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RESEARCH ARTICLE / ARASTIRMA MAKALESİ

## EKONOMİK BÜYÜME, DOĞAL KAYNAK RANTI VE YENİLENEBİLİR ENERJİ TÜKETİMİNİN YÜK KAPASİTESİ FAKTÖRÜ ÜZERİNE ETKİLERİ: SEÇİLMİŞ ASYA ÜLKELERİ ÜZERİNE PANEL AMPİRİK ANALİZİ

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### Özet

Çalışma, ekonomik büyüme, doğal kaynak rantı ve yenilenebilir enerji tüketimi gibi faktörlerin, 11 Asya ülkesinde daha yüksek çevresel sürdürülebilirliği gösteren yük kapasitesi faktörünü artırmaya katkıda bulunup bulunmadığını incelemeyi amaçlamaktadır. Çalışmada, 1990-2021 dönemine ait veriler kullanılmıştır. Ampirik analizlerde, panel kesit bağımlılık testleri, panel eğim homojenlik testleri, panel ikinci nesil birim kök testleri, eş bütünleşme testleri, panel kantil uzun dönem tahmin testleri ve panel nedensellik testleri gibi çeşitli panel ekonometrik yöntemler uygulanmıştır. Genel sonuçlar, ekonomik büyüme, doğal kaynak rantı ve yenilenebilir enerji tüketiminin, yük kapasitesi faktörünü artırarak hem ekonomik hem de çevresel sürdürülebilirliği sağlayabilen çevre dostu faktörler olduğunu göstermiştir. Çalışma ayrıca gelişmiş ülkelerin, panel grubundaki gelişmekte olan ülkelere çevresel ve ekonomik sürdürülebilirliği sağlamada yardımcı olabileceğini de ortaya koymuştur. Ayrıca çalışmada panel nedensellik testlerinden elde edilen sonuçlar, ekonomik büyümeden yük kapasitesi faktörüne ve yük kapasitesi faktöründen doğal kaynak rantına doğru tek yönlü nedensellik ilişkisini, yük kapasitesi faktörü ile yenilenebilir enerji tüketimi arasında ise çift yönlü nedensellik ilişkisini ortaya koymuştur. Çalışma, elde edilen genel bulguların değerlendirilmesiyle son bulmaktadır.

**Anahtar Kelimeler:** Ekonomik büyüme, doğal kaynak rantı, yenilenebilir enerji tüketimi, yük kapasitesi faktörü

**JEL Kodu:** C23, F64, O44, P18, P28

## THE EFFECTS OF ECONOMIC GROWTH, NATURAL RESOURCE RENT AND RENEWABLE ENERGY CONSUMPTION ON THE LOAD CAPACITY FACTOR: A PANEL EMPIRICAL ANALYSIS ON SELECTED ASIAN COUNTRIES

### Abstract

The study aims to examine whether factors such as economic growth, natural resource rents, and renewable energy consumption contribute to increasing the load capacity factor, which indicates greater environmental sustainability in 11 Asian Countries. Data covering the period 1990-2021 was used in the study. Various panel econometric methods were applied in the empirical analyses, including panel cross-section dependence tests, panel slope homogeneity tests,

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panel second-generation unit root tests, cointegration tests, panel quantile long-run estimation tests, and panel causality tests. The overall results indicate that economic growth, natural resource rents, and renewable energy consumption are environmentally friendly factors that can ensure both economic and environmental sustainability by increasing the load capacity factor. The study also revealed that developed countries can assist developing countries in the panel group in achieving environmental and economic sustainability. Furthermore, the results obtained from the panel causality tests revealed a unidirectional causal relationship from economic growth to the load capacity factor and from the load capacity factor to natural resource rent, and a bidirectional causal relationship between the load capacity factor and renewable energy consumption. The study ends with the evaluation of the general findings.

