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ARE SHOCKS TO ALUMINIUM CONSUMPTION TRANSITORY OR PERMANENT?

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ABSTRACT: *This paper investigates whether shocks to aluminium consumption for 36 countries over the period 1967-2010 are transitory or permanent. A variety of time-series and panel data unit root tests are employed. The presence of structural breaks is taken into account when performing those tests. Following the Narayan-Popp univariate unit root test, aluminium consumption series for approximately 77.8% of countries is found to follow a non-stationary process. However unit root tests tend to have low power when the time span is relatively short and the results should be treated with some caution. Most of the panel unit root tests also point towards similar process. While these shocks can be transmitted to other economic sectors, past behaviours of aluminium consumption cannot be used for forecasting purposes. Mineral policies will have a permanent impact on the long-run trend of aluminium consumption.*

JEL Classifications: *C23, Q31*

Keywords: *Aluminium consumption, cross-sectional dependence, structural breaks, unit root tests.*

1. INTRODUCTION

Refined aluminium is one of the most commonly used materials in modern societies. It is used in various sectors such as energy, building, transport, packaging, etc. Primary aluminum production starts with the bauxite mining of which is then processed into alumina and eventually into aluminium. Aluminium production requires a high amount of electricity. For instance, 6 to 8 kilowatt-hours of electrical energy is needed to produce one pound of aluminum. Moreover, the production processes involve environmental problems such as greenhouse gases and material usage (Luo and Soria, 2007). Yet, aluminium has proven eco-friendly properties (Du *et al.*, 2010) and its recyclability is practically unlimited. Its demand has been increasing steadily over the last decades.

Aluminium consumption is intrinsically linked with other real macroeconomic variables such as income, employment, urbanization, etc. As such, it is crucial to determine whether shocks such as resource conservation policies, will have a transitory or permanent effect. To do so, the unit root properties of aluminium consumption are investigated. From the time when

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Dickey and Fuller (1979) come up with their ground-breaking work, the unit root literature has been evolving at a fast pace and has emerged as a new and major branch of research in the fields of energy and resource economics. If aluminium consumption is found to be non-stationary i.e. contains a unit root, then shocks will be permanent. Aluminium consumption will not return to its long-run equilibrium trend. This is consistent to hysteresis or path dependency in aluminum consumption. In contrast, if aluminium consumption is found to be stationary, then shocks are temporary and the series will eventually return to its fundamental path.

The presence of a unit root has important policy implications[1]. First, the aluminium industry is interconnected to various sectors throughout the economy. If shocks are temporary, then those sectors which are linked to aluminium consumption via flow-on effects will not be affected and as such may not passed on those shocks to macroeconomic variables such as income or employment. But, shocks can be transmitted to those sectors especially if they are persistent. This indeed has major influence on economic studies relating to the cointegrating relationship between aluminium consumption and other macroeconomic variables.

Second, in the modelling of aluminium demand and forecasting, the nature of shocks is of foremost consequence. If aluminium consumption is mean-reverting, then shocks will be temporary. Past behaviours of aluminium consumption can be used to generate future aluminum consumption. These forecasts[2] could be of particular interest to aluminium companies in case of a need to step up production to meet a prospective rise in aluminum demand. Investment in the aluminium industry is quite costly and a smelter project can cost up to $2 billion (African Development Bank, 2008). Moreover, once operation has started, a smelter cannot be stopped and resumed easily. The production potline has to be kept active 24 hours a day year-round. In case of interruption, which for instance may be due to electricity blackouts, the metal in the pots will solidify and this will require high rebuilding costs (Hequet, 2012). As such, forecasts can help investors to manage their inventory and assess the risks associated with the aluminum industry. However, if aluminium consumption follows a random walk, then shocks will be permanent. Consequently, historical movements in aluminium consumption cannot be used to generate forecasts.

Third, if shocks are temporary, then any policies like mineral conservation will only have short-term effects. Policies with long-term goals will not be effective. But, if shocks are permanent, then those types of policies will be effective. Since aluminium production involves exploitation of non-renewable resources and environmental hazards, policies to restrict aluminium production and consumption could be enacted. For instance, an aluminium consumption tax will have a significant effect.

Though the energy literature relating to stochastic process is evolving at a relatively fast pace, no rigorous studies have been done for metal consumption. This paper intends to bridge this gap and investigates the implications of shocks on aluminium consumption. The remainder of the paper is organized as follows: Section 2 surveys the literature. Section 3 describes the data and methodologies. Section 4 presents the results. Various generations of time-series and panel unit root tests are employed. Overall, aluminium consumption is found to be non-stationary. Section 5 concludes and provides some policy implications.

2. OVERVIEW OF RELATED LITERATURE

Nelson and Plosser (1982) are among the firsts to examine the stochastic properties of macroeconomic data and their works have subsequently triggered a voluminous literature relating to the testing such processes in various fields. One of such field where the impact of shocks has been studied extensively is the energy literature. Smyth (2012) provides a recent review of this literature. The recent resurgence of interest in testing the stochastic properties of energy consumption and other economic variables is principally due to the availability of more and more reliable and powerful tests with regard to time-series and panel data frameworks.

From the mineral perspective, the literature remains relatively scanty. Most of the relevant studies have tested for a unit root as a first stage procedure towards testing whether there is a long-run relationship between metal consumption, economic growth and other economic variables. Using conventional augmented Dickey-Fuller (ADF) unit root test, Ghosh (2006) finds a non-stationary process for steel consumption for India for the time span of 1951–1952 to 2003–2004. Huh (2011) reports similar result for steel consumption for Korea over the period 1975-2008 when making use of ADF and Phillips-Perron (PP) time-series unit root tests. Jaunky (2012) employs various panel data unit root tests and uncover a non-stationary process for aluminium consumption of 20 high-income countries, covering the period 1970-2009. These studies are conducted to mainly assess the impact of metal consumption on economic growth. Jaunky (2013) analyzes the stochastic properties of copper consumption for the 37 countries over the period 1967-2010 with the use of time-series and panel unit root tests. His findings corroborate with the previous metal studies. About 86% or 32 copper consumption series are found to follow a non-stationary process.

