



The Stationarity of Productivity Shocks: Evidence from 25 OECD and Big-7 Countries

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ABSTRACT

We apply the panel covariate augmented Dickey–Fuller test to test stationarity of the productivity series for the OECD and Big-7 economies. The approach takes cross-sectional dependence into account. Using hours-worked per worker, we find that the series is non-stationary for the 25 OECD countries; but for the Big-7 the results are mixed. So, this paper achieves a battery of panel unit root tests to examine the stationarity properties of the series named hours worked per employee. The study period covers 1960-2012 for the OECD and the Big-7 countries. The tests we use account for cross-sectional dependence and those that do not account for such dependence. Our results suggest that an analyst might infer that hours worked fall after a positive technology shock, when it may go up in a true data-generating process. The findings also suggest that although in a true data-generating process, the series may go up from a positive technology shock, analysts may infer a fall. The stationarity of the series is relevant in determining the effect of positive technology shock on productivity.

Keywords: Productivity Shock, Panel Unit Root, Cross-sectional Dependence, OECD and Big-7 Countries

JEL Classifications: C22, C23, J22

1. INTRODUCTION

What is the impact of a positive technology shock on per capita hours worked; investment; consumption; average productivity and output? In theory, positive productivity shocks in real business cycle models (RBCs), under real rigidity (Francis and Ramey, 2002) or sticky price (Galí, 1999), can generate negative effects on hours. Based on the evidence from a large and growing body of literature and an analysis of aggregate data, per capita hours worked fall after a positive technology shock. Galí (1999) documents that innovations in technology generate shocks that affect long-run level of labour productivity. However, hours worked fall after a positive shock in technology; and is protracted to the point that technology shocks generate negative correlation between outputs and hours worked. Noting that hours worked are in effect strongly pro-cyclical, he concludes that some other shocks might be at work and possibly be playing a dominant role in business cycles; where technology shock has only a minor role. Christiano et al., (2003; 2004) point out that a positive shock to

technology drives up per capita hours-worked, consumption, investment, average productivity and output - a result that is in sharp contrasts with other findings. Maybe, the difference in the results is the product of specification error - the way the literature models the low-frequency component of hours worked.

While some of the findings complement Galí (1999) (e.g., Shea [1998]; Basu et al. 2006; Francis and Ramey, 2002), Christiano et al., (2003) make the same fundamental identification assumption as Galí (1999), Galí et al., (2003), and Francis and Ramey (2001) and yet ends up with different results. She concludes: It all depends on how we treat the hours worked series. If it is assumed, as Francis and Ramey (2002) do-per capita hours worked is a difference stationary process, and apply the difference specification-hours worked falls after a positive technology shock. On the other hand, if per capita hours worked is assumed to be a stationary process and apply the level specification, we get the opposite results. Whether or not the specification is correct, the simple univariate hypothesis tests do not offer much of a consolation. They can neither reject

the null hypothesis of a difference-stationary process; nor the stationarity of hours worked. This is not an unexpected outcome as we know that univariate models cannot distinguish a difference stationary stochastic process from a persistent stationary process. The standard RBC models posit that hours worked rise after a positive technology shock. “In effect, RBCs models are doubly dammed: They address things that are unimportant, and they do it badly at that” (Christiano et al., 2003. p. 1). Given the role of technology shocks in business cycle analyses over the past three decades, the observation that Galí is a “...potential paradigm shifter” seem appropriate (Francis and Ramey, 2001. p. 2).

The finding that hours worked fall from a positive technology shock, has drawn considerable academic curiosity. Some even tried to construct general equilibrium business cycle models to explain the result. Galí (1999) and others argue that the sticky prices might offer a plausible explanation. Francis and Ramey (2001) and Vigfusson (2002), on the other hand argue that such finding is consistent with the modified RBC models which are broader in scope and more inclusive. Also, such models predict a rise in output, average productivity, investment, and consumption.