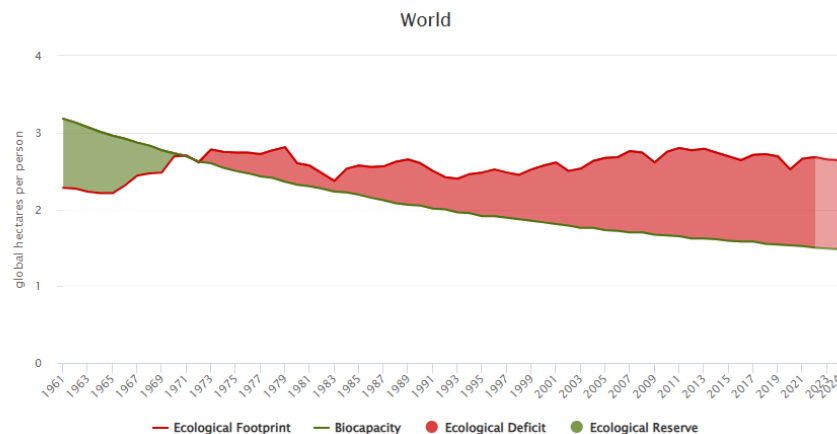
**Keywords:** Economic growth, natural resource rent, renewable energy consumption, the load capacity factor

**JEL Codes:** C23, F64, O44, P18, P28

## 1. INTRODUCTION

The load capacity factor, the ratio of ecological footprint per capita to biocapacity per capita, measures the world environmental degradation where the higher level of load capacity indicates the lower environmental degradation (Awosusi et al., 2024; Yang et al., 2024; Özkan et al., 2024 and Hammami et al., 2025). Biocapacity is the capacity of the ecosystem including natural resources, animals and fishes while ecological footprint is the absorption of the ecosystem (Niccolucci et al., 2012). Biocapacity reduces because of several human activities including hunting, fishing, industrialization, agriculture activities, deforestation and build-up land that raise ecological footprint (Pence et al., 2024). This implies that the world load capacity factor constantly decreases because of human activities and as a result increases environmental degradation. Graphic 1 shows that biocapacity per capita has been decreasing constantly while ecological footprint increases since 1961. The graphic also shows that ecological footprint per capita was below biocapacity per capita until 1972 while it started above biocapacity per capita from 1972 onwards for which ecological deficit has been expanding until now. Therefore, the overall global footprint network statistics indicate the world has been facing an ecological deficit since 1972 which has been expanding constantly. Although human beings use natural resources to sustain, they use fossil energy related natural resources mainly in the industrial sectors that release CO<sub>2</sub> emissions and as a result increases ecological footprint (Pata & Karlilar Pata, 2024).

