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Dynamics of Wood Pulp Production: Evidence from OECD Countries

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Abstract: This paper investigates whether shocks to pulp for paper production for 17 Organisation for Economic Co-Operation and Development (OECD) members over the period 1980–2012 are transitory or permanent. A variety of univariate and panel data unit root tests are employed. The presence of structural breaks is taken into account when performing those tests. Based on the Narayan-Popp univariate unit root test, wood production series for approximately 64.71% of countries is found to follow a non-stationary process. However, univariate unit root tests tend to have low power when the time span is relatively short. Consequently, three generations of panel unit root tests are considered. Cross-sectional dependence is detected. The first generation of unit roots do not effectively control for cross-sectional dependence, while the second and third generations do. The third generation accounts mainly for cross-sectional co-integration. As a confirmatory analysis, both unit root tests that tests for the null of non-stationarity and stationarity are considered. Most of the panel unit root tests point towards a non-stationary process. Hence, while these shocks can be transmitted to other economic sectors, past behaviours of wood production cannot be used for forecasting purposes. Forest conservation policies can have a permanent impact on pulp for paper production.

Keywords: wood pulp; production shocks; pulp production; cross-sectional dependence; structural breaks; unit root tests

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1. Introduction

Non-wood (e.g., cotton, linen fibres, etc.) and wood resources currently are being used to produce pulp, paper, soft boards, etc. Wood has particularly been exploited since the development of mechanical pulping in 1840. The timber resources used to make wood pulp are referred to as pulpwood. Wood pulp comes from softwood trees, such as spruce, pine, fir, larch, and hemlock, and hardwoods such as eucalyptus, aspen, and birch. However, the major source of pulp which meets more than 80% of demand comes from forests [1]. Indeed, it has been argued that there has been unsustainable deforestation, with a negative effect on the native forest ecosystems and habitats of several species, in connection to pulp and paper industry. This causes environmental concerns especially in the context of ecosystem services and climate change.

From a policy viewpoint, it is essential to assess whether shocks, such as forest conservation policies (FCP), will have a temporary or persistent effect. FCP principally aim at creating long-term sustainable exploitation of the forest and growth of the forestry. To address this question, the main aim for this study is to analyse the long-run properties of pulp for paper production series. If pulp for paper production is found to be non-stationary, then shocks will be permanent. Pulp for paper production will not return to its long-run equilibrium trend after a shock which is consistent with hysteresis or path dependency. In contrast, if pulp for paper production is found to be stationary, then shocks are temporary and the series will eventually adjust to its long term level or trend.

There are several implications of the presence of a unit root. First, the pulp for paper industry is interconnected to newsprint, offices, etc. If shocks are transient, then those sectors which are linked to the level of pulp for paper production via flow-on effects will not be permanently affected. Those shocks will not be passed on to other related sectors in the long-run. Yet, shocks can be transmitted to those sectors if they are persistent. This can influence studies relating to the co-integrating link between pulp for paper production and other macroeconomic variables. Second, in modelling pulp for paper supply forecasts, the nature of shocks is of utmost importance. If pulp for paper production is stationary, then shocks will be temporary. Past behaviour of pulp for paper production can be used to generate future pulp for paper production data. These forecasts could be of particular interest to wood producers in case of a need to step up production to meet an eventual rise in demand. Forecasts can help to assess the risks and costs involved in the pulp for paper production process. If pulp for paper production follows a random walk, then shocks will be permanent. Statistical forecasting methods are typically based on stationary time-series. If a series is non-stationary, then historical movements cannot be used to produce robust forecasts. However, if the first difference of the series is stationary, then such series can be used to perform forecasting. However, first- or higher-order differences can lead to a loss of long-term valuable information. Finally, if pulp for paper production is stationary, then any FCP will only have short-term effects. Pulp for paper production will eventually revert back to its fundamental path or equilibrium value after being subject to such external shocks. Policies with long-term objectives will not be effective. If shocks are found to be persistent, then the government policies will be effective.