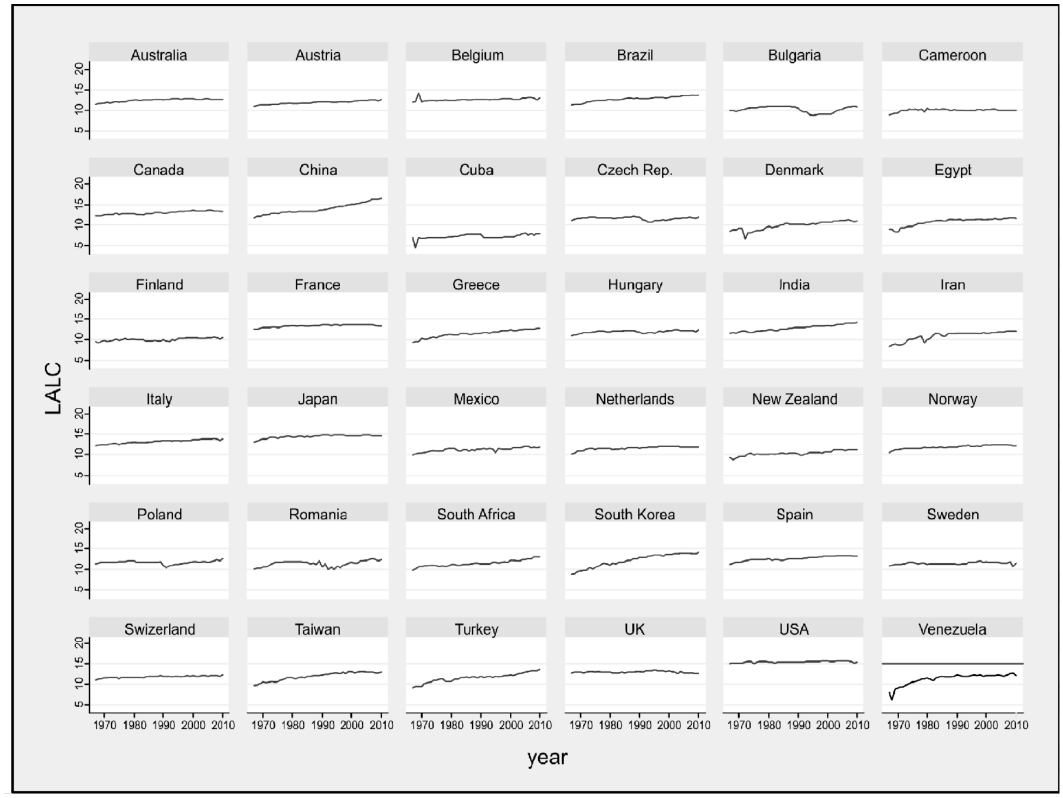
3. DATA AND METHODOLOGY

Data for refined aluminium consumption are obtained from the World Bureau of Metal Statistics (various years). Selection of countries is purely guided by the availability of data and preference is given to the time-span. As such, 36 countries are chosen with 44 years of data spanning over the period 1967-2010. All data are converted into the natural logarithms. To verify the stochastic properties of aluminium consumption, various time-series and panel unit root tests are utilized. The question of whether a series is mean-reverting is investigated by means of two different regressions. 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 exhibit a trend over time and hence it is more fitting to consider a regression with both a constant term and a trend instead of a constant term only. Figure 1 shows the evolution of the natural logarithm of aluminium consumption (*LALC*) over the period 1967-2010. Indeed, most of the aluminium series tend to follow an upward trend over time. For the sake of comparison, both deterministics will be considered. The aluminium series is integrated of order of d, i.e. $LALC_t \sim I(d)$, if it were to be differenced by d times to become stationary. For example, a stationary process is a series which is I(0).

A panel unit root test which is based on an ADF test type can be illustrated as follows:

$$\Delta LALC_{it} = \mu_i + \beta_i t + \rho_i LALC_{it-1} + \alpha_{im} \sum_{m=1}^{k_i} \Delta LALC_{i,t-m} + e_{it} \qquad (1)$$

Figure 1: Year on Year of *LALC* for Individual Countries, 1967-2010



Source: Computed.

where $\Delta LALC_{it} = LALC_{it} - LALC_{it-1}$, t is the time trend for country i, k is the lag length, and ρ_i is the mean-reverting coefficient. Moreover, e_{it} is the idiosyncratic disturbance assumed to be *identically and independently distributed.* If the null hypothesis is accepted (i.e. H_0: $\hat{\rho}_i = 0$), then the series contains a unit root. None of the existing unit root tests is devoid from statistical shortcomings in terms of size and power properties. Accordingly, it is practical to perform a battery of unit root tests to infer overwhelming evidence in order to determine the order of integration. Furthermore, this provides a means to shed light on the comparative limitations and strengths of different time-series or panel unit root test.

Conventional time-series unit root tests such as the ADF test as proposed by Dickey and Fuller (1981) are first computed. This is followed by the Narayan and Popp (2010) time-series unit root tests. These tests test the H_0 of non-stationarity and can be supplemented with a test of the H_0 of stationarity such as the Kwiatkowski *et al.* (KPSS, 1992) test. Such joint testing is usually known as "*confirmatory analysis*" (Romero-Ávila, 2008). In parallel, panel data tests are also applied. Assuming common persistence parameters across units, i.e. $\rho_i = \rho$ for all i, Levin *et al.* (LLC, 2002) first propose a panel unit test. Relaxing this assumption whereby ρ_i is varying freely across units, Im *et al.* (IPS, 2003), Madalla and Wu (1999), Pesaran (2007), Im *et al.* (ILT, 2010) and Chang and Song (2009) tests are applied. The Hadri (2000) Lagrange multipler (LM) test which is based on the KPSS test is also computed. To ensure good size and power properties of the unit root tests, the choice of the maximum lag truncation ($k_{\max}$) is crucial. As indicated by Ng and Perron (2001), these tests are worked out using the lags selected by the modified AIC (MAIC) which is given by $k_{\max} = \text{int}\left(12\left(T/100\right)^{1/4}\right)$. The maximum lag is consequently set to 9.

