

Article

The Determinants of Forest Products Footprint: A New Fourier Cointegration Approach

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Abstract: This study aims to determine the factors that affect the forest products footprint (FPF) in Brazil during the period 1965–2018 by proposing a new cointegration test which augments the Engle-Granger cointegration test with a Fourier function (Fourier Engle-Granger) and allows multiple structural breaks in the long-run relationship. Since the results of the unit root tests show that all variables are nonstationary, we applied the Fourier Engle-Granger cointegration test and revealed that there was a long-term relationship between the forest products' footprint, energy consumption, gross domestic product, and trade openness. Although energy consumption was found to have a decreasing effect on FPF, the remaining variables were found to have a healing effect on FPF. Policymakers in Brazil should consider shifting energy consumption to clean energy sources and sustain international trade and economic growth in the current form to consider the FPF.

Keywords: structural breaks; long-run relationship; footprint

1. Introduction

According to a report prepared by the United Nations, the consumption of primary wood products will increase by 37% to 3124 billion m³ by 2050 compared to 2020 [1]. In the face of this increasing demand, it is evident that the economy of Brazil, with the second largest forest area of 815 million hectares (after Russia with 496 million hectares), will be positively affected by this increase [2]. The forest industry in Brazil plays a significant role in the economy through investment, job creation, income production, and tax revenue. The sector accounts for 1.2% of the Brazilian GDP [3]. According to the Indústria Brasileira de Árvores (IBA), the sector creates approximately two million jobs, both directly and indirectly, and this number increases to three million when induced job posts are taken into account. In addition, the share of exports in this sector is 4.4 percent. Historically, most of Brazil's forest products exports have been comprised of wood pulp, solid wood products, and paper products, which accounted for 94% of the country's total forest exports in 2020. Brazil is currently the second largest exporter of wood pulp and is ranked 14th in terms of solid wood products [3].

The ecological footprint (EF) is an indicator which was developed by the Global Footprint Network to track human demand for ecological assets, and the forest products footprint (FPF) is one of the important components of the EF. The FPF is computed based on the annual consumption of timber, cellulose, timber products, and fuelwood by a nation. This is because the FPF is a consumption-based approach for measuring human impact on forests [4]. The FPF enables the assessment of the environmental impact of consuming products and promotes sustainable practices for their use.

The dynamics and determinants of the ecological footprint have been extensively studied in the literature. The ecological footprint (EF) has been extensively investigated over the last few years. For example, some studies consider the dynamics of EF and test whether shocks have permanent or transitory effects on EF (see Ulucak and Lin, [4]; Solarin and Bello, [5]; Yilanci, et al. [6], Eren and Alper, [7]; Bello et al. [8]; Yilanci et al., [9,10]), whereas others test the convergence hypothesis in the EF concept (see Ulucak and Apergis, [11];



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Solarin, et al. [12]; Yilanci and Pata, [13]; Işık, et al. [14]; Tillaguango, et al. [15]; Yilanci et al. [16,17]; Ursavas and Yilanci, [18]; Alper et al. [19]; and Arogundade et al. [20]).

There are some studies that consider EF as an environmental degradation indicator and test the EKC hypothesis for countries for different periods. For instance, Al-Mulali et al. [21] undertook one of the first studies to examine the validity of the EKC hypothesis by using EF. They tested the EKC hypothesis in 93 countries and validated the EKC hypothesis in upper-middle- and high-income countries, but not in low- and lower-middle-income countries. Ozturk et al. [22], Ulucak and Bilgili [23], Destek et al. [24], Destek and Sarkodie [25], Altıntaş and Kassouri [26], Dogan et al. [27], and Ansari [28] are among the studies that test the EKC hypothesis. Some studies also considered the EF hypothesis when testing the pollution halo/haven hypothesis (see Balsalobre-Lorente et al. [29]; Destek and Okumus, [30]; Nathaniel et al. [31]; and Chaudhry et al. [32] among others.)

Focusing on the components of EF would help identify the environmental factors upon which human activities exert an impact, facilitating the development of policies in this regard. However, there are only a limited number of studies that consider components of EF instead of EF. It is possible to categorize the studies into two parts: those that solely examine the characteristics of a single series, and those that investigate relationships with other variables.