There is a large literature devoted to the study of stochastic properties of macroeconomic data which started with the seminal work of [2]. Narayan et al. [3] provide a review of the application of unit root tests with respect to macroeconomics and energy variables. With the availability of more and more powerful unit root tests, studies such as stochastic properties of energy data have contributed to advance the literature. Smyth [4] provides a recent review of the implications of shocks mainly on energy variables. He argues the sensitivity of results depending on the methodology used and type of energy considered. Other recent studies include [5–8], among others. From the production perspective, such literature remains relatively scant. For instance, [3] examine the long-run properties of crude oil production for 60 countries employing a range of panel data unit root tests for the period 1971 to 2003. They apply the Lagrange multiplier (LM) panel unit root test with one structural break. Their results suggest that, for a world panel and smaller regional based panels, crude oil and natural gas liquid (NGL) production are jointly stationary. Barros et al. [9] examine the time-series behaviour of oil production for OPEC member countries within a fractional integration modelling framework recognizing the potential for structural breaks and outliers. The analysis is undertaken using monthly data from January 1973 to October 2008 for 13 OPEC member countries. Their results indicate there is mean reverting persistence in oil production with breaks identified in 10 out of the 13 countries examined. Thus, shocks affecting the structure of OPEC oil production will have persistent effects in the long run for all countries. From the production of forest products perspective, Jaunky and Lundmark [10] investigate whether shocks to wood fuel production for 18 European Union (EU) countries over the period 1960–2012 are transitory or permanent. They apply a variety of univariate and panel data unit root tests. Following the Narayan and Popp [11] univariate unit root test, wood fuel production series for approximately 77.8% of countries is found to follow a non-stationary process. For the overall panel, the wood fuel production series is found to be non-stationary. Hence, shocks to fuel wood production are permanent. Thus, little research on the stochastic properties of forest products data has been done. This paper intends to bridge this gap by investigating the implications of shocks on pulp for paper production for the OECD.

2. Materials and Methods

The data for pulp for paper production are compiled from United Nations Food and Agriculture Organization (FAO). Specifically, 17 OECD countries are chosen over the period 1980–2012 and the selection is based on the data availability. The number of observations for each country and the OECD panel are 33 and 527, respectively. To study the stochastic properties of pulp for paper production, several univariate and panel unit root tests are applied. To conduct the tests, two different regressions are usually considered. One regression includes a constant term only, while the other contains both a constant term and a time trend. In general, macroeconomic data tend to display a trend over time. Hence, it is more appropriate to consider the regression with both a constant term and a trend. In general, most of the panel unit root tests are based on an augmented Dickey-Fuller (ADF) test. The null hypothesis that the series contains a unit root is tested. A battery of tests is employed as no single unit root test is devoid from statistical limitations in terms of size and power.

Complementary univariate unit root tests, as proposed by [11] and KPSS [12], are considered. The unit root test the H_0 of non-stationarity (e.g., ADF and Narayan-Popp tests) can be accompanied by a test of the H_0 of stationarity (e.g., KPSS test). This confirmatory analysis adds power to the testing framework. Univariate procedures tend to suffer from a loss of power when small sample sizes are used. Alternatively, panel data techniques allow for an increase in number of observations and testing power. Numerous tests, such as LLC [13], IPS [14], Maddala and Wu [15], Taylor and Sarno [16], Pesaran [17], ILT [18], and Chang and Song [19] are considered. These tests test for the H_0 of non-stationarity. With reference to [20,21] tests for the H_0 of stationarity are also applied.