The objective of the paper is to apply the panel covariate augmented Dickey–Fuller (CADF) test proposed by Costantini and Lupi (2013) to check stationarity of the hours worked per worker series for the OECD and the Big-7 economies. The test is based on the P value combination methods. A distinct feature of this approach is that it takes cross-sectional dependence into account. We find that the series is non-stationary for the former; but mixed for the latter countries. This paper contributes by providing further evidence on stationarity of the hours worked for the countries studied by applying a recently developed test which is novel.

Knowledge of the effects of productivity shocks on employment is important for policy makers for several reasons. First, whether employment, measured in terms of total hours worked, rises or falls after a positive shock should help delineate the class of macroeconomic models which predict such effect. Regardless of whether such shocks are the prime sources of aggregate fluctuations, the information can help to influence macroeconomic policy consideration. Second, recent evidence from the US industry data has produced the exact opposite conclusions. Using Dale Jorgenson’s annual KLEM data from 1949-1996, Basu et al. (2006) find that the total hours worked falls after a positive shock to total factor productivity (TFP) in 22 of the 29 industries examined; while Chang and Hong (2006), using the annual NBER-CES Manufacturing Industry Database from 1958 to 1996, find that for over two-thirds of the 2-digit industries, total hours worked recorded a rise after such TFP shock. The findings make it imperative to present further evidence from other industrialized countries in an effort to gain a broader perspective on the related issues. Accommodation of productivity shock can boost aggregate demand sufficiently and increase hours-worked in a sticky price model (Dotsey, 2002; Galí et al., 2003). For policy reasons it is important to know the reasons for such outcome. The motivation behind this paper is to offer further empirical evidence on the noted above. Specifically, differencing of a stationary series or detrending a non-stationary series produces specification error (Nelson and

Kang, 1981). The distinction is crucial in predicting RBC models. The labour market response to technological shocks in structural vector autoregression models depends on the specification of hours worked. As noted earlier, if hours worked are in levels, we see increase after positive technology shock. On the other hand, if hours worked are set in first differences, the series falls following the same shock. It follows that determination of the time series characteristic of hours worked can be critical prior to defining these models.

Our results suggest that an analyst might, on average, infer that hours worked fall after a positive technology shock; when it may go up in a true data-generating process. Indeed, the magnitude of the fall is very close to the actual decline in hours worked implied by the estimated difference specification. In addition, the level specification easily encompasses the impulse responses of other relevant variables. Second, the difference specification does not embrace the level specification. The rest of this article is organized as follows. Section 1 describes the data sources and the variables. Section 2 outlines the methodology. Section 3 reports the empirical results. Finally, we draw the conclusion in section 4, based on the results of the study.

2. DATA AND METHODOLOGY

2.1. Data and Variables

The annual data (1960-2012) on hours worked for the 25 OECD and the Big-7 countries are taken from the (Output, Labor, and Labor Productivity, 1950-2012) of the Conference Board and Groningen Growth and Development Centre at the University of Groningen. The choice of the countries has been dictated by the availability of data and the economic group they represent. A list of the countries in the panel is presented in Table 1. The series “hours-worked” refer to the annual hours worked per worker for an employee or self-employed person, during the accounting period. The figures include paid overtime but exclude paid leave hours. The method is widely used in labour productivity literature and is perceived as an adequate measure of labour intensity.

2.2. Methodology

Breitung and Pesaran (2008) and Baltagi (2005) recommend the use of panel data to increase the power of unit root tests when a univariate time series data is short in length, when possible. We use panel dataset wherein we apply a battery of second generation panel unit root test (Hurlin, 2010; Tiwari et al., 2012 for more on the first and second generation panel unit root tests). As noted, a major advantage of these tests is that they take in to account the cross-sectional dependence. Also, these tests are more useful when co-movements are observed in the national business cycles and the countries are part of the same economic region (Hurlin, 2010).