First, we focus on the studies that examine the dynamics of a single variable. Solarin et al. [33] examine the integration properties of the fishing grounds footprints (FGF) of 89 countries employing fractional integration techniques. The findings of the study show that most of the series are nonstationary; that is, shocks have permanent effects on most series. Kassouri [34] investigated the convergence pattern of the FGF for the countries in the Gulf of Guinea and the Congo Basin region using a nonlinear panel unit root test. These findings support the weak evidence of convergence in FGFs. Solarin [35] tested the stochastic properties of FPF in 89 countries over the 1961–2016 period by applying a panel stationarity test, which allows multiple structural changes via a Fourier function. The results suggest that the FPFs have a unit root, that is, the FPF will not return back to its original mean after a shock. Finally, Solarin et al. [36] test the persistence of shocks on the built-up land footprint (BLF) in 89 countries using fractional integration methods. These results support heterogeneity in the integration levels of the BLFs.

Karimi et al. [37] examined the determinants of FPFs in 17 Asia-Pacific countries from 2000 to 2017 using spatial econometric methods in an EKC framework. They found supportive evidence for EKC, and that some of the control variables, such as natural resource rents, urbanization, and energy intensity, have no effect on FPF, but government integrity, tax burden, business freedom, and monetary freedom indices have an increasing effect on FPF, and indices of trade freedom and investment freedom have a decreasing effect. They conclude by recommending that policymakers prioritize foreign direct investment and free trade. Farooq and Dar [38] examined the validity of the environmental Kuznets curve in India from 1975 to 2017 using FPF as an environmental degradation indicator. The findings of the study approve an N-shaped FPF-induced EKC in India. Yilanci et al. [39] considered the fishing grounds footprint and tested the validity of the EKC for China during the 1961–2017 period. They used the total fisheries production as a control variable. The results of this study support the validity of EKC. The results also show that total fisheries production has an increasing effect on FGF in the long- and short-run. Yilanci et al. [40] tested the pollution halo and EKC hypothesis in Indonesia from 1976 to 2018 using FGF. They found supportive evidence for both of the hypotheses. The turning point, which is a threshold value for people ignoring the environment and prioritizing their income, was found as 4579.51 US Dollars. In addition, fishery trade openness, which was used as a control variable in this study, was found to have a decreasing effect on FGF.

As seen in this review, there is emerging literature on the components of EF. This study is the first to contribute to the literature by examining the determinants of FPF in Brazil. To this end, energy consumption, GDP, and trade openness will be used as determinants. This study is novel in terms of the sample and variables used. A new test is proposed that models the structural change in the cointegration relationships between the relevant variables using a Fourier function, which is intended to provide a theoretical contribution to the literature.

2. Materials and Methods

This study aims to determine the factors affecting FPF in Brazil from 1965 to 2018. The selection of this period is due to the availability of FPF data. For this purpose, the following model is used:

$$FPF_t = f(GDP, EC_t, TO_t)$$

where FPF_t shows the forest products footprint per capita measured in global hectares, and was obtained from the website of the Global Footprint Network (<https://data.footprintnetwork.org/>, accessed on 15 February 2023). GDP is the per capita gross domestic product constant at 2015 US dollar prices, and TO is trade openness, which is obtained by summing exports and imports and dividing the total by GDP , which indicates the degree to which a country's trade is linked to the global economy. These two series were obtained from the data service of the World Bank. EC denotes the per capita energy consumption measured in gigajoules and was obtained from the Statistical Review of World Energy of BP. We use the series in logarithmic form for empirical purposes.

Table 1 presents the descriptive statistics of data:

Table 1. Descriptive Statistics.

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
LEC	3.585	3.650	4.139	2.470	0.448	−1.009	3.234	9.278 (0.010) **
LFPF	−0.545	−0.544	−0.392	−0.788	0.100	−0.670	2.806	4.119 (0.127)
LGDP	8.712	8.768	9.129	7.918	0.310	−1.044	3.608	10.635 (0.005) *
LTO	−1.918	−2.048	−1.246	−2.768	0.448	0.075	1.667	4.050 (0.132)

Note: * and ** show the significance at the 1% and 5% levels, respectively, where L is the logarithm of the relevant series.