4. RESULTS

The time-series unit root test statistics are reported in Tables 1(a) and 1(b). Following the ADF tests with a constant and trend, 30 series (Australia, Brazil, Bulgaria, Cameroon, Canada, China, Cuba, Czech Republic, Denmark, Finland, France, Hungary, India, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Romania, South Korea, South Africa, Spain, Sweden, Switzerland, Taiwan, Turkey, UK, USA and Venezuela) are found to be non-stationary while 6 series (Austria, Belgium, Egypt, Greece, Iran and Mexico) are stationary or I(0) at conventional levels. However, the ADF test statistics tend to have low power against I(0) alternatives which are nearer to being I(1). In addition, the ADF test which includes both constant and trend tends to have less power relative to the one with a constant only.

The KPSS test tends to be more a powerful test than the ADF test. For instance, the test can more clearly distinguish between a series which appears to be stationary and non-stationary in case the data are not adequately sufficient to conclude about the order of integration. Following the KPSS with a trend, 17 (Australia, Cameroon, Egypt, France, Greece, Iran, Italy, Japan, Netherlands, Norway, Poland, South Africa, South Korea, Taiwan, UK, US and Venezuela) and 19 (Austria, Belgium, Brazil, Bulgaria, Canada, China, Cuba, Czech Republic, Denmark, Finland, Hungary, India, Mexico, New Zealand, Romania, Spain, Sweden, Switzerland and Turkey) series are uncovered to be non-stationary and stationary respectively. These results contrast significantly with the tests of the H_0 of non-stationarity. Nevertheless, as indicated by Caner and Kilian (2001), unit root tests for the H_0 of stationary tend to have serious size distortions when the H_0 is close to the alternative of a unit root. Consequently some cautions should be exercised before making any conclusion about the stochastic process of the aluminium consumption series.

However, these tests ignore the occurrence of structural breaks in the data and this can lead to a fall in power of the test to reject a unit root even if the trend stationarity holds (Perron, 1989). Breaks can occur due to economical, political or technological shocks. Yet, the PP unit root test which allows for the occurrence of a break, suffers similar shortcomings as the ADF test. In addition, the assumption of exogenous or known break is rather synonymous to data-mining. This is liable to invalidate the sampling distribution theory underlying conventional time-series unit root testing (Christiano, 1992). Zivot and Andrews (1992) recommend a test which relaxes the assumption of an exogenous structural break and allows for the break to be endogenously determined from the data.

However, in the occurrence of two or more breaks, the Zivot-Andrews test tends to lose power. Narayan-Popp unit root test addresses this issue and two specifications are formulated to capture the presence of two breaks in the series. The first test controls for two breaks in the level while the second tests accounts for same number of breaks in the level and slope of a $LALC_t$ series. These tests are found to have correct size, stable power and to identify structural breaks accurately. Referring to the first test, 26 (Australia, Belgium, Brazil, Bulgaria, Canada, China, Cuba, Czech Rep., Egypt, France, Hungary, India, Italy, Netherlands, New Zealand, Norway, Poland, Romania, South Africa, South Korea, Spain, Taiwan, Turkey, UK, US and Mexico) and 10 (Austria, Cameroon, Finland, Greece, Iran, Japan, Denmark, Sweden, Switzerland, and Venezuela) series are computed by the to be non-stationary and stationary respectively. The second test tends to coincide with the first one in terms of number of countries which follow a stationary or non-stationary process. Indeed, the second tests reveal a non-stationary and stationary process for 28 (Australia, Brazil, Bulgaria, Canada, China, Cuba, Czech Republic, Denmark, France, Greece, Hungary, India, Iran, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Poland, Romania, South Korea, South Africa, Spain, Sweden, Turkey, UK and US) and 8 (Austria, Belgium, Cameroon, Egypt, Finland, Switzerland, Taiwan and Venezuela) series respectively. In total, about 77.8% of the sample is found to be non-stationary.

The two structural breaks tend to coincide with the different energy crises over the four decades. The first break tends to fall in the early 1980's and this period correspond to the massive hike in the oil price following the 1979 Iranian Revolution and the 1980-1981 Iran-Iraq war. The second break tends to fall mainly between early and mid 1990's. These periods match once more a spike in oil price as a consequence of the 1990 Iraqi Invasion of Kuwait and to the mounting global concerns about climate change which eventually resulted in the emergence of the 1997 Kyoto Protocol. Indeed, both the Narayan-Popp time-series unit root tests seem to capture those structural shocks. In total, about 77.8% of the sample is found to be non-stationary.

One of the major econometric problems which researchers encounter is the lack of data points over sufficiently long period of time. The number of observations at individual level is only 44 for the period 1967-2010. However, time-series methods are likely to have low power. As argued by Toda (1995), even 100 observations may not ensure good performance of some time-series testing. One promising solution is to exploit panel data techniques which allow for a substantial increase in number of observations ($T \times N$) and testing power. The panel unit root test can be rather sensitive to the maximum order of lags. The individual lags of the time-series ADF tests can be employed to perform various panel unit root tests such as LLC, IPS and Pesaran tests. This may yield more precise test statistics instead of using a common lag structure for the different units within a specific panel. The 36 countries are segmented in two major groups, such as advanced and developing economies. The former group follows the definition of the International Monetary Fund (IMF). The developing countries are further divided into sub-groups according to their geographical location, namely the Eastern Europe, Africa, Asia and Latin America groups. The group labelled "World" consists of all the aluminium series of the 36 countries.

