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**Article**

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# The Nexus among Civil Aviation, Energy Performance Efficiency and GDP in terms of Ecological Footprint: Evidence from France and Finland

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**ABSTRACT**

The major goal of this research paper is to determine the long-run linkage among variables and the impact of civil aviation, energy productivity (efficiency), economic growth (GDP), on ecological footprint through conducting the multivariate regression method, Phillips-Ouliaris and Engle-Granger, Jarque-Bera Normality, and Cusum tests from 1970 to 2020. According to results of multivariate regression method, civil aviation, energy efficiency, and economic growth affect the ecological footprint from 1970 to 2020 in France which is coincide with Phillips-Ouliaris and Engle-Granger tests. On the contrary, there is no effect of independent variables on dependent variable (ecological footprint) in Finland which is consistent with Phillips-Ouliaris and Engle-Granger tests. In this respect, The long-run relation of the model is verified by the cointegration test of Engle-Granger and Phillips-Ouliaris for France. However, there is no long-run co-integration among variables for Finland from 1970 to 2020. To sum up, empirical results of France is verified EKC hypothesis. However, EKC hypothesis is not verified for Finland.

**Keywords:** Civil Aviation, Energy Efficiency, Economic Growth, Ecological Footprint, Multivariate Regression
**JEL Classifications:** L93, P18, O47, Q57, C22, C31, C32

## 1. INTRODUCTION

Air transportation, which is a sub-sector of the transportation sector, has gained a strategic importance in recent years. Air transportation, which also directs other sectors in terms of national economy, tends to develop continuously with its technology and labor-intensive structure. In parallel with this development, airline companies are also considered as important companies through a global organizational structure. Especially, the airline industry is a highly competitive industry. In addition to this feature, the heterogeneous nature of the airline passenger market necessitates the management of airline companies to be consistently successful.

Energy efficiency is a key issue for the energy policies of most industrialized countries, due to its central role in economic, technological and social growth. Considering the high need for energy resources, the importance of environmental sustainability and the economic downturn, the prospects for progress in energy efficiency are increasing day by day.

Energy efficiency is taken into account as a fundamental element to achieve environmental targets, optimize expenditures in order to meet energy requirements, and achieve adequate energy security levels. The air transport industry is one of the fastest growing industries today. In this context, the far-reaching effects at local, regional and global levels increase as well (De Rubeis et al., 2016).

Increasing demand for air transport paves the way for growth in the aviation industry. This phenomenon increases the need for airports and encourages the growth of existing airports or the construction of new ones. With rising demands and capacity increases, airports that serve more flights make it difficult to realize the concept of sustainable development by exposing the environment to more carbon dioxide emissions. Sustainability can be expressed as the ability to survive, endure and "sustain." The quality that an item, system, or process has over time. In economics, this quality will be given by the capacity to provide profitability, benefit, although very limited or limited understanding. Sustainability, in a broader context, means meeting our present needs without compromising the ability of future generations to meet their needs, i.e. using resources responsibly to achieve the ever-challenging balance between economic growth, environmental care and social well-being (García and Sanz, 2018).

Airports are investments that consume a lots of energy and power both in the construction phase and in the operation phase. This is mainly due to the high power demand for large buildings (both passenger terminals and non-passenger areas) equipped through the heating air-conditioning systems, for lighting the electrical equipment, and the energy requirements from the many facilities located inside. Approximately 70% of the energy consumed in airport terminal buildings is executed for air conditioning, cooling and heating purposes. In countries with a cold climate, this rate may be higher. In addition to providing the electrical energy necessary to assist air transport operations, electrical energy is also needed for airport buildings, aircraft hangers and other airport facilities. Therefore, energy management including heating, ventilation, air conditioning and lighting is extremely critical for airports (Baxter et al., 2019).

The main objective of this manuscript is to contribute to the academic literature in terms of several issues which is illustrated respectively. This manuscript concantrate on civil aviation, energy performance efficiency, economic growth, and environmental pollution in order to summarize a literature review.

The main questions of interest are whether civil aviation, economic growth, and energy activities enhance the ecological footprit among France and Finland. If it is proven empirically that all these activities cause environmental pollution, various implemented policies will be presented in the conclusion part of the article. Although the causal linkage among GDP and civil aviation has been studied before, the core contribution of this reseach is to examine this linkage combining it with the degree of energy efficiencey and ecological footprint.

The remainder of the manusript is organised as follows. Part 2 presents a brief literature review. Part 3 describes the data and the methodology of the paper. Part 4 discusses the empirical findings, and concludes by providing some suggestions to policy makers in both France and Finland within the context of EKC hypothesis.

## 2. LITERATURE REVIEW

A remarkable part of academic literature has investigated various features of the effect of civil aviation on environmental pollution. In this sense, recent academic research regarding the relationship between air transport, economic growth, and environmental pollution (Eğilmez, 2020; Erdogan et al., 2020; Gyamfi et al., 2022; Kalayci and Özden, 2021; Kalayci and Yazici 2016; Ozkan et al., 2019; Ozturk et al., 2021; Sohail et al., 2021; Yazici, 2022) have suggested that reducing the existence of dirtiness is so vital in terms of protecting the environment which is mostly depend on the government policies and economic sanctions.