The values in Table 1 show that LGDP has the maximum mean, whereas LTO has the minimum mean. LFPF has the least variation, which shows that the values of LFPF are more tightly clustered around the mean than those of the other series. LTO has the maximum standard deviation, which shows that the values of LTO are more spread out from the mean than in the remaining series. The p -values of the Jarque-Bera test indicate that LFPF and LTO are normally distributed.

We illustrate the share of Brazil's total FPF in the total FPF worldwide, and Brazil's per capita FPF (global hectares) in Figure 1.

Although Brazil's share decreased in certain years, it peaked in 2003 and started to decrease thereafter, reaching 0.045 in 2018. When evaluating the FPF per capita in Brazil, a decrease is observed until 1973, after which there was an increase up to 1980, its highest point. Thereafter, irregular increases were observed in different years, with the minimum value being recorded in 2015. Subsequently, there has been a steady uptick in its value.

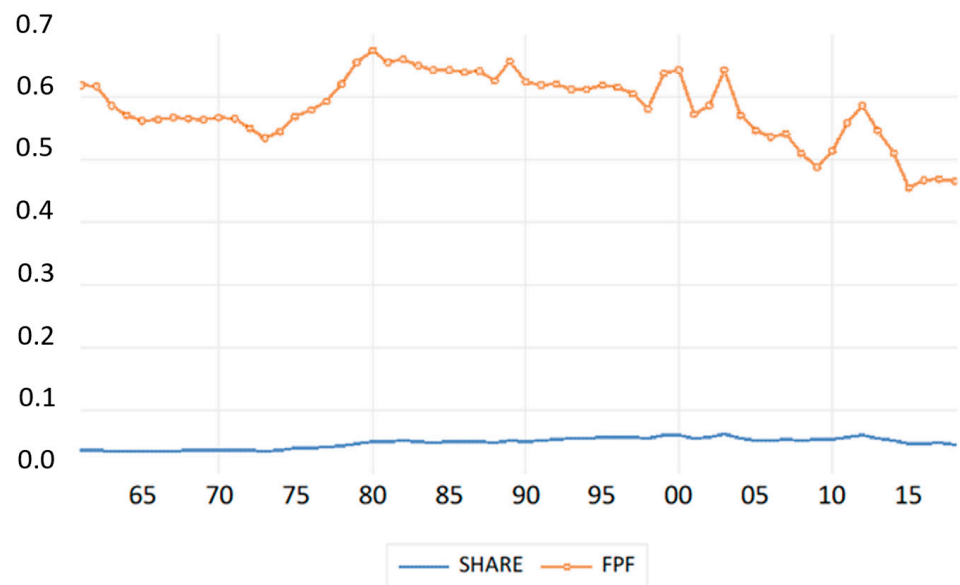


Figure 1. FPF Dynamics of Brazil.

3. Econometric Methodology

The performance of traditional residual-based cointegration tests that examine the null hypothesis of the no-cointegration relationship between the considered variables is affected by the structural changes that occur due to economic crises, technological changes, political regime shifts, and similar shocks. As Gregory and Hansen [41] note, if there is a structural change in the long-run relationship, the power of cointegration tests, such as Engle-Granger [42], which ignore these changes, will be reduced. Several cointegration tests have been introduced to consider structural breaks in cointegration relationships. While Gregory and Hansen [41] considered one unknown shift, Hatemi-J [43] extended this test to allow for two structural breaks. Both tests capture regime shifts by incorporating dummy variables and assume that the number of breaks is known a priori.

The study by Becker et al. ([44], BEL hereafter), who used Gallant's [45] Flexible Fourier form to model unknown structural breaks, brought new depth to the unit root testing literature, because previous studies generally used Perron's [46] modeling strategy of structural breaks by using dummy variables. BEL [44] showed that a single frequency of the Fourier approximation can mimic various breaks, including sharp and smooth breaks and unattended nonlinearities. Several unit root tests, such as those by BEL [44], Enders and Lee [47], and Rodrigues and Taylor [48], who employed a variant of the Flexible Fourier form, have been introduced to the literature. The main advantage of using trigonometric terms is that the locations, numbers, and forms of the structural breaks do not need to be predetermined. In this study, we extend the residual-based cointegration test of Engle-Granger [42] using Fourier approximation to test the existence of a cointegration relationship that allows unknown forms of breaks.