The first test to be considered is the LLC test which is mainly founded on the assumption of homogeneity in the AR(1) coefficients of the ADF specifications. As per Table 2(a), the LLC test tests the H_0 of a non-stationary process for $LALC_{it}$. When considering the test with a trend, 2 (Eastern Europe and Africa) and 5 (Advanced Economies, Developing Economies, Asia, Latin America and World) groups are found to be non-stationary and stationary at conventional levels respectively. However, the LLC assumptions are restrictive and are unlikely to hold in practice. The test assumed homogeneity in the autoregressive of order one (AR(1)) coefficients of the ADF specifications. It ignores the presence of structural breaks and assumes cross-sectional independence among units. But, cross-sectional dependency can occur due to common factors. For instance, financial crises in the USA can be transmitted to other countries. Overall consumer price can be driven be those external shocks leading to global recession. The LLC test is liable to suffer from size distortion in the presence of such contemporaneous correlation between the disturbances across units (O'Connell, 1998).

Auxiliary tests are thus vital to fully assess the order of integration of $LALC_{it}$. In line with Koedijk *et al.* (2004), the degree of cross-sectional dependence can be evaluated by examining the pair-wise correlations of the first-differences in two series. For instance, the pair-wise correlation coefficients[3] of $\Delta LALC_t$ are 0.542, 0.279, 0.112, 0.240 and 0.022 between France and US, Bulgaria and Poland, Cameroon and South Africa, China and India, and Mexico and Venezuela respectively. The pair-wise correlations range from -0.370 to 0.862. In general, the correlation coefficients are found to be mainly positive and rather substantial. This indicates the presence of cross-correlations in the innovations of the panel. As maintained by Banerjee *et al.* (2004), cross-sectional dependence tends to bias panel data unit root tests towards the alternative hypothesis. As a result, it is critical to consider more powerful and up-to-date tests.

IPS (2003) propose a panel unit root test which can control for both heterogeneity between groups and cross-sectional dependence by using demeaned data. Although the IPS panel unit root test tends to be more powerful than the LLC panel unit root test it still tends to have low power in panels with small T (Karlsson and Löthgren, 2000). Using demeaned data as reported in Table 2(b), the IPS panel unit root test statistics with trend illustrate a non-stationary process for 3 (Eastern Europe, Africa and Asia) and a stationary process for 4 (Advance Economies, Developing Economies, Latin America and World) groups.

The Maddala-Wu panel unit test is also performed. This non-parametric test is considered to be more powerful than the LLC or IPS tests and allows as much heterogeneity across countries as possible. Correspondingly, it does not require a balanced panel. If a mixture of stationary and non-stationary series in the group is included as an alternative hypothesis, then the test is more appropriate to use. It tends to have the highest power in differentiating the null from the alternative. The H_0 of non-statinonarity of all the series is tested against the alternative of at least one stationary series in the panel. The Maddala-Wu panel unit root test employs the approach of Fisher (1932) to derive test statistics which combine the p-values from individual unit root tests such as ADF and PP in each cross-sectional unit. The test which includes the trend will be considered for inference. As exposed in Table 2(c), the Fisher-ADF reveals a non-stataionary and stationary process for 2 (Advanced Economies and Eastern Europe) and 5 (Developing Economies, Africa, Asia, Latin America and World) groups respectively. Rather similar results are obtained for the Fisher-PP test where 2 (Eastern Europe and Asia) and 5 (Advanced Economies, Developing Economies, Africa, Latin America and World) groups are found to follow a non-stationary and stationary process respectively. In fact, similar outcome are obtained for both Fisher test statistics when excluding the time trend from the panel unit root tests.

The Hadri panel unit root test offers an attractive alternative where it tests the H_0 of stationarity. Unlike the LLC or IPS test, the Hadri test performs relatively well in panel data with short T (Barhoumi, 2005). It possesses high power and has the advantage of being robust to non-normality. Moreover, this test can also be robust to serial correlation and heteroskedasticity. The tests which include the trend will be used for inferences. Table 2(d) reports a non-stationary process for all seven panels especially when demeaned data is used. However, the caveat issued by Caner and Kilian (2001) with regard to unit root tests for the H_0 of stationarity should be borne in mind while considering these results.

According to Herwartz and Siedenburg (2008), the first-generation tests like the LLC, IPS, Maddala-Wu and Hadri tests are prone to suffer from sever size distortions in the presence of contemporaneous cross-correlation among units. The IPS and Hadri panel unit root tests attempts to control for cross-sectional dependence by using demeaned data. But this approach assumes the existence of a common factor with same effect on all individual units. Such assumption is rather unfeasible and unlikely to hold in practice. Furthermore, the demeaning of data may not fully tackle the size problems produced by the magnitude and variation of cross-sectional dependence (Strauss and Yigit, 2008). The Maddala-Wu test also encounter similar problems as it relies on the assumption of cross-sectional independence.

Pesaran (2007) suggests a panel unit root test which can allow for the presence of cross-sectional dependence in a more general pattern. Such test can be considered as a second-generation of panel unit root test. To control for cross-sectional dependence, instead of demeaning, the standard ADF regression models are augmented with the cross-section averages of lagged levels and first-differences of the individual aluminium consumption series. The Pesaran test is based on the averages of the individual cross-sectionally augmented ADF (CADF) statistics. The test is found to have good size and power properties even when N and T are somewhat small. As displayed in Table 2(e), the tests which include a trend show a non-stationary and stationary process for 4 (Advanced Economies, Eastern Europe, Africa and Asia) and 3 (Developing Economies, Latin America and World) groups respectively.

Similar to time-series tests, panel unit root test statistics tend to be derived from biased parameter estimates if structural breaks are ignored. ILT (2010) develop a new LM based panel unit root test which allows for heterogeneous structural breaks in both the intercept and slope of each cross-sectional unit in the panel. They extend their LM test to control for cross-sectional dependence by employing the CADF procedure *à la* Pesaran (2007) and derive a cross-sectionally augmented LM (CALM) test. Existing panel unit root tests allowing for breaks tend to depend critically on the nuisance parameters specifying the size and break locations. To address this problem, ILT (2010) formulate a method which renders the asymptotic properties of their test invariant to the nuisance parameters. They derive these asymptotic properties and examine the finite-sample properties of their tests. These are found to be are robust to various locations of trend-shifts.