**Graphic 1:** Biocapacity per capita and Ecological Footprint per capita all over the world

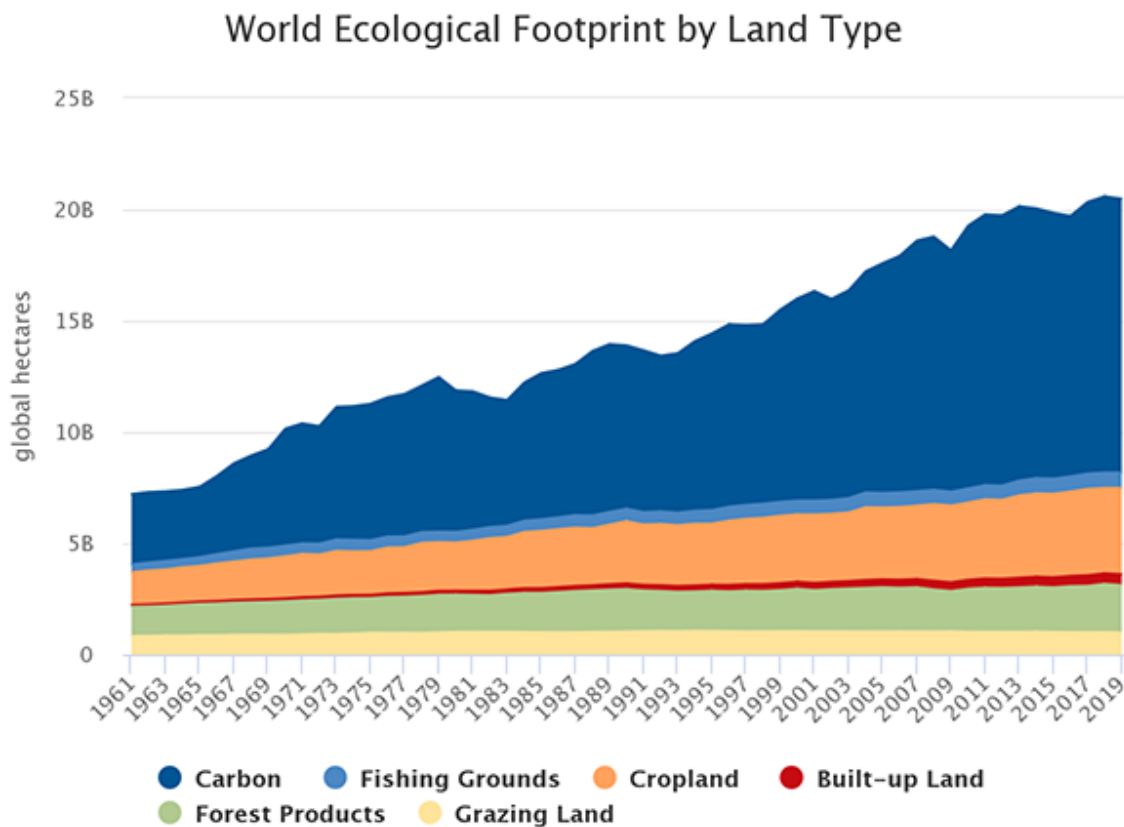


Source: Global Footprint Network (2025)<sup>2</sup>

<sup>2</sup> <https://data.footprintnetwork.org>

According to the Global Footprint Network (GFN) database, ecological footprints occur mainly because of several human activities including the consumption of carbon emissions, fishing grounds, cropland, build-up land, forest products and grazing land. All these activities increase ecological footprint and therefore reduce the biocapacity for which environmental degradation increases. The world ecological footprint can be shown below in graphic 2. The following graphic indicates that the world ecological footprint increases constantly during the period between 1961-2019 where the contribution of carbon footprint is highest. Here carbon footprint increases because of the use of fossil energy sources that release CO<sub>2</sub> emissions (Paraschiv & Paraschiv, 2020). Therefore, the use of fossil energy sources mostly increases the ecological footprint and as a result decreases the biocapacity.

**Graphic 2:** World ecological footprint by land type



Source: Global Footprint Network (2025)<sup>3</sup>

Natural resources, especially fossil energy that are mostly used in the industrial sector, determine the economic growth of a country, that further determines the living standard of the people (Ben-Salha et al., 2021 and Yu, 2023). Therefore, it is necessary to use natural resources efficiently, especially to use fossil energy sources efficiently to reduce ecological footprint. This further increases the load capacity that can ensure both economic and environmental sustainability. Liu & Chen, (2024) revealed that natural resources reduce green economic growth while factors

<sup>3</sup> <https://data.footprintnetwork.org>

including labor force, gross fixed capital and trade openness play positive roles in enhancing green economic growth. The study further advised to make proper investment in technological development that can ensure efficient use of natural resources, especially the efficient use of fossil energy in the production sector that can ensure both economic and environmental sustainability and as a result ensure green economic growth. As Khan et al., (2022), Yuan & Zhang, (2024) and Yu et al., (2025) found that the intensity of natural resources is higher during the initial stage of economic growth, the study indicates that the intensity of natural resources is higher in developing countries while lower in developed countries. Therefore, load capacity can increase in countries that are relatively developed because they have the capacity to increase investment for technology and renewable energy development. In fact, Khan et al., (2023) added that green economic growth requires more clean energy development where human capital can play an important role. The study is in line with Roy, (2024) predicted that human capital and trade openness in developed economies can increase the productivity of natural resources that may favor economic growth without polluting the environment.