We consider the following cointegration regression to apply this test:

$$y_{1t} = d(t) + \beta' x_t + u_t \quad (1)$$

where $t = 1, 2, \dots, T$. The dependent variable y_t is a scalar, and $x_t = (x_{1t}, \dots, x_{mt})$, is a $(m \times 1)$ vector of independent variables. $d(t)$ is a deterministic function of t that can be approximated using the following Fourier expansion with a single-frequency component:

$$d(t) = \alpha_0 + \gamma_k \sin\left(\frac{2\pi kt}{T}\right) + \delta_k \cos\left(\frac{2\pi kt}{T}\right) \quad (2)$$

where α_0 represents the traditional deterministic term, including a constant with or without a linear term, T shows the number of observations, and k represents the Fourier frequency, the values of which are selected using the value that minimizes the sum of squared residuals (SSR). When $\gamma_k = \delta_k = 0$, there is no nonlinear trend, and the traditional Engle-Granger cointegration test emerges.

We obtain the following equation when we implement Function (2) in Model 1:

$$y_{1t} = \alpha_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + \beta' y_{2t} + u_t \tag{3}$$

To test the null hypothesis of no cointegration, we apply the augmented Dickey–Fuller unit root test to the residuals of Model 3. Hence, we estimate the following autoregression:

$$\Delta \hat{u}_t = \rho \hat{u}_{t-1} + \sum_{i=1}^p \gamma_i \hat{u}_{t-i} + \varepsilon_t \oplus \tag{4}$$

where $\varepsilon_t \sim i.i.d.(0, \sigma^2)$, we let τ_{FEG} show the t-statistics for the null hypothesis of no cointegration, $H_0 : \rho = 0$, which is computed as:

$$\tau_{FEG} = \frac{\hat{\rho}}{se(\hat{\rho})} \tag{5}$$

where $\hat{\rho}$ denotes the ordinary least squares estimator of ρ while $se(\hat{\rho})$ is the standard error of $\hat{\rho}$.

The critical values for the Fourier cointegration test (FEG) are obtained via simulations considering a different number of regressors ($n = 1, 2, 3$) and frequency values ($k = 1, 2, 3, 4, 5$). We report them in Table A1, considering that both constant and constant and trend cases for the sample sizes are $t = 100, 500$, and 1000 . As shown in Table A1, the asymptotic distribution of the test statistic depends on the frequency (k) and number of regressors (n), while, ceteris paribus, an increase in k and/or n creates a decrease in critical values. We also present the finite-sample properties of the FEG test in Table A2, which shows that the test has small size distortions and good power properties in the presence of breaks.

4. Results

To apply the FEG cointegration test, the series must be integrated at one. Therefore, as a first step in the analysis, we test the integration levels of the variables using augmented Dickey-Fuller (ADF) and Zivot-Andrews (ZA) unit root tests. Table 2 presents the results of the unit root tests.

Table 2. Results of Unit Root Tests.

Series	ADF Unit Root Test	Zivot-Andrews Unit Root Test	
	Test Statistics	Test Statistics	Break Date
LEC	−2.231 (0.198) [7]	−4.267 [1]	1976
LFPP	−0.363 (0.908) [2]	−3.242 [2]	1978
LGDP	−2.598 (0.1) [5]	−3.974 [2]	1981
LTO	−1.211 (0.664) [0]	−3.734 [0]	1992

Note: Numbers in parentheses show p -values, and numbers in brackets show optimal lag lengths. The critical value of the ZA test at the 10% level is -4.82 .

The results in Table 2 indicate that all of the series of interest have a unit root. As the variables have a unit root, we then applied the FEG cointegration test to test the long-run relationship between the variables. By using SSR, we found the optimal frequency to be 1, and the test statistic as -4.801 , which is statistically significant at the 10% level. Thus, we

conclude that there is long-term relationship between the variables. Next, we estimated the long-run coefficients using the fully modified ordinary least squares (FMOLS):

The results in Table 3 indicate that all regressors in the long-run model have a significant effect on the FGF.

Table 3. The FMOLS Results.

Variable	Coefficient
C	2.219 (1.501)
LEC	0.835 (4.626) *
LGDP	−0.753 (−3.138) *
LTO	−0.418 (−7.961) *

Note: * denotes significance at the 1% level. The numbers in parentheses show t-statistics.