As reported in Table 2(f), the LM_L and LM_{TL} tests, which assume one or two breaks in the level and both level and trend respectively, tend to lend support to stationary process for aluminium consumption for all the different panels, apart from Eastern Europe and Asia.

Nevertheless, this tendency is reverse when computing the $CALM_L$ tests which allow for both cross-sectional dependence and one or two structural breaks in the level. All seven groups are found to follow a non-stationary process. In contrast, the $CALM_{LT}$ test which controls for two breaks in the level and trend, offers evidence of a stationary process for all the various groups, excluding the Asia. The findings are not very conclusive though on average the evidence tends to point towards a lack of mean-reversion especially when controlling for cross-sectional dependence.

The incidence of cross-sectional cointegration has been recently debated in the panel data literature and constitutes new avenue for research. Long-run dependence occurs when two or more countries share a common stochastic trend. This can once more biased panel unit root test statistics leading to the erroneous rejection of the null of non-stationarity (Banerjee *et al.*, 2004). Cross-sectional cointegration can therefore invalidate both first- and second-generation tests. A third-generation test (Breitung and Cubadda, 2011) which can control for both short-run and long-run co-movements across units is as a consequence required. Based on the Chang (2002) nonlinear IV panel unit root test, Chang and Song (2009) advocate a test employing a set of orthogonal functions as instrument generating function (IGF) to tackle any forms of dependence. The test however does not control for structural breaks. Referring to Table 2(g), 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 countries while the minimum tests evaluate the H_0 of non-stationarity of some individual countries within the panel. Practically all test statistics of the seven panels strongly confirm a non-stationary process for $LALC_{it}$.

According to Karlsson and Lothgren (2000), rejection of the panel unit root null may be driven by a few stationary series and the whole panel can be incorrectly modeled as stationary. For robust inferences, the Chang-Song test has been redone for the whole $LALC_{it}$ series by excluding the 8 series which are found to be I(0) as per the Narayan-Popp test. No major difference in the final to the results is to be found. All the Chang-Song test statistics are found to accept the H_0 of non-stationarity.

Alternately, when looking for a reason for the presence of a unit root the mean and volatility of $LALC_{it}$ can be examined. The degree of volatility can be measured by computing the standard deviation. According to Narayan *et al.* (2008), countries with high volatility are more apt to witness a lack of mean reversion. This is because countries with volatile consumption deviations from the long-run equilibrium path due to shocks are likely to be larger and therefore the divergence from the fundamental path will tend to be permanent (Barros *et al.* 2011). These shocks can be treated as structural breaks and this reinforces the rationale of acknowledging and controlling for structural breaks when undertaking the different unit root tests (Narayan *et al.*, 2008). As reported in Table 3, the mean and Asian panel has the highest volatile consumption as well as a relatively large mean. In almost all cases, the various panel unit root tests support the presence of a unit root for such panel. Individual countries as well as the different panels tend to exhibit relatively high volatility of aluminium consumption. Such finding tends to be substantiated with the result of lack of mean reversion in the majority of countries and especially for the panels.

