UNIT ROOTS, PERSISTENCE, AND THE MEASUREMENT OF PREWAR OUTPUT SERIES

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Abstract

Recent studies find that U.S. real GNP for 1869-1929 has no unit root. The note presents Monte Carlo evidence showing that linear trend interpolation used for constructing prewar GNP series may be responsible for this finding.

1. Introduction

The extent to which shocks have permanent effects on the level of macroeconomic time series has been extensively debated since Nelson and Plosser (1982) published their seminal contribution. Empirical work on this topic using U.S. real GNP series has led to markedly different conclusions depending on whether prewar GNP series for 1869-1929 or post World War II series are analysed. Stock and Watson (1986), Campbell and Mankiw (1987), and Perron (1988) find that U.S. prewar GNP is well described by a deterministic trend plus stationary fluctuations around the trend. By contrast, postwar U.S. GNP appears to follow a stochastic trend, i.e. it has a unit root, and shocks will therefore induce persistent changes in the level of the series [see for example Campbell and Mankiw (1987)].

This note first re-examines the persistence properties of prewar real GNP. Campbell and Mankiw (1989) suggest that the standard U.S. GNP series based on Kuznets's (1961) work is unreliable because business-cycle fluctuations are overstated. In section 2, I analyse recently published prewar series by Balke and Gordon (1989) and Romer (1989). I find that these alternative GNP series are also well described as transitory fluctuations around a deterministic trend. Stock and Watson (1986) conjecture that linear trend interpolation might be responsible for the low persistence in U.S. prewar data. Section 3 reports the results of a Monte Carlo experiment confirming that linear interpolation will reduce the amount of persistence in an originally persistent series drastically.

Whether we perceive the low persistence in prewar GNP as an established fact or a possible figment of the data construction process is important for at least two reasons. First, several authors including Cochrane (1988) study data sets combining prewar and postwar GNP data. If linear interpolation has a substantial effect on the persistence properties of a time series, their results may be sensitive to inclusion of the interpolated prewar data. Second, accepting low persistence in prewar data as an established fact implies different perspectives on the effects of economic policy regimes. For example, DeLong and Summers (1988) argue that high persistence in postwar GNP can be traced to successful Keynesian demand management whereas low persistence in prewar GNP indicates large welfare-reducing transitory fluctuations.

2. Empirical evidence

Dickey and Fuller (1979) propose a unit root test based on the regression

$$Y_t = \mu + \beta[t-(T+1)/2] + \alpha Y_{t-1} + \epsilon_t. \tag{1}$$

Below, Y_t stands for the logarithm of real GNP, T is the sample size, and ϵ_t denotes a regression disturbance term. The null hypothesis of a unit root in GNP is given by $\alpha=1$, and the relevant test distribution is tabulated in Fuller (1976).

I use Cochrane's (1988) non-parametric measure of persistence as an alternative statistic to evaluate the evidence for a unit root. It is defined

$$V^k = 1 + 2 \sum_{j=1}^{k} [1-j/(k+1)]r_j, \tag{2}$$

where r_j is the *j*th sample autocorrelation of the first differences of Y_t and k the number of autocorrelations included in the calculation of V^k. It appears to be common practice to report V-measures for different sizes of k up to about 2/3 of sample size. If GNP fluctuates around a deterministic trend, estimates of V^k will be close to zero at least for large k. For a random walk, the V-measure is close to 1 if k is small but will be biased downwards if k increases. The asymptotic standard error of the V-measure is given by $V^k/[.75T/(k+1)]^{1/2}$ [Campbell and Mankiw (1987, p.873)].

Three real U.S. prewar GNP series are analysed: The widely used real income series listed in Friedman and Schwartz (1982, pp. 122-24), which is largely based on work by Kuznets (1961), and the two revised prewar GNP series recently published by Balke and Gordon (1989, pp. 84-85) and Romer (1989, pp.22-23). The time range is 1869-1929, and the series are expressed in per capita terms using the population series listed in Friedman and Schwartz (1982).