5. Discussion

The results obtained can be evaluated from two different perspectives. The first is the unit root test, which was implemented to reveal the integration levels of the variables showing that the FGF series has a unit root; that is, the effect of a shock to these variables will be permanent; and the implemented policies would be effective and long-lasting. This finding is in line with [4], who also found the FPF to be nonstationary for the USA, and [35], who found strong evidence of a unit root in FPF for 89 nations. Second, we determined the factors that are influencing the FPF using a new Fourier cointegration test. The results indicate a long-run relationship between the FPF and energy consumption, gross domestic product, and trade openness. The long-run coefficients demonstrate that energy consumption has a detrimental effect on the FPF. A 1% increase in energy consumption causes the FGF to increase by 0.835%. For sustainable economic growth, the increase in energy consumption cannot be stopped. In 2018, renewable energy consumption and fossil fuel (oil, natural gas, and coal) shares in primary energy consumption were 19% and 53%, respectively, in Brazil (see BP [49]), indicating that an increase in energy consumption will have a detrimental effect on the environment because the share of fossil fuel consumption is higher than that of renewable energy consumption. In addition, 16.583×10^3 tonnes of oil equivalent (TOE) was consumed in 2009 for energy use, whereas in 2018, this quantity increased by 16.758×10^3 TOE, showing that the amount of wood used for energy consumption increased over the ten-year period. These results confirm the findings of Arouri et al. [50], Ilham [51], Chen et al. [52], Lu [53], and Adekoya et al. [54].

The coefficient of LGDP has a negative value; that is, the gross domestic product has a healing effect on FGF, that is, an increase in GDP improves the environment. This circumstance is intimately related to the Environmental Kuznets Curve. As income increases, awareness about the environment grows. Individuals demand enhanced ecological conditions, prompting governmental bodies to enforce policies and legislation aimed at mitigating contamination and facilitating a shift towards more sustainable technological advancements. As FGF is a consumption-oriented index, the healing effect of GDP indicates that consumers might lean towards recycling. A 1% increase in LGDP causes a 0.753% decrease in FGF. This result supports the findings of Chandran and Tang [55], Dogan and Turkekul [56], Osuntuyi and Lean [57], and Jahanger et al. [58].

Trade openness has a decreasing effect on LFPF. If there is a 1% increase in trade openness, the FPF decreases by 0.418% in Brazil, which suggests that trade liberalization mitigates environmental contamination by delegating manufacturing processes to foreign nations that boast eco-friendly technologies that are capable of suppressing emissions. Such a deleterious outcome conveys that the nation in question reaps the benefits of unfettered commerce, while concurrently enhancing ecological standards (see Dada et al. [59]). This result is in line with Destek and Sinha [60], who found that trade openness has a diminishing effect on the ecological footprint. These results support the findings of Liu et al. [61], Ozturk et al. [22], Khan et al. [62], and Yao et al. [63], but are contrary to the findings of Kongbuamai et al. [64], and Dada et al. [59].

6. Conclusions

This study considered a consumption-oriented environmental degradation indicator, the forest grounds footprint (FGF), and aimed to examine the determinants of the index in Brazil from the 1965 to 2018 period. The examination was conducted by proposing a new cointegration test that allowed multiple smooth breaks in the long-run relationship. Because this test was an augmentation of the traditional Engle-Granger cointegration test with a Fourier function, we called this test the Fourier Engle-Granger (FEG) cointegration test. Owing to the FEG cointegration test, we do not need to know the exact location, form or number of breaks a priori. The suggested test can prevent the potential loss of power in the cointegration tests that allow structural breaks by adding dummy variables to the testing equations. The simulation results show that the FEG test has small size distortions and good power properties, especially in the presence of breaks.

The results of the FEG cointegration test revealed a long-term relationship between the forest grounds footprint and gross domestic product (GDP), energy consumption, and trade openness (TO). The coefficients of long-run estimation show that energy consumption has an increasing effect on FGF, whereas GDP and TO have a decreasing effect on FGF. Therefore, policymakers in Brazil should consider increasing international trade to protect environmental quality. In addition, energy consumption should be diversified, and the intensity of energy consumption should be shifted to clean energy. Moreover, economic growth should be maintained through current components.

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Data Availability Statement: The data can be obtained from the databases of the Global Footprint Network, British Petroleum, and the World Bank.