The study mainly observes whether the factors including economic growth, natural resource rent and renewable energy consumption can play positive roles to enhance the load capacity factor in selected Asian countries including Bangladesh, China, Indonesia, India, Japan, South Korea, Sri Lanka, Malaysia, Nepal, Pakistan and Singapore where the study period covers between 1990-2021. Moreover, the study examines whether countries having developed economies can help emerging or lower income developing countries in increasing the load capacity factor through the enhancement of economic growth, natural resource rent and renewable energy consumption. For that the countries that have been selected for the current study are mixed with having advanced, emerging and lower income developing economies. For instance, Bangladesh and Nepal are having lower income developing economies whereas China, Indonesia, India, Sri Lanka, Malaysia and Pakistan are countries emerging economies. On the other hand, Japan, South Korea and Singapore are the Asian countries that have advanced economies. The study applies several panel econometric techniques for empirical analysis.

The study consists of the following sections: Theoretical framework in section 1; literature review in section 2; methodology in section 3; and empirical analysis in section 4.

## 2. THEORETICAL FRAMEWORK

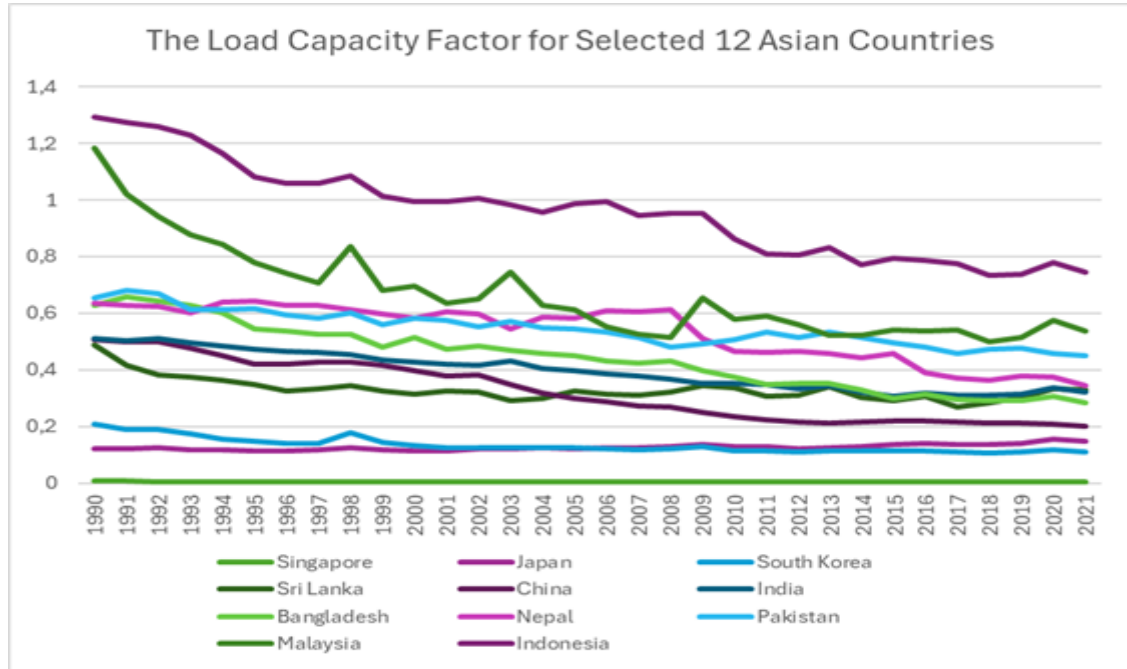
As it has been mentioned earlier that the load capacity factor is mainly the ratio of biocapacity per capita to ecological footprint per capita, it can be explained based on the equation providing below:

$$\text{Load capacity factor} = \frac{\text{Biocapacity per capita}}{\text{Ecological footprint per capita}} \quad (1)$$

Based on the equation 1, the load capacity factor changes either changing biocapacity per capita or ecological footprint per capita. To ensure environmental sustainability, it is necessary to control ecological footprint per capita that can keep the load capacity factor increasing or remaining stable. Graphic 3 shows the load capacity factor for selected Asian countries for the year between 1990-2021 where the only three selected Asian developed countries including Singapore, Japan and South Korea have the lowest load capacity while Malaysia and Indonesia have the highest load capacity. However, the graphic indicates that the load capacity for Singapore, Japan and South Korea remain stable while the load capacity for other countries decreases constantly during

the period. This implies that countries having developed economies can manage to keep the load capacity relatively stable.