Table 1, panel A, contains the results of the Dickey-Fuller test. The test statistics $t(\alpha)$ reject the null hypothesis of a unit root for all three series at the 10 % significance level. Included lagged differences of GNP to account for serial correlation proved insignificant and the first-order autocorrelation coefficient of the residuals, r_1, indicates no autocorrelation at lag one. Panel B of table 1 reports persistence estimates. The first row gives estimates of the V-measure for an artificially generated random walk. Compared with the estimates for the random walk, the persistence of the three prewar GNP series is substantially lower at all values of k. Even if Dickey-Fuller test results are considered unreliable, the V-measures indicate that the trend in prewar GNP is better approximated by a deterministic rather than a stochastic trend.

3. Linear interpolation and persistence

Estimates of prewar U.S. GNP had to be based on a sketchy data base. For example, the single most important data source, the *Census of Manufactures*, was taken every ten years from 1869 to 1899 and every five years from 1899 to 1919. Romer (1989, p. 8) describes the linear interpolation procedure used by Kuznets (1961) to construct his prewar GNP series for 1869-1918.[1] The effects of linear interpolation on a time series containing a unit root is now illustrated by a Monte Carlo experiment. The original data generating process is given by

$$Y_t = Y_{t-1} + \epsilon_t - \theta\epsilon_{t-1}, \tag{3}$$

where ϵ_t is a white noise disturbance assumed to be standard-normally distributed. Including a drift term does not affect the Monte Carlo results. Assuming various values for θ, equation (3) is used to generate artificial output series

1 Friedman and Schwartz (1982, p. 101) state that they used linear interpolation to revise Kuznets's series for the wartime periods 1917-1919 and 1942-45.

with 50 observations. The starting values for ϵ_t and Y_t are set equal to zero. Then the interpolated series is constructed assuming that only realisations at t = 1, 10, 20, 30, 40, and 50 are observed. Trend values for the remaining observations are generated by linear interpolation between the observed values. To account for deviations from trend, the moving average part of the original series, $\epsilon_t - \theta\epsilon_{t-1}$, is added to the interpolated values.

Table 2 lists persistence measures for lag lengths 2, 5, and 10. Only V-measures up to k=10 are reported because the sample autocorrelation function of the interpolated series can be expected to level off quickly after the first few autocorrelations for the type of process used in the Monte Carlo experiment.

Considering the random walk case first, the application of trend interpolation to the random walk series has reduced persistence drastically. For negative values of the moving average parameter, the original process will be more persistent than a random walk. Linear interpolation reduces the persistence of these series substantially but some persistence remains in the interpolated series. If the original process has low persistence to start with (θ=0.25), the V-measures indicate almost no persistence in the interpolated series.

Further insight into the effects of interpolation is provided by the sample autocorrelations of the interpolated series. For the random walk case, linear interpolation introduces a negative first-order autocorrelation coefficient of -0.43. This implies a root for the moving average part of the first differenced interpolated process close to 1.0, which is a characteristic of processes consisting of stationary movements around a deterministic trend.[2] Similarly, negative autocorrelation is introduced by interpolation for the more persistent processes. Turning to the actual prewar GNP series, the first two autocorrelations of the Friedman-Schwartz series are -0.17 and -0.21, of the Balke-Gordon series -0.14 and -0.06, and of the Romer series -0.04 and -0.31. These patterns might be due to the effects of interpolation as illustrated by the Monte Carlo experiment.

2 The case of the random walk indicates that linear interpolation can introduce moving average terms in a time series. Schwert (1987) provides evidence that the actual size of the Dickey-Fuller test can exceed the nominal size substantially if moving average terms are present in the first differenced representation of a time series. This caveat is relevant for the interpretation of the Dickey-Fuller tests in table 1 but not for the persistence measures.

4. Conclusions

Prewar real U.S. GNP appears not to be driven by a stochastic trend. The note argued that linear trend interpolation may be responsible for this finding. However, the Monte Carlo evidence should not be interpreted as positive evidence for a unit root in prewar U.S. GNP. It can not be ruled out that the actual but unobserved prewar GNP series followed a deterministic trend. Nevertheless, the Monte Carlo evidence casts serious doubts on the validity of persistence results based on prewar U.S. GNP.