3. Results

The univariate unit root test statistics are reported in Table 1. According to the ADF tests with a constant and trend, 14 series are found to be non-stationary, while three series are stationary. The ADF test tends to have low power against stationary alternatives which are nearer to being non-stationary. As per [22], the ADF test tends to have low power in the presence of an unknown mean and trend. Additionally, when it contains both a constant and trend, it tends to have less power relative to the test with a constant only. The KPSS test is a more powerful test than the ADF test. It can markedly distinguish between a series which appears to be stationary and non-stationary in case the data are not sufficient to make conclusions about the order of integration. As per the KPSS test with a trend, 15 and only two series are found to be non-stationary and stationary, respectively. Yet, the KPSS test tends to have extreme size distortions when the H_0 of a stationary series is close to the alternative of a unit root [23]. Hence, the test may reject H_0 even if the true series is stationary.

The two previous univariate unit root tests fail to capture the presence of structural breaks. This can lead to a decline in power of the test to reject a unit root even if trend stationarity holds [24]. The Narayan-Popp test allows for the presence of two endogenous breaks and two tests are considered. The first test allows for two breaks in the level while the second tests accounts for same number of breaks in the level and slope of an $LPULP_t$ series. These tests are found to have suitable size and stable power. Corresponding to the first test, apart from Canada, 16 time-series for Austria, Chile, Finland, France, Germany, Italy, Japan, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, and USA are computed to be non-stationary. In line with the second test, a non-stationary and stationary process for 11 (Austria, Canada, Chile, France, Germany, Italy, Japan, Norway, Spain, Sweden, and USA) and six (Finland, The Netherlands, New Zealand, Portugal, Sweden, and Switzerland) series are computed, respectively. Indeed, the second tests reveal to be non-stationary and stationary respectively. In other words, about 64.7% of the individual series tend to be non-stationary according to this Narayan-Popp test. A caveat about the difficulty of obtaining reliable results with two structural breaks in a sample of 33 observations needs to be accounted for and the interpretations should be made with care. As observed in Table 1, the breaks coincide with several economic crises. Demand shocks could be explained by the excessive hike in oil price following the 1979 Iranian Revolution and the 1980–1981 Iran-Iraq War. The second break coincides with another spike in oil prices mainly due to the 1990 Gulf War, the 1997 Kyoto Protocol and the 2005 Gudrun storm.

Table 1. Univariate unit root tests.

Country	ADF [1]		KPSS [2]		Narayan-Popp					
					$M1_{B,L}$			$M2_{B,L}$		
	Without Trend	With Trend	Without Trend	With Trend	*t*-Value	T_{B1}	T_{B2}	*t*-Value	T_{B1}	T_{B2}
Austria	−2.52(2)	−4.04(0) $^{+}$	1.24(2) *	0.17(2) $^{+}$	−3.66(3)	1987	2003	−4.25(0)	1998	1995
Canada	−1.68(3)	−0.72(0)	0.29(2)	0.28(2) *	−5.01(0) $^{+}$	2005	2007	−3.50(3)	1991	2005
Chile	−0.60(0)	−2.80(1)	1.29(2) *	0.08(2)	−2.78(0)	1988	1991	−3.08(0)	1991	2003
Finland	−1.74(4)	−0.03(4)	1.06(2) *	0.23(2) *	−0.26(3)	1996	2005	−6.80(0) *	1996	2004
France	−1.27(3)	−0.61(3)	0.35(2) ‡	0.32(2) *	−2.90(0)	1988	1996	−4.45(0)	1988	1995
Germany	−1.99(3)	−2.58(3)	0.47(2) $^{+}$	0.20(2) $^{+}$	−2.20(0)	1999	2004	−2.41(3)	1992	1999
Italy	−2.76(1) ‡	−2.67(1)	0.58(2) $^{+}$	0.22(2) *	−3.28(0)	1990	1997	−4.24(1)	1996	1999
Japan	−1.65(0)	−1.63(0)	0.36(2) ‡	0.28(2) *	−2.92(0)	1987	1996	−3.17(0)	1992	1997
The Netherlands	0.27(2)	−1.98(0)	0.72(2) $^{+}$	0.13(2) ‡	1.31(1)	1991	2005	−7.92(0) *	1992	2005
New Zealand	−2.25(1)	−1.73(1)	1.22(2) *	0.19(2) $^{+}$	−4.04(0)	1990	1999	−6.42(0) *	1995	2007
Norway	0.01(0)	1.45(2)	0.45(2) ‡	0.29(2) *	0.98(2)	1994	2003	1.11(2)	1988	1994
Portugal	−2.67(1) ‡	−7.92(0) *	1.14(2) *	0.21(2) $^{+}$	−0.69(2)	1986	1992	−7.06(0) *	1986	1992
Spain	−0.39(0)	−1.44(0)	1.02(2) *	0.22(2) *	−1.98(0)	1992	2004	−2.48(0)	1992	2004
Sweden	−1.38(0)	−2.35(0)	1.18(2) *	0.11(2)	−3.45(0)	1996	1999	−4.05(0)	1989	1999
Switzerland	0.14(1)	−1.92(1)	0.98(2) *	0.22(2) $^{+}$	−2.64(0)	2005	2007	−4.88(0) ‡	1992	2005
UK	−1.73(1)	−4.14(2) $^{+}$	0.30(2)	0.29(2) *	−2.58(0)	1988	2003	−5.47(1) $^{+}$	1991	2005
USA	−1.76(0)	−2.13(0)	0.35(2) ‡	0.31(2) *	−1.95(2)	1993	2000	−3.74(0)	1993	2000