**Graphic 3:** The load capacity factor for selected 12 Asian countries



Source: Global Footprint Network (2025)<sup>4</sup>

### 3. LITERATURE REVIEW

As natural resources increase ecological footprint, it is necessary to ensure its efficient use, especially in production that may ensure both economic and environmental sustainability (Świąder et al., 2020 and Kish & Miller, 2025). For this reason, the current study conducts literature based on past studies where the effect natural resource rent on the load capacity factor was examined. While natural resource rent was used in all studies to examine its effect on the load capacity factor, other variables including economic growth, industrial value added, foreign direct investment and others were used in all studies to examine their effect on the load capacity factor. While the effect of economic growth was used in all studies except in Musah et al. (2024), the effect of renewable energy consumption was used in only two of these studies including Du et al. (2024) and Sun et al. (2024b). All these studies used panel data models by applying several panel econometric models. The details of the literature review are shown in table 1.

In all past studies, natural resources were found to increase the load capacity factor in ASEAN countries (Du et al., 2024), G-7 countries (Jin et al., 2024), Asian-Pacific Economic Cooperation (APEC) countries (Sun et al., 2024b), and developing countries (Wang et al., 2024), while it was found to decrease the load capacity in G-10 countries (Musah et al., 2024), Asian pacific emerging countries (Sun et al., 2024a), and highly resources consuming countries including Brazil, China, France, Germany, India, Indonesia, Japan, the Russian Federation, South Africa, the United Kingdom, and the United States of America (Ni et al., 2022). Like natural resources and economic growth, several other factors including renewable energy consumption, foreign investment, trade openness and others can affect the load capacity factor. All these studies used several panel

<sup>4</sup> <https://data.footprintnetwork.org>

econometric models including augmented mean group (AMG), common correlated affect mean group (CCEMG), cross sectional autoregressive distributed lag (ARDL), fixed effect ordinary least square (FE-OLS), fully modified ordinary least square (FMOLS), method of moment quantile regression (MMQR) and general method of moment (GMM) to conduct the panel long-run estimation. All these studies revealed that there exists cross-sectional dependency among variables for which the effect of one country affects others.

Natural resources reduce environmental quality by reducing the load capacity factor in countries or economies mainly because of higher dependency on natural resource consumption (Akadiri et al., 2025). Here higher natural resource consumed countries or economies might need to import natural resources because of fulfilling their demand that increases environmental degradation and as a result reduces the load capacity factor. Liu et al., (2022) stated that constant economic growth in an economy reduces the dependency on natural resource consumption in the long run. The reason is that constant economic growth increases the income level per capita, improves natural resource efficiency and develops industrial sector for which necessary financial resources can be utilized for renewable energy development that can replace fossil fuel consumption in the production sector. This further increases economic growth without increasing environmental degradation and thus natural resources don't only increase the load capacity but also ensure constant economic growth in the long run. Moreover, Erdogan et al., (2024) indicated that countries having abundant natural resources can be able to export natural resources to other countries and therefore can have an opportunity to ensure both economic and environmental sustainability. Li et al., (2024) added that the efficient use of natural resources enhances economic growth in the long run mainly because of developing specialization, human capital, technology and innovation in the long run.

**Table 1:** Literature review

| Source              | Study Area | Period    | Methodology         | Conclusion                             |
|---------------------|------------|-----------|---------------------|----------------------------------------|
| Ni et al. (2022)    | Country-11 | 1996-2019 | CS-ARDL, AMG, CCEMG | NRR(-), DIG(+), GOV(+), GDP(-)         |
| Du et al. (2024)    | ASEAN-6    | 1990-2020 | MMQR, FE-OLS, FMOLS | NRR(+), BEC(+), FDI(≠), SG(+), GDP(-)  |
| Jin et al. (2024)   | G-7        | 1995-2022 | MMQR                | NRR(+), EDU(+), GDP(-), TO(+)          |
| Musah et al. (2024) | G-10       | 1994-2019 | CS-ARDL, CCEMG      | NRR(-), ETAX(+), ERT(+), FDI(+)        |
| Wang et al. (2024)  | Country-96 | 2000-2018 | GMM                 | NRR(+), FDI(≠), IND(≠), GDP(-)         |
| Sun et al. (2024a)  | APAC-34    | 2002-2021 | GMM                 | NRR(-), EA(-), FDI(≠), GDP(-)          |
| Sun et al. (2024b)  | APAC-17    | 1990-2019 | AMG, CCEMG          | NRR(+), ERT(+), REC(+), URB(+), GDP(-) |