Panel unit root tests (mainly first generation panel unit root tests) are based on several restrictive assumptions such as panel units are cross-sectionally independent. Maddala and Wu (1999) and Choi (2001) independently propose solution to such restriction using P value combination tests. The null hypothesis is: All the series in the panel are $I(1)$ against the alternate that at least one of the series is $I(0)$. The tests are based on the idea that the P values

Table 1: Countries used in the model: OECD and Big-7

25 OECD countries			Big-7 countries	
Australia	Germany	Mexico	Switzerland	Canada
Austria	Greece	Netherlands	Turkey	France
Belgium	Iceland	New Zealand	United Kingdom	Germany
Canada	Ireland	Norway	United States	Italy
Denmark	Italy	Portugal		Japan
Finland	Japan	Spain		United Kingdom
France	Luxembourg	Sweden		United States

from N independent augmented Dickey–Fuller (ADF, 1984) tests can easily be combined to test joint hypothesis concerning all N = 1 units.

Both papers highlight that under the null, the P values P_i ($i = 1, \dots, N$) are independent $U_{(0,1)}$ variables so $-2 \log P_i \sim \chi^2(2)$,

$$P: = -2 \sum_{i=1}^N \log P_i \xrightarrow{d} \chi^2(2N), \tag{1}$$

Choi (2001) also considers different P values combination tests. He points out that the inverse normal combination tests are based on the fact that under the null,

$$Z: = \frac{1}{\sqrt{N}} \sum_{i=1}^N \Phi^{-1}(P_i) \xrightarrow{d} N(0,1) \tag{2}$$

Has the best overall performance, where convergence, as noted, holds for fixed N and $T \rightarrow \infty$. The advantages of the P value combination approach are (a) simplicity; (b) flexibility in specifying a different model for each panel unit; (c) ease in the use of unbalanced panels; (d) opportunity to use any unit root test; and (e) convergence results can be proved using (fixed-N) T-asymptotic.

The assumption that the panel units are cross-sectionally independent, however, is very restrictive. For this reason, building upon Hartung (1999) framework, Demetrescu et al. (2006) propose a modified Choi’s inverse-normal combination test that can be used even when the P values are not independent, given fixed N. Specifically, Hartung (1999) demonstrates that if the probits $\phi^{-1}(P_i)$ are correlated with common correlation δ , then under the null,

$$Z_H: = \frac{1}{\sqrt{N(1+\delta(N-1))}} \sum_{i=1}^N \Phi^{-1}(P_i) \sim N(0,1) \tag{3}$$

As a practical approach, Demetrescu et al. (2006), used the following formulation for simulations. However, a more general form allows for unequal weights of the P values which better controls the significance levels (Hartung, 1999. p. 851).

$$\hat{Z}_H := \frac{\sum_{i=1}^N \Phi^{-1}(P_i)}{\left\{ N \left[1 + \left(\hat{\delta}^* + 0.2 \sqrt{\frac{2}{N+1}} (1 - \hat{\delta}^*) \right) (N-1) \right] \right\}^{\frac{1}{2}}} \tag{4}$$

Where $\hat{\delta}^*$ is a consistent estimator of δ such that $\hat{\delta}^* = \max \left\{ -1/(N-1), \hat{\delta} \right\}$ with,

$$\hat{\delta} = 1 - (N-1)^{-1} \sum_{i=1}^N \left(\Phi^{-1}(p_i) - N^{-1} \sum_{i=1}^N \Phi^{-1}(p_i) \right)^2 \tag{5}$$

Hanck (2008) offers a very different point of view wherein he observes that panel unit root can be recast in terms of a multiple test problem. In his methodology the complete null hypothesis is: All the series are I(1), against the alternate that at least one series is I(0). We know (Shaffer, 1995) that the complete null cannot be rejected on the basis that $\min(P_i) < \alpha (i=1, \dots, N)$ alone for a pre-specified α , because such a procedure would result in a test having a size much larger than α . In fact, Simes (1986) shows that if a set of N hypotheses $H_{0,1}, \dots, H_{0,N}$ are all true, and the associated test statistics are independent, the $\Pr(P_{(i)} > i\alpha/N) = 1 - \alpha$, where the $P_{(i)}$ ’s are the ordered P values such that $P_{(1)} \leq P_{(2)} \leq \dots \leq P_{(N)}$. Furthermore, Sarkar and Chang (1997) show that Simes’ equality holds in the presence of positively dependent test statistics. Hanck (2008) suggests that the panel unit root null hypothesis can be tested simply by using the intersection test presented in Simes (1986). The test is easily performed by denoting $P_{(i)}$, the ordered sequence of the NP values of unit root test, on each individual series. For any given pre-specified significance level α , the null is rejected if $P_{(i)} \leq i\alpha/N$ for any $i = 1, \dots, N$.