Table 1
Time Series Unit Root Tests

Country	*ADF*		*KPSS*		*Narayan-Popp*					
	Without Trend	*With Trend*	*Without Trend*	*With Trend*	$M1_{B,L}$ *t-value*	T_{B1}	T_{B2}	$M1_{B,L}$ *t-value*	T_{B1}	T_{B2}
***Advanced Economies*:**										
Australia	-3.311(0)†	-2.400(0)	0.715(5)†	0.225(5)*	-0.716(9)	1978	1989	-3.425(0)	1981	1989
Austria	-0.538(1)	-3.453(0)‡	0.825(5)*	0.106(4)	-5.693(8)*	1983	1993	-5.866(7)†	1983	1993
Belgium	-0.219(5)	-4.567(4)*	0.799(4)*	0.076(5)	-3.697(6)	1982	1987	-4.973(4)‡	1979	1992
Canada	-1.174(0)	-1.165(0)	0.782(5)*	0.078(5)	1.773(3)	1983	1986	0.271(0)	1983	1986
Czech Rep.	-1.534(0)	-1.370(0)	0.138(5)	0.095(5)	-3.315(1)	1990	1994	-3.837(0)	1990	1994
Denmark	-2.061(0)	-2.403(0)	0.748(5)*	0.085(4)	-1.606(9)	1985	1996	-3.870(0)	1980	1986
Finland	-1.401(3)	-2.157(3)	0.598(5)†	0.087(5)	-5.379(0)*	1983	1994	-5.848(0)†	1989	1994
France	-2.150(0)	0.534(2)	0.671(5)†	0.215(5)†	1.224(2)	1980	1998	-2.679(0)	1980	1995
Greece	-0.996(0)	-3.493(0)‡	0.827(5)*	0.152(5)†	-4.248(0)‡	1993	1996	-4.475 (8)	1980	1992
Italy	-1.495(0)	-2.967(0)	0.815(5)*	0.146(4)†	-2.617(0)	1992	1995	-3.642(5)	1980	1992
Japan	-2.395(8)	-0.739(8)	0.697(5)†	0.195(5)†	-4.766(3)†	1982	1987	-3.835(9)	1980	1987
Netherlands	-1.235(1)	-1.917(1)	0.740(5)*	0.146(5)†	-3.844(9)	1980	1989	-1.589(4)	1981	1989
New Zealand	-0.566(0)	-2.582(0)	0.761(5)*	0.094(4)	-2.617(0)	1990	1993	-3.206(0)	1981	1990
Norway	-1.945(0)	-2.108(0)	0.802(5)*	0.128(4)‡	-2.436(7)	1994	1998	-1.976(0)	1994	1998
South Korea	-1.778(0)	-2.183(0)	0.816(5)*	0.209(5)†	-1.841(5)	1979	1998	-3.797(6)	1980	1997
Spain	-1.140(3)	-2.491(3)	0.804(5)*	0.069(5)	-1.098(3)	1980	1982	-1.441(8)	1980	1987
Sweden	-1.590(1)	-1.487(1)	0.438(5)‡	0.073(5)	-6.518(0)*	1993	1997	1.662(9)	1989	1993
Switzerland	-1.760(1)	-3.530(0)	0.792(5)*	0.160(5)	-6.550(1)*	1984	1992	-6.231(0)*	1984	1992
Taiwan	-2.384(1)	-1.610(1)	0.800(5)*	0.211(5)†	0.965(5)	1980	1983	-6.374(0)*	1980	1997
UK	-0.360(1)	-0.217(1)	0.123(5)	0.123(5)	-3.429(0)	1987	1991	-3.853(7)	1991	1998
USA	-1.698(0)	-2.254(0)	0.578(5)†	0.081(4)	-1.365(0)	1982	1991	-1.745(0)	1982	1991
Developing Economies:										
Eastern Europe:										
Bulgaria	-2.708(3)‡	-2.987(3)	0.171(5)	0.106(5)	-3.829(7)	1990	1998	-2.203(0)	1990	1993
Hungary	-2.025(0)	-2.323(0)	0.459(5)†	0.097(5)	-2.212(4)	1989	1991	-1.728(4)	1990	1993
Poland	-1.406(0)	-1.534(0)	0.144(5)	0.134(5)‡	-2.212(0)	1989	1991	-2.359(7)	1989	1995
Romania	-2.312(3)	-2.264(0)	0.214(5)	0.105(5)	-2.386(2)	1989	1991	-1.789(5)	1988	1997
Africa:										
Cameroon	-1.586(8)	-1.945 (8)	0.241(5)	0.149(5)†	-4.451(7)‡	1979	1984	-5.342(7)†	1978	1986
Egypt	-4.926(2)*	-4.629(2)*	0.712(5)†	0.198(5)†	-3.844(5)	1984	1991	-6.113(0)*	1985	1996
South Africa	2.970(6)†	-1.923(0)	0.844(5)*	0.144(4)‡	-2.318(2)	1982	1989	-1.954(7)	1983	1993
Asia:										
China	2.171(1)	-1.365(0)	0.825(5)*	0.178(5)†	-0.198(0)	1988	1991	-3.539(9)	1985	1988
India	0.060(0)	-2.500(0)	0.843(5)*	0.097(4)	-2.075(0)	1981	1983	-2.815(5)	1983	1994
Iran	-2.064(0)	-3.301(0)‡	0.748(5)*	0.200(5)†	-9.219(2)*	1978	1986	-2.198(7)	1979	1984
Turkey	0.948(4)	-2.819(0)	0.820(5)*	0.108(5)	-1.601(3)	1980	1985	-1.037(2)	1980	1985

contd. table 1

Country	*ADF*		*KPSS*		*Narayan-Popp*					
					$M1_{B,L}$			$M1_{B,L}$		
	Without Trend	*With Trend*	*Without Trend*	*With Trend*	*t-value*	T_{B1}	T_{B2}	*t-value*	T_{B1}	T_{B2}
Latin America:										
Brazil	-0.250(1)	-3.014(0)	0.805(5)*	0.150(5)$^{+}$	-1.400(8)	1980	1989	0.471(9)	1980	1989
Cuba	-1.575(0)	-1.678(0)	0.420(5)$^{+}$	0.100(5)	-3.416(3)	1990	1998	-3.680(2)	1981	1994
Mexico	-2.491(0)	-3.569(0)$^{+}$	0.713(5)$^{+}$	0.106(4)	-5.979(0)*	1981	1994	-3.676(6)	1981	1994
Venezuela	-3.604(4)*	-2.980(4)	0.701(5)$_{+}$	0.200(5)$^{+}$	-4.927(0)$^{+}$	1981	1986	-4.789(0)‡	1981	1998

Source: Computed. Note: ADF critical values (CV) without and with a trend are -3.68, -2.97 and -2.62; and -4.29, -3.56 and -3.22 at 1%, 5% and 10% significance levels respectively (MacKinnon, 1991). 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. 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% level of significance (T=50) for model $M2_{B,L}$. The optimal lag is in parentheses. *, $^{+}$ and ‡ denote 1%, 5% and 10% levels respectively.

Table 2(a)
LLC Panel Unit Root Test Statistics

Group	*Without Trend*	*With Trend*
Advanced Economies	-2.508 [0.006]*	—2.450 [0.007]*
Developing Economies	-0.513 [0.304]	-2.910 [0.002]*
Eastern Europe	0.241 [0.595]	1.169 [0.879]
Africa	0.102 [0.541]	1.494 [0.932]
Asia	-0.428 [0.335]	-2.349 [0.009]*
Latin America	-5.226 [0.000]*	-4.818 [0.000]*
World	-0.407[0.342]	-2.206 [0.014]$^{+}$

Source: Computed. Note: The lag lengths for the panel test are based on those employed in the univariate ADF test. Assuming no cross-country correlation and T is the same for all countries, the normalized t^* test statistic is computed by using the t-value statistics. After transformation by factors provided by LLC, the t^* tests is distributed standard normal under the II_0 of non-stationarity. 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.

Table 2(b)
IPS Panel Unit Root Test Statistics

Group	*Raw Data*		*Demeaned Data*	
	Without Trend	*With Trend*	*Without Trend*	*With Trend*
Advanced Economies	-3.965 [0.000]*	-3.186 [0.001]*	-1.921 [0.027]	-2.672 [0.001]*
Developing Economies	-1.518 [0.065]‡	-3.057 [0.001]*	-1.063 [0.090]‡	-3.188 [0.005]*
Eastern Europe	-2.374 [0.009]*	-0.953 [0.170]	-1.425 [0.077]‡	0.439 [0.330]
Africa	0.387 [0.651]	-0.737 [0.230]	0.838 [0.799]	1.006 [0.843]
Asia	2.475 [0.993]	-0.597 [0.275]	-0.834 [0.202]	-1.298 [0.097]
Latin America	-3.499 [0.000]*	-3.564 [0.000]*	-5.781[0.000]*	-4.484 0.000]*
World	-4.000 [0.000]*	-4.406 [0.000]*	-0.691 [0.245]	-2.539 [0.006]*

Source: Computed. Note: The lag lengths for the panel test are based on those employed in the univariate ADF test. 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 $\Psi_{\bar{t}}$ test statistics for II_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.