[1] Augmented Dickey-Fuller test; [2] Kwiatkowski, Phillips, Schmidt and Shin test; Note: Following [25], the maximum lag is computed following k_{max} = int $(4(T/100))^{1/4} \approx 4$, where int denotes integer and T = 52. ADF critical values (CV) without and with a trend are −3.73, −2.99 and −2.63, and −4.35, −3.59, and −3.23 at 1%, 5%, and 10% significance levels, respectively. The optimal lag is chosen as per the Akaike Information Criterion. KPSS one-sided CV without a trend at 1%, 5%, and 10% levels are 0.739, 0.463, and 0.347 and with a trend, these are 0.216, 0.146, and 0.119, respectively. To yield the optimal bandwidth for the KPSS statistics, the quadratic spectral kernel is applied. T_{B1} and T_{B2} are the dates of the structural breaks. The one-sided critical values are −5.259, −4.514 and −4.143 respectively for model $M1_{B,L}$ and −5.949, −5.181, and −4.789 at 1%, 5%, and 10% levels of significance (T = 50) for model $M2_{B,L}$. The optimal lag is in parentheses. *, $^{+}$ and ‡ denote 1%, 5% and 10% levels, respectively. The data has spanned over the period from 1980 through 2012.

Next, several generations of panel unit root tests are applied. The test statistics are reported in Table 2. In the LLC test, The $LPULP_{it}$ series is found to be non-stationary at conventional levels of significance. The LLC test relies on the assumption of homogeneity in the AR (1) coefficients of the ADF specifications. Moreover, it overlooks the presence of structural breaks and assumes cross-sectional independence. Cross-sectional dependence can happen as a result of common factors. For example, economic crises in a major economy like the USA can be transmitted to the rest of the world. LLC test tends to suffer from size distortion in the presence of such contemporaneous correlation among the disturbances across units within the OECD panel [26].

The degree of cross-sectional dependence can be assessed by calculating the pair-wise correlations of the first-differences in two series [27]. The pair-wise correlation coefficients of $\Delta LPULP_{it}$ between two series are 0.616, 0.575, 0.529, 0.457, and 0.365 between Austria and Australia, Canada and France, Finland and Japan, Italy and Spain, and New Zealand and Norway, respectively. On the whole, the pair-wise correlation coefficients are found to be mostly positive and from −0.458 to 0.784. These results provide some evidence about the existence of cross-sectional correlations which can lead to biased panel data unit root tests towards the alternative hypothesis [28]. This raises the need for the use of more powerful tests.