The panel covariate Dickey–Fuller tests considered in Costantini and Lupi (2013) are extensions of the simple panel of the CADF test advocated in Hansen (1995), based on the P value combination methods outlined above, Hansen (1995) proves that significant power gains in unit root test can be achieved if stationary covariates are included in the conventional ADF (1984) tests. The basic idea behind Hansen’s test can be illustrated as follows: If we want to test for the presence of a unit root in series y_t given that a stationary covariate x_t exists which is linearly related to y_t , then adding x_t to the ADF regression for y_t increases the precision of the estimates and thus the power of the test. Prima facie, the idea may appear simple, but its application is far more complex than the standard procedure. For example, Hansen (1995) proved that the resulting unit root test statistic under the null no longer follows the Dickey–Fuller distribution instead it follows a distribution according to a weighted sum of a Dickey–Fuller and a standard normal distribution, where the weights are functions of a nuisance parameter. To be more specific, consider;

$$a(L) \Delta y_t = \delta y_{t-1} + v_t \text{ and } v_t = b(L) (\Delta x_t - \mu_x) + e_t \tag{6}$$

Where, $a(L) := (1 - a_1 L - a_2 L^2 - \dots - a_p L^p)$ is a polynomial in lag operator L, $(\Delta x_t \sim I(0))$, $\mu_x := E(\Delta x)$, $b(L) := (b_0 L^{-q_2} + \dots + b_{q_1} L^{-q_1})$ is a polynomial where both leads and lags are allowed. Furthermore, consider the long-run covariance matrix,

$$\Omega = \sum_{k=-\infty}^{\infty} E \left[\begin{pmatrix} v_t \\ e_t \end{pmatrix} \begin{pmatrix} v_{t-k} \\ e_{t-k} \end{pmatrix} \right] = \begin{pmatrix} \omega_v^2 & \omega_{ve} \\ \omega_{ve} & \omega_e^2 \end{pmatrix} \quad (7)$$

Define the long-run squared correlation between v_t and e_t as,

$$\rho^2 = \frac{\omega_{ve}^2}{\omega_v^2 \omega_e^2} \quad (8)$$

Here the test equation looks very similar to the standard ADF equation:

$$a(L) \Delta y_t = \delta y_{t-1} + b(L) (\Delta x_{t-1} + e_t) \quad (9)$$

A constant and a trend models can be added in the CADF test as in the simple ADF test. Subject to the fulfilment of some regularity conditions, Hansen (1995) shows that, under the null of unit root, the t ratio for the coefficient in equation (9) is such that,

$$\hat{t}(\delta) \xrightarrow{\omega} \rho \frac{\int_0^1 W dW}{\left(\int_0^1 W^2 \right)^{1/2}} + (1-\rho^2)^{1/2} N(0,1) \quad (10)$$

Where, W is a Wiener process, $N(0,1)$ a standard normal independent of W . When a model with a constant or a constant and a linear trend is used, W is replaced by a demeaned or a detrended Wiener process, respectively (Hansen 1995, for details). Once the issue of computing the P values from equation (10) is resolved, it becomes easy to apply P value combination methods to derive a panel CADF test.

Costantini and Lupi (2013) picked up their idea from here and proposed a panel CADF test (they label pCADF) and offered a technique for computing the asymptotic P values. The P value combination suggested by Costantini and Lupi (2013) is same as Choi (2001) when no cross-dependence is detected; and Demetrescu et al. (2006) in the presence of cross-dependence. Costantini and Lupi (2013) suggest using a stationary covariate for each variable and test the average of the first difference of the other series in the panel; as the alternate. Also, the difference of the first principal component among the series under investigation can also be used (Costantini and Lupi, 2013 for details). The latter procedure aims at extracting an underlying nonstationary common factor among the observed series, and uses its first differences as the stationary covariate. Of course, in this case, the panel CADF test refers explicitly to cross-dependent time series. In general, given that different stationary covariates can be selected for each series, the method can be applied to panels comprised of independent units.