Conflicts of Interest: The author declares that they have no conflict of interest.

Appendix A. Size and Power Properties

We analyzed the finite sample properties of the suggested test by considering the following data generation process (DGP):

$$\Delta y_{1t} = \alpha_0 + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + \delta_1(y_{1,t-1} - \beta y_{2t}) + \phi_1 \Delta y_{2t} + \varepsilon_{1t},$$

$$\Delta y_{2t} = \psi' \Delta y_{2t-1} + \varepsilon_{2t},$$

$$\Omega = E(\varepsilon_t \varepsilon_t') = \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{21} & \sigma_2^2 \end{bmatrix}.$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})$, $\sigma_1^2 = \sigma_{\Delta y_{1t}}^2$ and $\sigma_2^2 = \sigma_{\Delta y_{2t}}^2$. We assume that $\beta = 1$ and $\sigma_{12} = \sigma_{21} = \theta$. Similar DGPs have been used in several prior studies [see Banerjee et al. [65], Lee et al. [66], Banerjee et al. [67], among others.]. We conducted simulations using 20,000 replications at the 5% significance level. We examined the performance of the test from different perspectives:

- we let the persistent measure ψ change in the range $\{0, 0.9\}$;
- we set $\sigma_1^2 = 1$, while letting the σ_2^2 vary along with $\{1, 16\}$; and,
- we also evaluated two sets of γ_1 , and γ_2 as $\gamma_1 = \{0, 3\}$ and $\gamma_2 = \{0, 5\}$.

We report the results in Table A1.

Table A1. Finite Sample Performance of the FEG Cointegration Test.

ψ	σ_2^2	γ_1	γ_2	Model with a Constant				Model with a Constant and a Trend			
				$T = 100$		$T = 300$		$T = 100$		$T = 300$	
				$\delta_1 = 0.0$	$\delta_1 = -0.1$	$\delta_1 = 0.0$	$\delta_1 = -0.1$	$\delta_1 = 0.0$	$\delta_1 = -0.1$	$\delta_1 = 0.0$	$\delta_1 = -0.1$
0	1	0	0	0.053	0.233	0.053	0.761	0.048	0.101	0.053	0.609
0	16	0	0	0.052	0.234	0.051	0.758	0.051	0.099	0.049	0.607
0.9	1	0	0	0.045	0.175	0.039	0.755	0.049	0.096	0.045	0.594
0.9	16	0	0	0.046	0.173	0.038	0.753	0.050	0.095	0.043	0.598
0	1	3	0	0.066	0.214	0.053	0.816	0.048	0.097	0.053	0.646
0	16	3	0	0.066	0.217	0.051	0.815	0.051	0.098	0.049	0.646
0.9	1	3	0	0.060	0.219	0.039	0.807	0.049	0.089	0.045	0.634
0.9	16	3	0	0.059	0.220	0.038	0.807	0.050	0.091	0.043	0.640
0	1	0	5	0.053	0.677	0.053	1	0.048	0.163	0.053	1
0	16	0	5	0.052	0.677	0.051	1	0.051	0.164	0.049	1
0.9	1	0	5	0.045	0.638	0.039	1	0.049	0.166	0.045	1
0.9	16	0	5	0.046	0.640	0.038	1	0.050	0.172	0.043	1
0	1	3	5	0.053	0.517	0.053	1	0.048	0.117	0.053	1
0	16	3	5	0.052	0.521	0.051	1	0.051	0.117	0.049	1
0.9	1	3	5	0.045	0.429	0.039	1	0.049	0.105	0.045	1
0.9	16	3	5	0.046	0.430	0.038	1	0.050	0.109	0.043	1

Note: $\delta_1 = 0.0$, and $\delta_1 = -0.1$ represents the size, and power properties, respectively.

The results show that, as the sample size increases, the power of the test also increases (the conventional Engle-Granger [42] cointegration test loses power and suffers from size distortions in the presence of breaks. The results are available from the author upon request). In addition, in the case of $\gamma_1 \neq \gamma_2 \neq 0$, when the magnitude of the break increases, the power of the FEG test increases and becomes 1 in most cases. When the persistent measure ψ increases, the power of the test seems to decrease in the case of $\gamma_1 = \gamma_2 = 0$. In this case, an increase in σ_2^2 causes an increase in the power of the test in most cases. Overall, the test seems to have small size distortions and good power properties with regard to the existence of breaks.