**NOTE:** BEC = Bioenergy consumption, DIG = Digitalization, EA = Energy aid, EDU = Education, ERT = Environmental related technology, ETAX = Environmental tax, FDI = Foreign Direct Investment, GDP = Economic growth, GOV = Governance, IND = Industrial value added, NRR = Natural resource rent, SG = Sustainable globalization, TO = Trade openness, URB = Urbanization.

#### 4. METHODOLOGY

This section describes the methodology that the current study uses to conduct empirical study. This includes data selection, model and panel econometric methods that are applied for the current study.

##### 4.1. Data Selection

For current study, several variables were collected from different sources including global footprint network (GFN), world development indicator (WDI) and United Nations Development Program (UNDP) internet addresses. Table 1 provides details for all variables and their sources.

**Table 2:** Variables and their sources

| Variable | Description of the variable                                                           | Source      |
|----------|---------------------------------------------------------------------------------------|-------------|
| LCF      | Load capacity factor (Biocapacity per capita gha/ecological footprint per capita gha) | GFN (2025)  |
| GDP      | GDP per capita (constant 2015 US\$)                                                   | WDI (2025)  |
| NRR      | Total natural resources rents (% of GDP)                                              | WDI (2025)  |
| REC      | Renewable energy consumption (% of total final energy consumption)                    | WDI (2025)  |
| HC       | Human development index                                                               | UNDP (2025) |
| GFC      | Gross fixed capital formation (% of GDP)                                              | WDI (2025)  |

##### 4.2. Model Specification

The study uses linear econometric model for empirical analysis. As the study uses panel data model, the econometric model can be shown as follows:

$$LNLCF_{it} = \beta_0 + \beta_1 LNGDP_{it} + \beta_2 LNNRR_{it} + \beta_3 LNREC_{it} + \beta_4 LNHC_{it} + \beta_5 LNGFC_{it} + \varepsilon \quad (1)$$

In equation 1,  $\beta_0$  is constant whereas  $\beta_1, \beta_2, \beta_3, \beta_4$  and  $\beta_5$  are the coefficients of all dependent variables.  $\varepsilon$  is the residual and  $i, t$  are cross-sectional and time-series. while  $LN$  is the logarithmic form of the variables. Here all the variables were transformed into logarithmic forms. In this equation,  $LNLCF$  is the dependent variables and  $LNGDP, LNNRR, LNREC, LNHC$  and  $LNGFC$  are the independent variables. While  $LNGDP, LNNRR$  and  $LNREC$  are the main dependent variables,  $LNHC$  and  $LNGFC$  are the control dependent variables. Therefore, the focus of the study is to examine what effects that  $LNGDP, LNNRR$  and  $LNREC$  might have on  $LNGDP$ . The descriptive statistics of all variables are provided in table 2 where the rejection of Jarque Bera test for all variables indicates that the variables that are selected for the current study are not distributed normally.