Hansen's CADF test rather than the conventional ADF test ensures that the panel test has better power properties. Costantini and Lupi (2013) applied Hartung's procedure for cross-correlation correction and are different from Demetrescu et al. (2006). The P value of the cross-correlation test advocated by Pesaran (2004) was lower than a pre-specified threshold whose default value was set to 0.10. As noted, in this paper, we applied the panel

CADF test advocated in Costantini and Lupi (2013). It may be noted here that the three versions differ in the way the stationary covariate is selected. The first (pCADF) consider the case where the correct stationary covariate (or a good proxy) is used. The second (pCADF.PC) assumes that the panel is balanced (if not it is transformed to balanced panel) and utilizes the differenced first principal component of the N series as the stationary covariate. The last (pCADF.DY) is again valid for a balanced panel and for each series takes the difference of the average of the other series as the stationary covariate. We also applied an extension to the CADF tests of the ADF-based test suggested in Hanck (2008) proposed in Lupi (2011). The four variants differ in terms of the test on which they are based. The first (sADF) is based on the P values of standard ADF tests, as in Hanck (2008). The others (sCADF, sCADF.PC, and sCADF.DY) are based on the P values of CADF tests, with the stationary covariates selected as above, and are suggested here for the first time. Given its relation to Simes' procedure, we label the latter test as sCADF. The null hypothesis and alternative hypothesis for all these methods however, are the same.

3. EMPIRICAL RESULTS

We now report the results of the panel estimates obtained from annual data from 1960 to 2012 on the hours worked per worker for the 25 OECD and the Big-7 countries (refer to Table 1 for the list of countries). This is a classical application in the panel unit root literature. The test results obtained by applying the procedures under both generations are reported in Table 2. The models have both constant and a trend. The null hypothesis is: All the series in the panel are I(1) against the alternate that at least one of the series is I(0). The null and alternative hypotheses are the same in all the tests we used in the paper.

Consider the results reported in Panel-A for the OECD countries (Table 2). The results of the Panel-ADF test (Choi test) and Panel-ADF test (pADF test) with a constant, the null hypothesis is rejected at the 5% level of significance, but in the Panel-CADF test (pCADF_PC) it is not rejected at the 5% level. However, Panel-ADF test (Choi test) and Panel-ADF test (pADF test) with a trend, the null hypothesis is not rejected at the 5% level, but in Panel-CADF test (pCADF_PC) it is rejected at the 5% level for the OECD countries. The results of other tests, e.g., (Simes [ADF]-based test, Simes-CADF [sCADF] and Simes-pCADF.PC [sCADF.PC]) the null hypothesis with constant and a trend term is rejected.

Now consider the results in Table 2 (Panel-B for the Big-7 countries). According to the results of the Panel-ADF test (Choi test) and Panel-ADF test (pADF test) with a constant term, the null hypothesis is rejected at the 5% level of significance. For the Panel-CADF test (pCADF_PC) the null is rejected at the 10% level for the Big-7 countries. For the model with constant, the results of other tests (Simes (ADF)-based test, Simes-CADF (sCADF), Simes pCADF.PC (sCADF.PC) suggest that the null is rejected for the Big-7 countries.

For model with a trend, we do not strongly reject the null hypothesis for the Big-7 countries when using Panel-ADF test

Table 2: Second generation unit root test results for OECD 25 and Big-7 countries