Altuntaş and Kılıç (2021) investigate the relationship between total airline passenger, freight traffic and Gross Domestic Product (GDP) for Turkey by implementing ARDL and Toda Yamamoto methods. According to the findings of the study, there is a cointegrated relationship between air transportation and GDP. In the study, while no statistically significant effect of freight traffic on economic growth is found in the long term, it was concluded that passenger traffic had an increasing effect on economic growth in the short term. The study also demonstrated that there is a bi-directional causality relationship between passenger traffic and GDP.Kiraci (2018) examines the relationship between air transport demand and GDP in Turkey through performing the Toda-Yamamoto and Hatemi-J methods, and it is concluded that there is a significant causality relationship between the demand for air transport and economic growth from 1960 to 2015.

Balsalobre-Lorente et al. (2021) apply non-parametric causality test to establish a causality network with the latest asymmetric autoregressive distributed latency methodology by using the data for the period 1970–2015 in Spain. In the study, it is concluded that air transport, urbanization process and social globalization have positive and important effects on economic growth.

Zhang and Graham (2020) elaborate the relationship between economic development and air transport by implementing the Granger causality test based on regionally developed and underdeveloped countries. As a result of the research, it was determined that economic growth increased the demand for air transportation. In this regional research, it has been seen that while air transport and economic growth affect each other in underdeveloped countries, air transport increases economic growth and employment in developed countries.

Habib et al. (2022) analyze the heterogeneous effect of civil aviation activities on $CO_2$ emissions in G20 economies from 1990 to 2016. In this context, the manusript performs advanced fixed-effect panel quantile regression that takes into account the distributional heterogeneity and unobserved discrete. According to empirical findings, the effect of the civil aviation activities on $CO_2$ emissions is quite heterogeneous. In other words, the impact of air freight, air passenger, and air transport intensity, on $CO_2$ emissions is positive and becomes more assertive through the rising the trend at upper quantiles and is pretty heterogeneous towards all quantiles.

Adedoyin et al. (2021) illustrate the relationship between air transport, renewable and non-renewable energy consumption, and economic growth from 1995 to 2016 by using sys-GMM method for low-income, upper-middle-income, and high-income economies. According to their findings, GDP contributes to the high carbon contents across the income group notably for low-income, upper-middle-income and high-income group; the impact of air transport on $CO_2$ emission is positive for lower-middle-income and high-income group and negative for the upper-middle-income group; the use of coal rents and energy consumption leads to high release of $CO_2$ emissions including the all the income groups; and an important boost in the utilization of energy leads to rise in carbon contents except for lower-income group.

Ali et al. (2022) reveal the relationship between energy efficiency, economic growth, industrial improvement, air transportation, and ecological footprint from 1983 to 2016 through ARDL model. Their emprical findings of research ascertain that economic complexity in China had been found to have a statistically crucial effect on the country's ecological footprint. Furthermore, the industrial improvement process contributes the ecological footprint in China. Especially, in the short term, air transport has a negative effect on the environment, but this impact diminishes over time. Finally, energy efficiency is negative and substantial both in the short and long run, thus demonstrating its positive role in decreasing the ecological footprint.

Simões and Schaeffer (2005) examine the participation of Brazilian air transportation within the sense of global climate change. It first shortly presents an inventory of $CO_2$ emissions caused by airborne activities in Brazil and then illustrates a trend projection through to 2023, demonstrating the progress of these emissions, through possible mitigation strategies. The abatement potential for each of these strategies is examined as well. It is forecasted that joint application of all these strategies within a typical projection of sustainability could result in a yearly decrease in carbon intensity caused by civil aviation in Brazil up to 28.5%.

It is also forecasted that the carbon contents abstained with a joint application of the mitigation alternatives analyzed may well reach 82,000 Gg (or 109 g) of $CO_2$ from 2003 through 2023.

Polloni-Silva et al. (2021) examine the relationship between environmental pollution and economic growth, population, energy intensity, industry and service sector for 27 states of Brazil between 2006 and 2015. As a result of the study carried out to determine the regional differences within the country, it has been determined that the economic growth and population in the rich and low-income regions have a positive effect on environmental pollution. In addition, it has been concluded that the increase in energy intensity in Brazil causes environmental pollution.

Efeoğlu and Pehlivan (2018) examine the effect of energy consumption on economic growth in Turkey and determine that there is a positive relationship between the existing variables. Yaniktepe et al. (2021) reveal that there is a positive linkage between energy consumption and economic growth in Turkey which verifies the EKC hypothesis.

Ozturk and Acaravcı (2010) study the long-run relationship between economic growth, carbon emissions, energy consumption and employment rate for Turkey from the period 1968 to 2005. ARDL boundary test results show the existence of a long-run relationship, the Granger causality test results show that there is no causal relationship between per capita carbon emissions and per capita energy consumption and real GDP per capita.