IPS [14] proposed a panel unit root test which can control for heterogeneity and cross-sectional dependence by using demeaned data. The demeaned variable has had its mean subtracted to form the series. The IPS panel unit root test tends to be more powerful than the LLC panel unit root test but it has low power in panels with small T [29]. As shown in Table 2, for both raw and demeaned data, the IPS panel unit root test statistics with trend illustrate a non-stationary process for the $LPULP_{it}$ series.

The Maddala-Wu panel unit root test is a non-parametric test and is found to be more powerful than the LLC and IPS tests. It allows for heterogeneity across countries and does not require a balanced panel. The test is suitable to use when a mixture of stationary and non-stationary series in the group are included as an alternative hypothesis. It has comparatively higher power in distinguishing the null from the alternative hypothesis. The H_0 of non-stationarity of all the series within a specific panel is tested against the alternative of at least one stationary series. The Maddala-Wu test applies the Fisher [30] approach to derive test statistics which combine the *p*-values from individual unit root tests, such as the ADF test in each cross-sectional unit. As presented in Table 2, the Fisher-ADF test which includes a trend provides evidence that at least one of the pulp for paper series follows a stationary process for the OECD panel.

The Hadri LM test is based on the KPSS approach and tests the H_0 of stationarity. Contrary to the LLC or IPS test, the Hadri LM test performs comparatively well in panel data with short T [31]. It is also robust to serial correlation and heteroskedasticity. The tests which include the trend will be employed for inferences.

The above four first-generation tests are likely to suffer severely from low power and size distortions in the presence of contemporaneous cross-correlation among units. To alleviate the effects of cross-sectional dependence, the first-generation tests utilize demeaned data. This approach assumes the existence of a common factor with similar effect on all individual pulp for paper series, but this is unlikely to hold in practice. The demeaning of data may not effectively tackle the size distortions produced by the magnitude and variation of cross-sectional dependence [32].

The second generation of panel unit root test relaxes the assumption of cross-sectional independency and controls for the presence of cross-sectional dependence in a more general pattern. Taylor and Sarno [16] advocate the multivariate ADF (MADF) test which is based on the seemingly unrelated regressions (SUR) panel framework. As displayed in Table 2, the MADF panel test statistics reject the H_0 of joint non-stationarity in favour of the alternative whereby at least one of the pulp for paper series in the panel is generated by a stationary process. Similar to the Maddala-Wu test, the rejection of the null should be interpreted with caution as they do not imply a stationary vector process for all the series in the OECD panel.

Pesaran [17] recommends an alternative test and the traditional ADF regression models are augmented with the cross-section averages of lagged levels and first-differences of the individual wood series. The Pesaran test is based on the averages of the individual cross-sectionally augmented ADF (CADF) statistics. The test has good size and power properties even when N and T are small. As revealed in Table 2, the test shows a non-stationary process for the $LPULP_{it}$ series.

Similar to the univariate unit root tests, panel unit root tests can be biased if structural breaks are ignored. ILT [18] suggest a new LM based test which allows for heterogeneous breaks in both the intercept and slope of each cross-sectional unit. They extend their LM test to control for cross-sectional dependence by employing the CADF procedure of Pesaran [17] and derive a cross-sectionally augmented LM (CALM) test statistic. Panel unit root tests which allow for breaks are found to depend critically on nuisance parameters specifying the size and break locations. These tests can be subject to serious size distortions. To tackle this problem, ILT [18] design a method which renders the asymptotic properties of their test invariant to these nuisance parameters. They derive these asymptotic properties and examine the finite-sample properties of their tests. These are found to be robust to the locations of trend-shifts. As reported in Table 2, the $LPULP_{it}$ series is found to follow non-stationary process in the presence of either one or two breaks.