Table 2(c)
Madalla and Wu Panel Unit Root Test Statistics

Group	*ADF*		*PP*	
	Without Trend	*With Trend*	*Without Trend*	*With Trend*
Advanced Economies	55.039 [0.086]‡	45.826 [0.316]	178.126 [0.000]*	161.489 [0.000]*
Developing Economies	103.746 [0.000]*	74.412 [0.000]*	58.388 [0.001]*	59.117 [0.005]*
Eastern Europe	18.013 [0.021]†	11.273 [0.187]	13.550 [0.094]‡	6.356 [0.608]
Africa	54.552 [0.000]*	21.011 [0.002]*	20.926 [0.002]*	15.650 [0.016]†
Asia	6.5704 [0.584]	17.055 [0.030]†	5.180 [0.738]	11.115 [0.195]
Latin America	25.295 [0.001]*	24.276 [0.002]*	20.033 [0.010]†	25.401 [0.001]*
World	158.785 [0.000]*	120.237 [0.000]*	236.514 [0.000]*	220.606 [0.000]*

Source: Computed. Note: The lag lengths are chosen according to the Bartlett kernel i.e. 3. Based on the p-values of individual unit root tests, the Fisher test assumes non-stationarity of all series under the II_0 against the alternative of stationarity for at least one series in the panel. The test has a χ^2 distribution with $2N$ degrees of freedom, where N is the number of cross-sectional units or countries.

Table 2(d)
Hadri Panel Unit Root Test Statistics

Group	*Serial Correlation*				*Heteroskedasticity*			
	Raw Data		*Demeaned Data*		*Raw Data*		*Demeaned Data*	
	Without Trend	*With Trend*	*Without Trend*	*With Trend*	*Without Trend*	*With Trend*	*Without Trend*	*With Trend*
Advanced Economies	28.341 [0.000]*	11.546 [0.000]*	25.675 [0.000]*	10.030 [0.000]*	85.131 [0.000]*	34.104 [0.000]*	62.920 [0.000]*	35.340 [0.000]*
Developing Economies	20.372 [0.000]*	11.020 [0.000]*	17.958 [0.000]*	12.255 [0.005]*	61.228 [0.000]*	36.595 [0.000]*	58.595 [0.000]*	33.594 [0.005]*
Eastern Europe	0.922 [0.178]	3.156 [0.001]*	2.939 [0.002]*	2.880 [0.000]*	9.401 [0.000]	15.208 [0.001]*	10.731 [0.002]*	12.653 [0.000]*
Africa	9.806 [0.000]*	6.887 [0.000]*	8.154 [0.000]*	7.199 [0.000]*	28.573 [0.000]*	19.598 [0.000]*	28.671 [0.000]*	19.427 [0.000]*
Asia	12.768 [0.000]*	7.310 [0.000]*	5.542 [0.000]*	8.637 [0.000]*	49.218 [0.000]*	20.069 [0.000]*	17.495 [0.000]*	22.591 [0.000]*
Latin America	10.354 [0.000]*	7.204 [0.000]*	8.180 [0.000]*	7.234 [0.000]*	34.029 [0.000]*	17.103 [0.000]*	20.526 [0.000]*	15.438 [0.000]*
World	34.004 [0.000]*	16.553 [0.000]*	29.051 [0.000]*	16.300 [0.000]*	104.542 [0.000]*	49.670 [0.000]*	88.029 [0.000]*	50.007 [0.000]*

Source: Computed. Note: Source: Computed. Note: 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 II_0 of stationarity is tested. The Bartlett kernel is set to be 3. The test statistics are robust to serial correlation and heteroskedasticity.

Table 2(e)
Pesaran CADF Panel Unit Root Test Statistics

Group	*Without Trend*	*With Trend*
Advanced Economies	-3.100 [0.001]*	-0.968 [0.167]
Developing Economies	-1.669 [0.048]*	-2.835 [0.002]*
Eastern Europe	-0.870 [0.192]	-0.693 [0.244]
Africa	1.800 [0.964]	-0.122 [0.451]
Asia	0.743 [0.771]	-0.345 [0.365]
Latin America	-2.239 [0.013]$^{+}$	-2.329 [0.010]*
World	-3.238 [0.001]*	-1.461 [0.072]‡

Source: Computed. Note: The lag lengths for the panel test are based on those employed in the univariate ADF test. The Pesaran CADF test of the II_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.

Table 2(f)
ILT Panel LM Unit Root Test Statistics

Group	LM_L		LM_{LT}		$CALM_L$		$CALM_{LT}$	
	One Break	*Two Breaks*	*One Break*	*Two Breaks*	*One Break*	*Two Breaks*	*One Break*	*Two Breaks*
Advanced Economies	-6.048*	-7.519*	-3.739*	-5.009*	2.063	5.510	-4.615*	-2.108^{+}
Developing Economies	-0.727	-3.670*	-2.842*	-7.257*	0.813	4.117	-3.153*	-1.979^{+}
Eastern Europe	2.694	3.683	-0.711	0.039	3.217	5.453	-1.463‡	-1.495‡
Africa	1.834	0.880	1.731	-6.491*	2.647	2.344	-3.188*	-3.979*
Asia	0.160	0.322	1.509	-0.392	2.895	4.199	1.486	1.669
Latin America	-7.818*	-4.253*	-2.773*	-8.717*	-0.888	1.073	-0.564	-1.781^{+}
World	-5.015*	-6.564*	-3.360*	-4.905*	5.655	7.903	-10.265*	-3.974*

Source: Computed. Note: The II_0 of non-stationarity is tested. The LM_L and LM_{LT} denote the LM test statistics with level breaks and level and trend breaks respectively. Following Pesaran (2007), cross-sectionally augmented versions of these tests are denoted by $CALM_L$ and $CALM_{LT}$ respectively. Critical values for the LM panel unit root test are distributed asymptotic standard normal and are -2.326, -1.645, and -1.282 at the 1%, 5%, and 10% levels, respectively.