Wu et al. (2021) determine that the change in renewable energy and fossil energy intensity for 18 developed countries is so crucial in terms of reducing environmental pollution from the period 2005 to 2016. In addition, it has been concluded that there is no effect of industrial structure and economic growth on environmental pollution.

Neagu and Teodoru (2019) elaborate the long-term relationship between economic complexity, energy consumption and greenhouse gas emissions. In this context, the energy consumption, economic complexity index and greenhouse gas emissions (thousand tons) data is used for 25 EU member countries from the period 1995 to 2016. Countries are divided into two as high economic complexity and low economic complexity through three panels by using panel cointegration test, DOLS, FMOLS and panel causality test. As a result of the research, it was revealed that economic complexity and energy consumption had a significant impact on greenhouse gas emissions in all three panels.

Zhao et al. (2022) investigate Household $CO_2$ (HECs) emissions in 30 provinces of China between 2000 and 2018 by using the STIRPAT model. In the study, it was emphasized that environmental pollution tends to increase in all provinces and Guandong, Shandong and Hebei provinces cause the most environmental pollution. In the study, it was concluded that economic growth had a positive effect on environmental pollution in provinces except Shanghai and Gansu. In the study, it has been evaluated that 40% of the national household $CO_2$ emissions in the country are caused by Guandong, Jiangsu, Hebei, Henan, Zhejiang, Anhui provinces. For this reason, the policies to reduce environmental pollution to be applied for these provinces are nationally so significant.

Okumuş and Bozkurt (2020) analyze the relationship between economic growth and environmental pollution in the context of the environmental Kuznets curve hypothesis from 1980 to 2013 for different income groups. In the analysis, per capita income, energy consumption, openness ratio, urbanization and carbon emission as the dependent variable were used as explanatory variables. A dummy variable is used for the environmental impact of the Kyoto Protocol. According to the results obtained, while the validity of the EKC hypothesis was confirmed in high-middle-income and low-middle-income country groups, it is not confirmed for developed and less-developed country groups. The coefficient of energy consumption in countries is positive and statistically significant. While trade liberalization increases carbon dioxide emissions in underdeveloped and low middle-income countries, it reduces carbon dioxide emissions in high-middle-income countries. While an increase in urbanization reduces carbon dioxide emissions in developed and underdeveloped country groups, it increases carbon dioxide emissions in high-middle income and low-middle income groups. The coefficient of the Kyoto dummy variable is negative in developed countries and positive and statistically significant in low-middle income countries. Qudrat-Ullah and Nevo (2021) elaborate the impact of renewable energy consumption and environmental sustainability on economic growth for 37 African countries. The GMM estimation technique is determined that renewable energy consumption, environmental sustainability, and economic growth have a positive relationship in both the short and long run. Ucan et al. (2014) examine the relationship between renewable energy consumption and economic growth in fifteen European Union (EU) countries for the period 1990–2011. In the study, the Panel Granger causality test method is used and the econometric model is established by determining the renewable energy consumption, non-renewable energy consumption, economic growth and gas emission variables. According to the findings, there is a causal relationship between renewable energy consumption and economic growth.

## 3. DATA AND METHODOLOGY

The major goal of this research paper is to determine the impact of civil aviation, economic growth (GDP), energy productivity (efficiency) on ecological footprint. In this sense, air transport, enerygy efficiency, GDP and ecological footprint data of France and Finland between 1970 and 2020 are analyzed by performing multivariate regression method, Phillips-Ouliaris and Engle-Granger, and Cusum tests. The data of civil aviation, and GDP are derived from World bank (2022a), and World bank (2022b) which are determined as independent variables. The data of ecological footprint is obtained from Global Footprint Network (2022) which is determined as dependent variable. Finally, the data of energy productivity is collected from Eurostat (2022)'s official website which is determined as independent variable. The data from 1970 to 2020 are taken to measure the impact of France and Finland's GDP, air transport volume and energy efficiency on the ecological footprint, by considering the sample size as more than 30 n > 30 in order to make it a parametric test.

The logarithms of the data of all variables were taken, respectively. The reason for taking the logarithm of the data is to provide easier linear distribution of them and to prevent variance explosion. Then, the @trend and error terms to detect whether there is spurious regression between the variables and the AR(1) command to find out if the residuals are randomly distributed which is added to the model. Since the result of @trend was >0.05. Thus, it is determined that there was no spurious regression between the variables.

On the other hand, according to Figure 1 and 2. (Autocorrelation Graph of France and Finland), the residuals are distributed randomly in the circle which indicates that there is no autocorrelation problem. The other indicator of the existance of autocorrelation problem or not is Durbin-Watson stat. The score should be around 1.30 > 2.70. According to Table 1. The result of Durbin-Watson is 2.25 which is demonstrate that there is no autocorrelation problem due to its optimal position (Table 2).