As an additional confirmatory test, the Hadri-Kurozumi test of the H_0 of stationarity is considered. This test is an extension of the Hadri test and it allows the LM test to control for cross-sectional dependence. The regression is augmented by cross-sectional averages of the observations, in same way as the Pesaran test which augments the traditional ADF regression. As exposed in Table 2, two test statistics are calculated. The ZA_{spc} and ZA_{la} statistics are the augmented panel KPSS test statistics with long-run variance corrected by lag-augmented methods [33,34]. The H_0 of stationarity is strongly rejected.

Table 2. Panel unit root tests for $LPULP_{it}$.

Test				
LLC	**Without Trend**		**With Trend**	
	2.30 [0.99]		−0.50 [0.31]	
IPS	**Raw Data**		**Demeaned Data**	
	Without Trend	**With Trend**	**Without Trend**	**With Trend**
	0.46 [0.68]	2.22 [0.99]	3.55 [1.00]	−0.50 [0.31]
Maddala-Wu	**Without Trend**		**With Trend**	
	23.4 [0.92]		48.0 [0.06] ‡	
Hadri	**Serial Correlation**			
	Raw Data		**Demeaned Data**	
	Without Trend	**With Trend**	**Without Trend**	**With Trend**
	43.52 [0.00] *	36.95 [0.00] *	43.45 [0.00] *	34.34 [0.00] *
	Heteroskedasticity			
	Raw Data		**Demeaned Data**	
	Without Trend	**With Trend**	**Without Trend**	**With Trend**
	11.12 [0.00] *	9.87 [0.00] *	11.68 [0.00] *	9.57 [0.00] *
MADF	**Statistics**			
	144 *			
CADF	**Without Trend**		**With Trend**	
	4.35 [1.00]		0.52 [0.70]	
ILT/CALM	**One Break**		**Two Breaks**	
	2.33		5.50	
Hadri-Kurozumi	$\mathbf{ZA_{spc}}$		$\mathbf{ZA_{la}}$	
	Without Trend	**With Trend**	**Without Trend**	**With Trend**
	55.50 *	696 *	36.1 *	2427 *
Chang-Song	$\mathbf{ta_a}$		$\mathbf{tm_a}$	
	0.171		−1.091	

Note (1): The lag lengths for the panel test are based on those employed in the univariate ADF test in Table 1. Assuming no cross-country correlation and T is the same for all countries; the normalized test statistic is computed by using the t-value statistics. The H_0 of non-stationarity is tested. It is then compared to the 1%, 5%, and 10% significance levels with the one-sided critical values of −2.326, −1.645, and −1.282, correspondingly. The *p*-values are in square brackets. The IPS test statistics are computed as the average ADF statistics across the sample. These statistics are distributed as standard normal as both N and T grow large. Assuming no cross-country correlation and T is the same for all countries, the Ψ_t test statistics for H_0 of joint non-stationarity are compared to the 1%, 5%, and 10% significance levels with critical values of −2.330, −1.645, and −1.282 correspondingly. The lag lengths are chosen according to the Bartlett kernel. Based on the *p*-values of individual unit root tests, the Fisher test assumes that all series are non-stationary under the H_0 against the alternative that at least one series in the panel is stationary. The test has a χ^2 distribution with 2N degrees of freedom, where N is the number of cross-sectional units or countries. The test is based on the ADF test. The z-test is based on the Lagrange multiplier (LM) tests are based on the average of the N country-specific KPSS LM-statistics under which the H_0 of stationarity is tested. The Bartlett kernel is equal to 4. The KPSS test statistics are compared to the 1%, 5%, and 10% significance levels with the one-sided critical values of 2.326, 1.645, and 1.282 respectively. The test statistics are robust to serial correlation and heteroskedasticity. The lag length is based on to the Bartlett kernel. The H_0 that all time-series in the panel are integrated of order one or I (1) processes is tested against the alternative that at least one series in the panel is stationary. An approximate 5% critical value, derived from Monte Carlo simulation, is equal to 27.491. Taylor and Sarno [16] omit a linear trend in their test. The lag lengths for the panel test are based on those employed in the univariate ADF test in Table 1. The Pesaran CADF test of the H_0 of non-stationarity is based on the mean of individual DF (or ADF) t-statistics of each unit in the panel. The z-test statistic is compared to the 1%, 5%, and 10% significance levels with the one-sided critical values of −2.326, −1.645, and −1.282, correspondingly. The maximum lag length is based on to the Bartlett kernel. The H_0 of non-stationarity is tested. In similar fashion to [17], cross-sectionally augmented versions of the transformed LM test statistics for trend or level shift are computed. The breaks are assumed to occur in the intercepts. We allow for time fixed-effects to mitigate cross-correlations. Critical values for the CALM panel unit root test are distributed asymptotic standard normal and are compared with the one-sided critical values −2.326, −1.645, and −1.282 at the 1%, 5%, and 10% levels, respectively. The lag length is based on to the Bartlett kernel. The H_0 of stationarity is tested. The ZA_{spc} and ZA_{la} test statistics are compared to the 1%, 5%, and 10% significance levels with the one-sided critical values of 2.326, 1.645, and 1.282, respectively. The nonlinear IV average and minimum tests are denoted by ta and tm while the subscript "a" refers to those tests with d orthogonal IGF with no covariate respectively. The tests include a constant term only. The H_0 of non-stationarity is tested. Each test statistic is compared to the 1%, 5%, and 10% significance levels with the one-sided critical values of −2.326, −1.645, and −1.282 for the average test while these are −3.243, −2.746, and −2.502 for the minimum test, respectively. The critical values for latter (N = 17) are computed by [19]. The data spanned over the period 1980–2012. * and ‡ denote 1% and 10% levels, respectively.