Table 2(g)
Chang-Song Panel Unit Root Test Statistics

Group	ta_c	ta_h	ta_a	tm_c	tm_h	tm_a
Advanced Economies	0.742	0.025	-0.943	-1.441	-0.756	-1.013
Developing Economies	-0.190	-0.496	-0.882	-1.393	-1.492	2.159
Eastern Europe	-2.140^{+}	-0.692	-1.453‡	-1.907‡	-0.972	-1.310
Africa	2.558	0.439	-0.209	-0.141	-0.604	-0.919
Asia	1.755	-0.177	-0.943	-0.529	-0.669	-1.048
Latin America	2.431	1.143	0.453	-0.244	-1.271	-1.311
World	0.444	0.133	-0.631	-1.441	-1.337	-1.370

Source: Computed. Note: The nonlinear IV average and minimum tests are denoted by the *ta* and *tm* while the subscripts *c*, *h* and *a* refer to those tests with single IGF and no covariate, with single IGF and covariate and orthogonal IGF with no covariate respectively. As per Chang and Song (2009), the tests include a constant term only. The II_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 the critical values for the minimum are referred to from Chang and Song (2009).

Table 3
Mean and Volatility

Countries	*Mean*	*Standard Deviation*
Advanced Economies:	12.173	1.409
Australia	12.406	0.415
Austria	11.814	0.436
Belgium	12.597	0.395
Canada	12.975	0.443
Czech Rep.	11.567	0.354
Denmark	9.85	1.02
Finland	10.068	0.353
France	13.283	0.262
Greece	11.483	0.89
Italy	13.172	0.451
Japan	14.361	0.372
Netherlands	11.584	0.416
New Zealand	10.357	0.586
Norway	11.853	0.443
South Korea	12.185	1.551
Spain	12.584	0.525
Sweden	11.506	0.258
Switzerland	11.786	0.279
Taiwan	11.915	1.003
UK	12.933	0.208
USA	15.355	0.175
Developing Economies	11.28	1.683
Eastern Europe:	11.302	0.915
Bulgaria	10.125	0.745
Hungary	11.988	0.329
Poland	11.72	0.376
Romania	11.427	0.704
Africa	10.729	0.95
Cameroon	9.928	0.327
Egypt	10.772	0.933
South Africa	11.488	0.725
Asia	12.32	1.583
China	13.97	1.297
India	12.814	0.727
Iran	10.942	1.135
Turkey	11.556	1.057
Latin America	10.616	2.21
Brazil	12.715	0.677
Cuba	7.227	0.577
Mexico	11.226	0.478
Venezuela	11.296	1.323
World	11.801	1.591

Source: Computed.

4. CONCLUSION AND POLICY IMPLICATIONS

The paper attempts to study the stochastic properties of aluminium consumption for 36 countries over the period 1967-2010. Various generations of time-series and panel unit root tests have been applied. The importance of structural breaks in the data has implications for the power of the unit root tests and can affect the final outcome. As discussed above, the selection of the best panel unit root test is not as straightforward as in the case of time series. Each of these tests has its major advantages and disadvantages. And these are discussed in the paper. The bulk of the literature does not resolve on one particular test but a myriad of tests before coming to a conclusion about the stochastic properties of the series (e.g. Mishra *et al.*, 2009; Narayan *et al.*, 2010; Jaunky, 2012, and countless others). For instance, the Narayan-Popp univariate test is obviously more powerful than other existing time-series tests. But for panel data, even the latest Chang-Song test, which controls for cross-sectional cointegration, ignores breaks. So it is a good exercise to run various tests and such practice has been done by the above-mentioned authors. Thus a rigorous approach is necessary.

Indeed, to acquire solid evidence, Narayan and Smyth (2007) have called upon the applications of unit root tests which can effectively controlled for structural breaks and cross-sectional dependence, to capture the effects of breaks, conventional tests coupled with latest unit root tests as the Narayan-Popp and Im e*t al.* tests have been applied. Structural breaks are found to particularly match the major energy crises over the decades. Cross-sectional dependence and a new aspect of this issue, namely cross-sectional cointegration have been plaguing panel unit root testing. The unit root properties have been verified by applying of the both traditional and latest panel unit root tests as per the Chang-Song test. In general, 77.8% of the individual aluminium consumption series in the selected sample is found to be non-stationary. Moreover, the hypothesis of a non-stationary process for the various sub-groups and whole panel cannot be rejected.

The policy implications are threefold. First, since shocks in aluminium consumption are bound to be permanent, other sectors may inherit these shocks too. Shocks to aluminium consumption can in effect affect aggregate demand. Second, with presence of a unit root in aluminium consumption, past behaviours are of little or no use in forecasting future aluminium consumption. Third, any mineral conservation policies are likely to have a permanent effect on the long-term trend of aluminium consumption which may in turn affect long-run growth rate of an economy. To sum up, the study of the stochastic processes of aluminium consumption can provide policymakers with useful information especially when designing environmental, energy and natural resource management policies with regard to the aluminium industry.

NOTES

1. For instance, Narayan and Smyth (2007), Apergis *et al.* (2010) and Smyth (2012) discuss the implications of shocks.
2. The forecasts and forecast standard errors tend to differ between stationary and non-stationary series. Forecast standard errors will become very large for more distant forecast periods if the series is non-stationary.
3. Detailed results of the pair-wise correlations are available upon request.

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