Two promising routes appear to be available to shed more light on the persistence properties of prewar GNP data. First, comparable data for Sweden, the United Kingdom, and Australia are presumably based on much better year-to-year information than U.S. data, and therefore less reliance on linear interpolation was necessary. In fact, DeLong and Summers (1988, table 3) analyse prewar per capita GDP data for Sweden and the United Kingdom and report non-parametric estimates of persistence consistent with a unit root in the series for both countries. Second, following Friedman (1961), analysis of monetary series may provide useful indirect evidence on the properties of prewar income series.

Table 1

Unit roots and persistence in prewar GNP.

(A) Dickey-Fuller tests[a]

$$Y_t = \mu + \beta[t-(T+1)/2] + \alpha Y_{t-1} + \epsilon_t$$

Series	μ	β	α	$t(\alpha)$	se	r_1
Friedman-Schwartz	-0.349 (0.094)	0.007 (0.002)	0.573 (0.109)	-3.92	0.057	0.029
Balke-Gordon	0.467 (0.125)	0.006 (0.002)	0.632 (0.102)	-3.61	0.043	0.034
Romer	0.382 (0.112)	0.005 (0.002)	0.701 (0.092)	-3.26	0.033	0.067

[a] Critical values for test statistic $t(\alpha)$ (sample size 50) are -3.18 (10%), -3.50 (5%), -4.15 (1%). *se* denotes the standard error of regression, and r_1 is the first-order autocorrelation coefficient of the residuals.

(B) Persistence measures[b]

Series	k=5	k=10	k=15	k=20	k=30
Random walk[c]	0.86 (0.35)	0.74 (0.41)	0.63 (0.42)	0.53 (0.40)	0.43 (0.36)
Friedman-Schwartz	0.35 (0.13)	0.13 (0.26)	0.17 (0.10)	0.06 (0.04)	0.07 (0.06)
Balke-Gordon	0.46 (0.17)	0.31 (0.15)	0.18 (0.11)	0.06 (0.04)	0.06 (0.05)
Romer	0.51 (0.18)	0.43 (0.22)	0.30 (0.18)	0.16 (0.11)	0.13 (0.11)

[b] Numbers in parentheses below V-measures are asymptotic standard errors.

[c] Artificially generated random walk (50 observations and 500 replications).

Table 2

Interpolation and persistence.

Original process: $Y_t = Y_{t-1} + \epsilon_t - \theta\epsilon_{t-1}$

	Process	Persistence			Autocorrelations	
		k=2	k=5	k=10	r_1	r_2
θ=0.00	Original	0.94 (0.27)	0.88 (0.36)	0.79 (0.43)	0.00	0.00
	Interpolated	0.18 (0.05)	0.25 (0.10)	0.30 (0.17)	-0.43	0.03
θ=-0.50	Original	1.67 (0.48)	1.56 (0.63)	1.39 (0.76)	0.40	0.00
	Interpolated	0.58 (0.16)	0.63 (0.23)	0.71 (0.40)	-0.11	-0.16
θ=-0.25	Original	1.37 (0.39)	1.30 (0.52)	1.19 (0.65)	0.24	0.00
	Interpolated	0.39 (0.11)	0.49 (0.20)	0.55 (0.30)	-0.26	-0.07
θ=0.25	Original	0.51 (0.14)	0.46 (0.19)	0.41 (0.23)	-0.24	0.00
	Interpolated	0.04 (0.01)	0.10 (0.04)	0.13 (0.07)	-0.54	0.10

[a] This table contains the results of a Monte Carlo experiment. Series from four ARIMA(0,1,1) processes (50 observations) constitute the original series. The trend interpolation procedure described in the text is used to construct the interpolated series from the original series. Autocorrelations for the original process are population autocorrelations. The results are based on 500 replications.

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