According to results of multivariate regression method at Table 1, civil aviation, energy efficiency, and economic growth affect the ecological footprint from 1970 to 2020 in France which is coincide with Phillips-Ouliaris and Engle-Granger tests at Tables 3-6. Probability is obtained as "0.0412" for civil aviation, "0.0000" for energy efficiency and "0.0163" for economic growth. On the contrary, there is no effect of independent variables on dependent variable (ecological footprint) in Finland at Table 2.

Probability is obtained as "0.6796" for civil aviation, "0.3133" for energy efficiency and "0.2267" for economic growth for Finland which is consistent with Phillips-Ouliaris and Engle-Granger tests at Tables 7 and 8.

Phillips-Perron and ADF unit root tests are performed at Table 3. In order to select whether series are stationary or not within this sense. Besides, Phillips-Ouliaris and Engle-Granger tests are used to comprehed the long-run co-integration between civil aviation, economic growth (GDP), energy productivity (efficiency) and ecological footprint. The ecological footprint is determined as dependent variable and the remaining of them are selected as independent variables containing civil aviation,

**Figure 1:** Autocorrelation graph of France

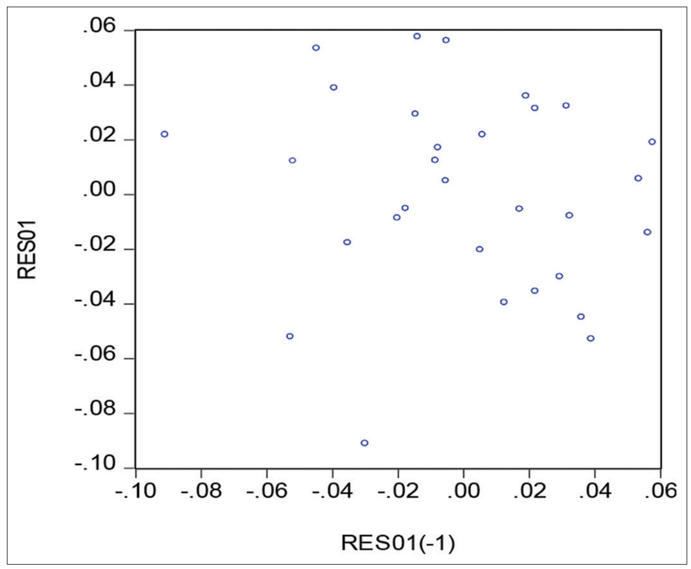



**Figure 2:** Autocorrelation graph of Finland

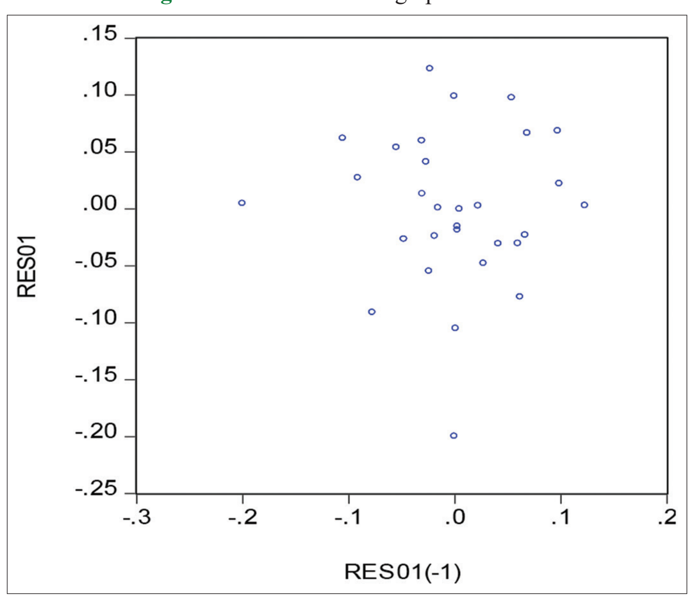


**Table 1: Results of multivariate regression for france**

| Dependent Variable: ECOL_FOOT, Sample: 1970 2020 | | | | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **SE** | **t-Statistic** | **Prob.** |
| CIVIL_AV | 0.044317 | 0.083318 | 0.531904 | 0.0412 |
| ENERGY_PRO | –0.171223 | 0.397679 | –0.430556 | 0.0000 |
| GDP | 0.151484 | 0.084362 | 1.795645 | 0.0163 |
| C | 14.91954 | 3.192485 | 4.673331 | 0.0000 |
| @Trend | –0.006173 | 0.007853 | –0.786161 | 0.4395 |
| AR (1) | 0.541496 | 0.207562 | 2.608836 | 0.0154 |
| R-squared | 0.970261 | Mean dependent var | 19.56917 | |
| Adjsted R-squared | 0.887827 | S.D. dependent var | 0.061835 | |
| F-statistic | 8.130823 | Durbin-Watson stat | 2.259675 | |

ln (Econ_foot) t = α0 + α1 ln (Civil_av) t + α2 ln (EP) t + α3 ln (GDP) t+et (1)

