trend might therefore be too negative. Current macroeconomic models only consider technology shocks as a source of permanent changes of GDP. The financial crisis has instead lowered household wealth and housing collateral permanently leading to lower consumption and higher unemployment rates. Monetary and fiscal policy that is based on the assumption of potential output following its pre-crisis path might be misguided and lead to increased inflation and large fiscal deficits without being able to increase output and lower unemployment in a sustainable way.

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