Panel unit root tests can suffer from size distortions and produce erroneous inferences in the presence of cross-sectional dependence [35]. A third-generation test, which can account for both short- and long-run co-movements across units, is required [36]. Several recent studies, which also examine the impact of shocks, e.g., [5–7], have ignored the implications of structural breaks and, especially, cross-sectional co-integration.

Chang and Song [19] put forward a panel unit root test which employs a set of orthogonal functions as instrument generating functions (IGF) to tackle any forms of dependence. As illustrated in Table 2, two types of panel unit root test statistics are computed. The average tests relate to the testing of the H_0 of non-stationarity for all individual OECD countries whereas the minimum tests evaluate the H_0 of non-stationarity of some individual countries within the OECD panel. In general, both tests confirm a non-stationary process for the $LPULP_{it}$ series. All of the results are summarized in Table 3.

Table 3. Summary of results.

Tests		Stochastic Properties
Univariate	ADF	Non-Stationary: Canada, Chile, Finland, France, Germany, Italy, Japan, The Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland and USA. Stationary: Austria, Portugal and UK.
	KPSS	Non-Stationary: Austria, Canada, Finland, France, Germany, Italy, Japan, The Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, UK and USA. Stationary: Chile and Spain.
	Narayan-Popp	Non-Stationary: Austria, Canada, Chile, France, Germany, Italy, Japan, Norway, Spain, Sweden and USA. Stationary: Finland, The Netherlands, New Zealand, Portugal, Switzerland and UK.
Panel	1st Generation:	
	LLC IPS Madalla-Wu Hadri 2nd Generation	Non-Stationary Non-Stationary At least one series is stationary Non-Stationary
	MADF CADF ILT Hadri-Kurozumi 3rd Generation:	At least one series is stationary Non-Stationary Non-Stationary Non-Stationary
	Chang-Song	Non-Stationary

Note: Where applicable, the conclusion is based on those unit root tests which include a linear trend. Results for the $M2_{B,L}$ Narayan-Popp test are reported. The data has spanned over the period from 1980 through 2012.