**Table 2: Results of multivariate regression for Finland**

| Dependent Variable: ECOL_FOOT, Sample: 1970 2020 | | | | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **SE** | **t-Statistic** | **Prob.** |
| CIVIL_AV | 0.008675 | 0.188382 | 0.046051 | 0.6796 |
| ENERGY_PRO | 0.467143 | 0.362922 | 1.287173 | 0.3133 |
| GDP | 0.297431 | 0.239735 | 1.240662 | 0.2267 |
| C | 8.942553 | 6.398425 | 1.397618 | 0.1750 |
| @Trend | –0.013971 | 0.014239 | –0.981128 | 0.3363 |
| AR (1) | 0.586025 | 0.289930 | 2.021266 | 0.0545 |
| R-squared | 0.874857 | Mean dependent var | 17.32462 | |
| Adjsted R-squared | 0.768571 | S.D. dependent var | 0.101678 | |
| F-statistic | 5.408591 | Durbin-Watson stat | 2.010429 | |

ln (Econ_foot) t = α0 + α1 ln (Civil_av) t + α2 ln (EP) t + α3 ln (GDP) t+et (2)

**Table 3: PP unit root test of France and Finland**

| Countries | Variables | PP I (0) | PP I (1) | Decision |
|---|---|---|---|---|
| France | Civil_Av | *–1.5758 (–3.6701)* | *–4.2387* (–3.6793)* | *I (1)* |
| | Energy_Pro | *2.2234 (–3.6701)* | *–7.0664* (–3.6793)* | *I (1)* |
| | GDP | *2.3079 (–3.6701)* | *–4.5999* (–3.6793)* | *I (1)* |
| | Ecol_Foot | *–1.2263 (–3.6701)* | *–7.8613* (–3.6793)* | *I (1)* |
| Finland | Civil_Av | *–1.7371 (–3.6701)* | –4.1101* (–3.6793) | *I (1)* |
| | Energy_Pro | *0.1390 (–3.6701)* | *–11.6532* (–3.6793)* | *I (1)* |
| | GDP | *–0.6517 (–3.6701)* | *–4.6463* (–3.6793)* | *I (1)* |
| | Ecol_Foot | *–2.7968 (–3.6701)* | *–8.5943* (–3.6793)* | *I (1)* |

*and **symbols indicate the series of findings in terms of unit root test which is performed in the calculation, 1% and 5% significance levels, respectively

**Table 4: ADF unit root test of France and Finland**

| Countries | Variables | ADF UR Test I (0) | ADF UR Test I (1) | Decision |
|---|---|---|---|---|
| France | Civil_Av | *–1.5709 (–3.6701)* | *–4.3400* (–3.6793)* | *I (1)* |
| | Energy_Pro | *0.9832 (–3.6701)* | *–7.0817* (–3.6793)* | *I (1)* |
| | GDP | *–1.2067 (–3.6701)* | *–4.5859* (–3.6793)* | *I (1)* |
| | Ecol_Foot | *–0.6704 (-3.7114)* | *–7.9345* (–3.6793)* | *I (1)* |
| Finland | Civil_Av | *–1.7550 (–3.6701)* | *–5.6543* (-3.6998)* | *I (1)* |
| | Energy_Pro | *–0.2250 (–3.6701)* | *–6.6450* (–3.6793)* | *I (1)* |
| | GDP | *–0.6127 (–3.6701)* | *–4.6777* (–3.6793)* | *I (1)* |
| | Ecol_Foot | *–1.0163 (–3.6998)* | *–8.3288* (–3.6793)* | *I (1)* |

*and ** symbols indicate the series of findings in terms of unit root test which is performed in the calculation, 1% and 5% significance levels, respectively.

economic growth (GDP), energy productivity (efficiency) within the context of EKC hypothesis. Phillips-Perron PP (1989) test is implemeted at Table 4. To find out the structure of series in terms of its stationarity.

In several instances of the cointegration test, two approaches are widely used as statistically. The Engle-Granger test (Engle and Granger, 1987) and the test developed by Phillips-Ouliaris (Phillips and Ouliaris, 1990). The equations for Phillips-Ouliaris (1990) co-integration test are illustrated at (3), (4), (5), (6) and (7) below. According to Tables 5 and 6., there is a co-integration linkage between the variables. In other words, a long-term relationship was found between the variables for France from 1970 to 2020.