Panel A - OECD countries	Constant model			Trend model		
Types of test statistic	Test statistic	P value	Test statistic	P value		
Panel-ADF test (Choi test)	-2.63037641	0.00426451	-1.2445669	0.1066455		
Panel-ADF test (pADF test)	-2.18941561	0.01428332	-1.0359256	0.1501184		
Panel-CADF test (pCADF_PC)	-1.2695288	0.1021263	-4.217658e+00	1.234263e-05		
Decision on H0 (%)						
	1	5	10	1	5	10
Simes (ADF)-based test	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Simes-CADF (sCADF)	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
SimespCADF.PC (sCADF.PC)	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Panel B - Big-7 Countries	Constant model			Trend model		
Types of test statistic	Test statistic	P value	Test statistic	P value		
Panel-ADF test (Choi test)	-2.47254972	0.00670765	-0.1092495	0.4565023		
Panel-ADF test (pADF test)	-2.75018133	0.00297811	-0.0952406	0.4620619		
Panel-CADF test (pCADF_PC)	-1.50335998	0.06637312	-0.5358142	0.2960435		
Decision on H0 (%)						
	1	5	10	1	5	10
Simes (ADF)-based test	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
Simes-CADF (sCADF)	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
Simes pCADF.PC (sCADF.PC)	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE

1. Panel-ADF: The Costantini and Lupi (2013) test is based on Choi (2001; 2006), when no cross-dependence detected
2. Panel-ADF (pADF test): This test is of Costantini and Lupi (2013) based on Demetrescu et al. (2006) in the presence of cross-dependence which has been detected through a cross-dependence test (Pesaran 2004). The Hartung’s correction has been used in the combination of the P values suggested in Demetrescu et al. (2006)
3. Panel-CADF (pCADF_PC): It is the Panel CADF test. This is proposed by Costantini and Lupi (2013). pCADF.PC assumes that the panel is balanced and utilises the differenced first principal component of the N series as the stationary covariate. In the present case we used max.lag.y=5, max.lag.X=5
4. Simes ADF-based: It is the ADF-based test in the original form proposed by Hanck (2008)
5. Simes pCADF: This is an ADF-based test proposed by Lupi (2011) advancing over Hanck (2008)
6. Simes pCADF_PC: This is an ADF-based test proposed by Lupi (2011) advancing over Hanck (2008) and that utilises the differenced first principal component of the N series as the stationary covariate
7. TRUE indicate that the test does not reject the null and FALSE shows that the null is rejected
8. In each case lag selection is based on AIC and we fixed maximum lag 5.

Source: Author’s calculation through R Development Core Team (2011) Software

(Choi test), Panel-ADF test (pADF test) and Panel-CADF test (pCADF_PC). The results from other tests e.g., (Simes (ADF)-based test, Simes-CADF (sCADF) and Simes-pCADF PC(sCADF.PC)) however, do not reject the null hypothesis.

4. CONCLUSIONS

This paper implements a battery of panel unit root tests to examine the stationarity properties of the series: Hours worked per employee. The study period covers 1960-2012 for the OECD and the Big-7 countries. The tests we use account for cross-sectional dependence and those that do not account for such dependence. The former are more useful when we observe co-movements in the national business cycles in the countries within the same economic region. In particular, we employ the panel CADF test recently proposed by Costantini and Lupi (2013). We also expand our tests to include the CADF tests of the ADF-based test suggested in Hanck (2013) and proposed by Lupi (2011). Given its similarity with the Simes’ procedure, we label the latter test as sCADF.

We find that the Panel-ADF test (Choi test) and the Panel-ADF test (pADF test) with a constant term reject the null hypothesis at the 5% level; but Panel-CADF test (pCADF_PC) does not reject at the 5% level for the OECD countries. For a trend model, the

results of other tests for OECD countries show a rejection of the null hypothesis with constant and trend models.

The results for the Big-7, the Panel-ADF test (Choi test) and Panel-ADF test (pADF test) reject the null hypothesis at the 5% level with constant model. However, these tests do not reject the null at the 5% in the model with trend. The results of other tests are different for the constant and the trend models. The findings on the series hours worked per worker for the OECD and the Big-7 countries have implications important for policy. First, the results provide evidence in favor of non-stationarity for the countries studied. Second, the findings are in line with most previous tests; and appear to originate from common as well as country specific sources. Third, although the results from the Big-7 countries offer mixed evidence, the joint hypothesis of non-stationarity hypothesis cannot be rejected. Fourth, annual hours worked per worker are set in first differences and these series record a fall following a shock. We find that an analyst would infer that annual hours worked per worker to fall after a positive technology shock, although may go up in a true data-generating process.

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