Along with [29], a rejection of a unit root may be caused by a few stationary series and the whole panel can be incorrectly modelled as stationary. Homogeneity of non-stationarity or stationarity properties is intrinsic to the joint testing of most panel unit root tests. To test this homogeneity assumption, the Chang-Song test has been recomputed for the whole $LPULP_{it}$ series by excluding those 6 individual series (Finland, The Netherlands, New Zealand, Portugal, Switzerland and UK) which are found to be stationary following the Narayan-Popp test with breaks in level and slope. For a second time, the Chang-Song panel unit root test statistics fail to reject the H_0 of non-stationarity in five cases. To some extent, the homogeneity assumption is satisfied.

Alternately, the mean and volatility of $LPULP_{it}$ can be examined when searching for a reason for the presence of a unit root. The degree of volatility can be measured by simply computing the standard deviation. Countries with high volatility tend to exhibit a lack of mean reversion. This is because countries with volatile pulp for paper production deviate from the long-run equilibrium path because shocks are likely to be larger and, for that reason, the divergence from the fundamental path will tend to be permanent [9]. As described in Table 4, Chile has the highest volatile pulp for paper production. Several individual countries as well as the whole OECD panel exhibit relatively high volatility of pulp for paper production. Such findings tend to be substantiated with the result of a lack of mean reversion in the majority of countries and particularly for the OECD panel.

Table 4. Mean and volatility of wood pulp production, 1980–2012.

Countries	Mean	Standard Deviation
Austria	14.177	0.146
Canada	16.913	0.136
Chile	14.438	0.683
Finland	16.083	0.195
France	14.616	0.167
Germany	14.652	0.144
Italy	13.396	0.162
Japan	16.128	0.103
The Netherlands	11.760	0.386
New Zealand	14.120	0.137
Norway	14.488	0.187
Portugal	14.268	0.312
Spain	14.418	0.265
Sweden	16.160	0.127
Switzerland	12.408	0.296
UK	12.856	0.458
USA	17.793	0.088

4. Discussion and Conclusions

The paper investigates the stochastic properties of refined pulp for paper production for 17 OECD countries over the period 1980–2012. Various generations of univariate and panel unit root tests are utilized. The significance of structural breaks in the series has important implications for the power of the unit root tests and can affect the final outcome. With regard to panel unit root tests, it is specifically important to control for cross-sectional dependence. At individual levels, about 64.71% of the pulp for paper production series has been found to follow a non-stationary process. In general, the panel unit root tests also reveal a non-stationary process. Therefore, shocks to pulp for paper production are more likely to be persistent. It can be noted that additional tests, like fractional integration, e.g., [37], could have been used to test for shocks.

The implication for the forestry sector takes two forms. Firstly, since the pulp and paper industry is one of the larger users of roundwood, a persistent change in their production level will affect their feed-stock demand. This will have an effect on the revenues of the forestry sector and might affect the rotation periods and harvesting operations. But since pulpwood also can be used as wood fuel (chipped) it also changes the supply of biofuel. This might in the long-run have a possible effect on the revenues streams for the forestry sector. Secondly, a long-term effect is that the ownership structure of the forests might change. The industrial ownership might be reduced in favour of small private owners and, thus, facilitate a change in owners' preferences. It might also facilitate less costly conversions of productive forest land to nature conservations, etc.

The policy implications are threefold. First, since shocks in pulp for paper production tends to be permanent, other economic sectors (e.g., printing presses) and macroeconomic aggregates (industrial production, employment, etc.) are likely to inherit from any FCP, too. Further studies could be conducted to explore such linkages. Second, from the modelling and forecasting perspective, the presence of a unit root in level form of the pulp for paper production series implies little or no use of past behaviours in predicting future production. It may still be possible to forecast the series by differencing the series to make it stationary and the change can be used to reconstruct the level. Third, any FCP can have long-term effects. This can lead to a rise in the supply of pulp for paper substitutes like field crop fibre or agricultural residues whose production could be more environmentally friendly.

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