After applying the unit root test of the series, Phillips-Ouliaris (1990) co-integration test is performed in order to determine the long-term relationship between the series of variables. In the cointegration test, whether the values are statistically important at a certain level of significance and the null hypothesis of "no cointegrated vector" is tested. If the statistical value is significant, the null hypothesis of "no cointegrated vector" is rejected. It is concluded that the series are correlated in the long run for the France. Phillips-Ouliaris (1990) co-integration test is one of the crucial method performed to residuals, and it includes two test statistics, namely variance ratio test and multivariate trace test. The variance ratio test statistic "$\acute{P}_u$" is shown in equation (3).

$$P'\mu = \frac{T\acute{\omega}_{11.2}}{T^{-1}\sum_{t=1}^{T}\hat{\mu}_t^2} \quad (3)$$

The $\hat{\mu}_t$ shown in equation (3) which is the residual of the long-term regression equation.

$$Y_t = \beta x_t + u_t \quad (4)$$

$$\acute{\omega}_{12} = \acute{\omega}_{11} + \acute{\omega}_{21}^{\acute{y}}\Omega_{22}^{-1}\acute{\omega}_{21} \quad (5)$$

$$\Omega y_t = T^{-1}\sum_{t=1}^{t}\hat{\varepsilon}_t^{\acute{y}}\hat{\varepsilon}_t + T^{-1}\sum_{s=1}^{L}\omega_{s1}$$

$$T^{-1}\sum_{t=1}^{T}(\hat{\varepsilon}_t\hat{\varepsilon}_{t-s} + \hat{\varepsilon}_{t-s}\hat{\varepsilon}_t) \quad (6)$$

The variance ratio test is a residual-based model that the null hypothesis (H0), which is stated as there is no cointegration (Adesina, 2018). The null hypothesis can be expressed in terms of the conditional variance parameter

$\acute{\omega}_{11.2}$ in the following form. The hypotheses in the variance ratio test are:

$$H_0 : \acute{\omega}_{11.2} \neq 0 \qquad H_1 : \acute{\omega}_{11.2} = 0$$

The trace statistic defined as $\acute{P}_z$ is indicated in equation (7).

"T" is indicated in equation (7), as the number of observations.

$$\grave{}p_z = \mathrm{Ttr}(\grave{}\Omega M_{zz}^{-1}) \quad (7)$$

$M_{zz}^{-1} = T^{-1}\sum_{t=1}^{T} Z_t Z_t^{\acute{y}}$ and $\grave{}\Omega$ are estimated in the equation (7).

According to the Phillips-Ouliaris (1990) cointegration test results given in Table 7, both test statistical values, Tau statistic and Z statistic for all series, are statistically significant at one and 5% significance level. The long-run relationship of the models are verified by the cointegration test of Engle-Granger and Phillips-Ouliaris for France at Tables 5 and 6. which is consistent with multivariate regression model's results at Table 1.

**Table 5: Result of engle-granger co-integration test of france**

| Dependent Var. | tau-statistic | Prob.* | z-statistic | Prob.* |
|---|---|---|---|---|
| ECOL_FOOT | –8.848163* | 0.0000 | –42.05714* | 0.0000 |
| CIVIL_AV | –2.641467** | 0.0243 | –33.52813** | 0.0211 |
| ENERGY_PRO | –7.387527* | 0.0001 | –36.27852* | 0.0003 |
| GDP | –5.038346** | 0.0176 | –27.53631** | 0.0143 |

*and **: Indicates that the null hypothesis (H0) is rejected according to 1% and 5% significance levels

**Table 6: Phillips-Ouliaris co-integration results of France**

| Dependent Var. | tau-statistic | Prob.* | z-statistic | Prob.* |
|---|---|---|---|---|
| ECOL_FOOT | –8.745582* | 0.0000 | –43.54694* | 0.0000 |
| CIVIL_AV | –6.235401** | 0.0361 | –26.61201** | 0.0199 |
| ENERGY_PRO | –7.457296* | 0.0001 | –36.83664* | 0.0002 |
| GDP | –5.121958** | 0.0148 | –26.45478** | 0.0210 |

*and **: Indicates that the null hypothesis (H0) is rejected according to 1% and 5% significance levels

As can be seen from Tables 5 and 6, according to both Engle-Granger and Phillips Ouliaris cointegration test results, it seems that there is a long-term cointegration relationship between the variables. After that, at the next stage, it should be investigated whether the model has econometric problems or not. First, it is determined whether the model has a normal distribution or not. For this, the existence of the normal distribution of the model is tested by using the Jarque-Bera statistic. As seen in Figure 3, the Jarque – Bera statistic is "1.613211" and the P-value is "0.446371" Since the probability value is >0.05, the residuals have a normal distribution. Thus, both Engle-Granger and Phillips Ouliaris cointegration tests are verified as statistically.

Same econometrical procedures are applied for Finland as well. According to the results of both Engle-Granger and Phillips Ouliaris cointegration test results at Tables 7 and 8., it seems that there is no long-term cointegration relationship between the variables. After that, at the next stage, it should be investigated whether the model has econometric problems or not.