Appendix B. Critical Values

Table A2. Critical Values of the FEG Cointegration Test.

<i>n</i>	<i>k</i>	Model with a Constant									Model with a Constant and Trend								
		<i>T</i> = 100			<i>t</i> = 500			<i>t</i> = 1000			<i>T</i> = 100			<i>t</i> = 500			<i>t</i> = 1000		
		1%	5%	10%	1%	5%	10%	1%	5%	10%	1%	5%	10%	1%	5%	10%	1%	5%	10%
1	1	−4.906	−4.302	−3.988	−4.756	−4.198	−3.898	−4.738	−4.175	−3.886	−5.354	−4.731	−4.423	−5.128	−4.576	−4.293	−5.074	−4.555	−4.274
	2	−4.665	−3.995	−3.648	−4.517	−3.912	−3.589	−4.503	−3.898	−3.579	−5.243	−4.582	−4.250	−4.995	−4.433	−4.136	−4.973	−4.410	−4.119
	3	−4.437	−3.743	−3.380	−4.333	−3.685	−3.349	−4.314	−3.686	−3.342	−5.002	−4.340	−3.997	−4.801	−4.230	−3.910	−4.804	−4.208	−3.901
	4	−4.285	−3.599	−3.252	−4.183	−3.554	−3.231	−4.172	−3.546	−3.221	−4.849	−4.175	−3.827	−4.697	−4.092	−3.767	−4.693	−4.088	−3.769
	5	−4.190	−3.520	−3.187	−4.091	−3.478	−3.165	−4.081	−3.477	−3.165	−4.774	−4.086	−3.739	−4.634	−3.997	−3.683	−4.593	−3.994	−3.677
2	1	−5.282	−4.655	−4.337	−5.067	−4.511	−4.220	−5.048	−4.487	−4.205	−5.641	−5.026	−4.705	−5.404	−4.855	−4.571	−5.367	−4.826	−4.550
	2	−5.168	−4.526	−4.189	−4.969	−4.394	−4.085	−4.949	−4.371	−4.065	−5.598	−4.954	−4.633	−5.329	−4.772	−4.480	−5.295	−4.748	−4.460
	3	−4.958	−4.283	−3.938	−4.804	−4.183	−3.870	−4.778	−4.172	−3.852	−5.450	−4.781	−4.436	−5.199	4.620	−4.313	−5.167	−4.597	−4.292
	4	−4.805	−4.122	−3.767	−4.647	−4.048	−3.722	−4.657	−4.040	−3.716	−5.294	−4.622	−4.271	−5.089	−4.487	−4.183	−5.065	−4.469	−4.158
	5	−4.708	−4.033	−3.689	−4.587	−3.964	−3.633	−4.536	−3.935	−3.629	−5.203	−4.508	−4.164	−5.006	−4.404	−4.086	−4.945	−4.370	−4.063
3	1	−5.596	−4.957	−4.640	−5.354	−4.796	−4.512	−5.315	−4.786	−4.497	−5.941	−5.294	−4.971	−5.638	−5.094	−4.814	−5.602	−5.070	−4.795
	2	−5.573	−4.918	−4.593	−5.330	−4.752	−4.460	−5.286	−4.727	−4.435	−5.926	−5.278	−4.961	−5.635	−5.078	−4.791	−5.590	−5.048	−4.762
	3	−5.393	−4.733	−4.394	−5.177	−4.597	−4.285	−5.150	−4.582	−4.277	−5.792	−5.141	−4.806	−5.515	−4.964	−4.659	−5.504	−4.940	−4.643
	4	−5.271	−4.605	−4.252	−5.071	−4.468	−4.148	−5.035	−4.134	−4.455	−5.698	−5.023	−4.681	−5.441	−4.843	−4.534	−5.404	−4.835	−4.529
	5	−5.155	−4.478	−4.127	−4.976	−4.378	−4.056	−4.959	−4.352	−4.042	−5.601	−4.905	−4.560	−5.361	−4.752	−4.436	−5.332	−4.743	−4.435

Note: *n*, *k*, and *T* show the number of independent variables, the number of frequencies of the Fourier function, and the sample size.

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