First, it is determined whether the model has a normal distribution or not. For this, the existence of the normal distribution of the

**Table 7: Result of Engle-Granger co-integration test of Finland**

| Dependent var. | Tau-statistic | Prob.* | z-statistic | Prob.* |
|---|---|---|---|---|
| ECOL_FOOT | –0.980483 | 0.9899 | –7.543121 | 0.8685 |
| CIVIL_AV | –1.535709 | 0.9954 | –8.180492 | 0.9613 |
| ENERGY_PRO | –0.921763 | 0.9947 | –7.543121 | 0.8942 |
| GDP | –0.941256 | 0.9992 | –7.543121 | 0.9360 |

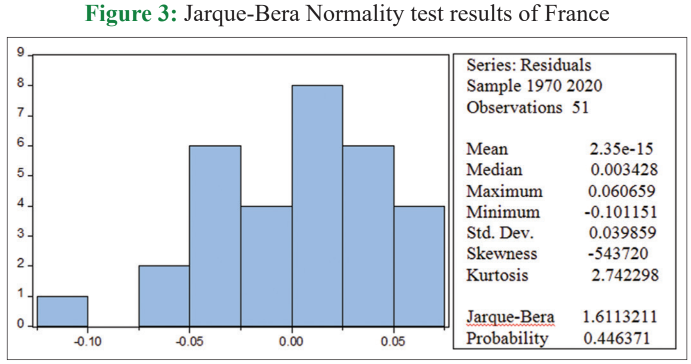
*and **: Indicates that the null hypothesis (H0) is rejected according to 1% and 5% significance levels

**Table 8: Phillips-Ouliaris co-integration results of Finland**

| Dependent var. | Tau-statistic | Prob.* | z-statistic | Prob.* |
|---|---|---|---|---|
| ECOL_FOOT | –0.961156 | 0.9267 | –6.924097 | 0.8736 |
| CIVIL_AV | –1.668943 | 0.9632 | –9.171350 | 0.9125 |
| ENERGY_PRO | –0.943267 | 0.9425 | –8.624067 | 0.8826 |
| GDP | –0.924579 | 0.9345 | –7.956793 | 0.9211 |

*and **: Indicates that the null hypothesis (H0) is rejected according to 1% and 5% significance levels

**Figure 3:** Jarque-Bera Normality test results of France



model is tested by using the Jarque-Bera statistic. As seen in Figure 4, the Jarque-Bera statistic is "2.320861" and the P-value is "0.313351" Since the probability value is >0.05, the residuals have a normal distribution. Thus both Engle-Granger and Phillips Ouliaris cointegration tests are verified as statistically.

To sum up, empirical results of France is verified EKC hypothesis within the context of multivariate regression method, Phillips-Ouliaris and Engle-Granger and Jarque-Bera Normality tests from 1970 to 2020. The independent variables including civil aviation, energy efficiency, and economic growth affect ecological footprint (dependent variable) at Table 1., and there is a stable relationship.

Among the variables at Tables 5 and 6. However, the independent variables do not affect the dependent variable for Finland from

**Figure 4:** Jarque-Bera normality test results of finland

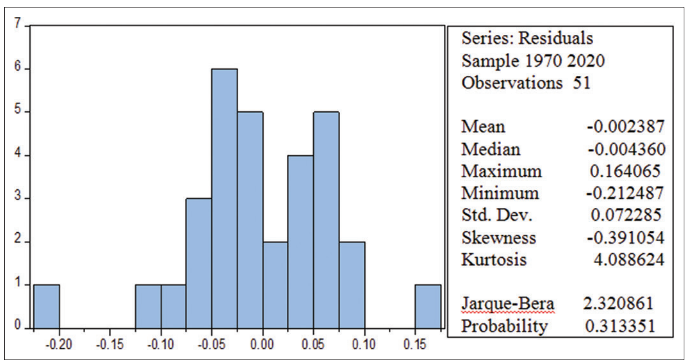



**Figure 5:** Cusum test for France

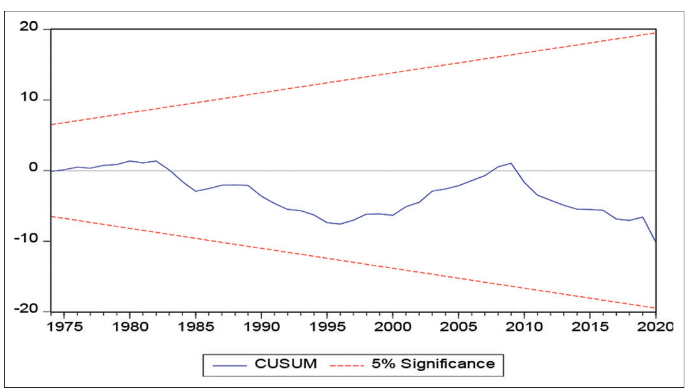
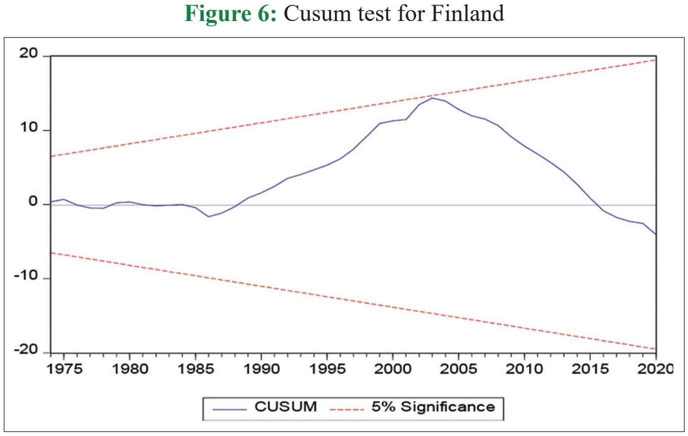



**Figure 6:** Cusum test for Finland




1970 to 2020 at Table 2. For this reason, The EKC hypothesis is not confirmed for Finland. On the other hand, Phillips-Ouliaris and Engle-Granger tests at Tables 7 and 8. for Finland from 1970 to 2020 indicate that there is no long-run relationship between variables. The results of both multivariate regression and Phillips-Ouliaris and Engle-Granger tests are consistent with eachother which proves that EKC hypothesis is not verified for Finland. In the economics literature, this issue has been discussed intensively, especially in recent years. When the novelties and contributions of this research paper to the academic literature are considered, time series models including multivariate regression, Phillips-Ouliaris, Engle-Granger tests reveal the long-term linkage among civil aviation, energy productivity (efficiency), economic growth (GDP), and ecological footprint from 1970 to 2020 for France. However, there is no long-run relationship between variables for Finland.

Cusum test is used to analyze the stability of the series in the long-term. There are two tests to investigate the stability of parameters. The test is developed by three researchers (Brown et al., 1975). The Cusum test relies on the cumulative sum of the recursive residuals.

The Cusum test ensures the pair of 5% critical lines at Figures 5 and 6. If the movement of expected value exceeded the critical line recommends instability. The findings indicate that the movement is inside the 5% significance critical lines recommend that the coefficients are stable in the sample period.

## 4. DISCUSSION AND CONCLUSION

The air transport sector has started to gain importance through the globalization process in the world economy which progresses rapidly. The importance of air transport in the globalizing world is increasing rapidly due to the contribution, opportunities and conveniences it provides. It is an undeniable fact that commercial activities between countries, travels for tourism, production techniques, and the increase in the desire to reach wider markets contribute to the increase in the demand for air passenger transportation. Aviation has become an indispensable choice for global business and tourism because it offers the only rapid transport network. Thermal solar energy systems are used less frequently than photovoltaic systems and generally in small airports. The main reason for this is that thermal solar energy systems are more expensive and are thought to be more suitable for residential uses. The use of solar energy at airports as an energy source both saves energy and contributes to reducing the environmental impact of airports. It is foreseen that the use of solar energy systems will become more widespread in other airports around the world in the future. Considering the environmental impacts of the aviation industry, this situation can be considered promising for a sustainable life around the world.

The development of the aviation industry, and especially the increase in the number of airports, has directed airports with high environmental impacts to alternative renewable energy sources within the scope of sustainable energy management. Today, a large number of airports use renewable energy systems and the most common examples are solar energy systems. Solar energy systems are used in airports in two different ways as photovoltaic systems or thermal solar energy systems. Photovoltaic systems can be preferred more by airports because they are both affordable and can produce high amounts of electrical energy. Photovoltaic solar in many airports while energy systems are used, it is seen that the number of airports operated entirely by solar energy is increasing day by day.

The long-run relation of the model is verified by the cointegration test of Engle-Granger and Phillips-Ouliaris for France which is confirm the EKC hypothesis. One of the main reasons for France's inability to achieve energy efficiency in terms of air transport is development of plans to improve the aerodynamic performance of aircraft and the inadequacy of applications for the use of biofuels. Besides, it can be considered that it is insufficient in collecting, analyzing and reporting data on the number of passengers and cargo per aircraft. As a matter of fact, France's highest administrative court, the Council of State, has fined the government a record 10 million Euros for failing to reduce air pollution to acceptable levels last year (2021).

The court stated that "if there is no action from the government in this regard within 6 months, it will be executed again". The court said that "it will re-examine air pollution levels in early 2022 and may impose a fine that is less or more depending on the outcome."

Unlike France, The Finnish government has developed programs to improve building energy efficiency in public institutions. In addition, the energy for heating and electrical energy consumption is reduced in public and municipal institutions. The energy efficiency strategies are applied in the airport by Finnish experts to reduce aircraft fuel consumption. In order to achieve this, it has developed applications for optimizing airport walking and taxiways.

The second important strategy of experts in terms of ensuring energy performance is the use of high efficiency aircraft engines. The third crucial strategy is developing applications to obtain maximum efficiency from daylight at the airport. Lastly, it has planned to improve fleet management and flight logistics through providing low carbon emissions. The policies implemented for energy efficiency overlap with the empirical findings of this article. As a result, Finland has built its energy efficiency strategy in terms of air transport and has served as a model to the world by providing the Kyoto Protocol' aims and goals.

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