**Table 3:** Descriptive Statistics of the variables

|             | <b>LNLCF</b> | <b>LNGDP</b> | <b>LNNRR</b> | <b>LNREC</b> | <b>LNHC</b> | <b>LNGFC</b> |
|-------------|--------------|--------------|--------------|--------------|-------------|--------------|
| Mean        | -1,398431    | 8,250986     | -0,732707    | 2,64897      | 4,188663    | 3,266219     |
| Median      | -0,969295    | 7,826075     | 0,143232     | 3,491951     | 4,21138     | 3,268448     |
| Maximum     | 0,256872     | 11,1233      | 3,291411     | 4,554929     | 4,551769    | 3,785905     |
| Minimum     | -5,694745    | 6,046721     | -8,684038    | -1,609438    | 3,676301    | 2,551372     |
| Std. Dev.   | 1,420291     | 1,480503     | 2,658931     | 1,686746     | 0,247154    | 0,2676       |
| Skewness    | -1,965261    | 0,375215     | -1,01524     | -0,800303    | -0,274634   | -0,537756    |
| Kurtosis    | 6,182914     | 1,771463     | 3,490939     | 2,287527     | 1,939701    | 3,173091     |
| J-Bera      | 375,1725     | 30,3959      | 64,00348     | 45,02018     | 20,91364    | 17,40474     |
| Prob.       | 0            | 0            | 0            | 0            | 0,000029    | 0,000166     |
| Sum         | -492,2478    | 2904,347     | -257,9128    | 932,4374     | 1474,409    | 1149,709     |
| S. Sq. Dev. | 708,0461     | 769,3526     | 2481,54      | 998,634      | 21,44084    | 25,13496     |
| Obs.        | 352          | 352          | 352          | 352          | 352         | 352          |

### 4.3. Panel Econometric Method

For panel data analysis, the study uses several panel econometric methods. To examine cross-sectional dependency problems among variables, the study applies Pesaran et al. (2008) bias adjusted LM test techniques introduced in Baltagi et al., (2012) whereas the study uses Pesaran & Yamagata, (2008) slope homogeneity test techniques to identify slope heterogeneity problems. The study uses second generation test techniques, that provide robust results after considering cross-sectional dependency and slope-heterogeneity problems, to conduct panel unit-root, panel cointegration, panel long run estimation and panel causality tests. For instance, the study uses Pesaran, (2007) cross-section IPS (CIPS) and cross-section augmented Dickey-Fuller (CADF) panel unit root test techniques, Westerlund, (2007) panel cointegration test techniques, Powell, (2022) panel long run estimation test techniques and Dumitrescu & Hurlin, (2012) panel causality test techniques.

## 4. EMPIRICAL ANALYSIS

The bias adjusted LM cross-sectional dependence test results provided in table 4 indicate that the null hypothesis of cross-sectional independence among variables was rejected at 1% significance level in all test techniques including LM one-sided test, LM adjusted two-sided test and LM CD two-sided test techniques. This implies that there exists cross-sectional dependence among variables. The cross-sectional dependence among variables implies that there exist spill-over effects among variables in the panel group. For instance, if variables have spill-over effects among each other in a specific panel group, then the independent variable in one country can affect the dependent variable in other countries.



**Table 4:** Results for Pesaran et al. (2008) bias adjusted LM panel cross-sectional dependence test techniques

| LNLCF as a dependent variable |                                  |                                 |
|-------------------------------|----------------------------------|---------------------------------|
| LM one-sided test             | LM <sub>adj</sub> two-sided test | LM <sub>CD</sub> two-sided test |
| 123.4***                      | 15.76***                         | 5.359***                        |

The subscript \*\*\*, \*\* and \* represent 1%, 5% and 10% levels of significance, respectively.

Results for slope heterogeneity test techniques are provided in table 4. Here the null hypothesis of slope homogeneity among variables is rejected at 1% significant level. This indicates that the slope heterogeneity problems among variables exist in the existing model. The existence of heterogeneity problems among variables indicates the inconsistent relationship between the covariate and dependence variable at all levels of independent variables.

**Table 5:** Results for Pesaran & Yamagata (2008) panel slope heterogeneity test techniques

| LNLCF as a dependent variable |                |
|-------------------------------|----------------|
| Delta                         | Adjusted Delta |
| 15.880***                     | 17.966***      |

The subscript \*\*\*, \*\* and \* represent 1%, 5% and 10% levels of significance, respectively.

To identify whether all variables are stationarity, CIPS and CADF panel unit-root test techniques are applied for the study. The overall results for panel unit-root test techniques that are shown in table 6 indicate that all variables are stationary at 1<sup>st</sup> difference which is valid at 1% significant level. Although the logarithmic form of the load capacity factor (LNLCF) was found to be stationary at level in CIPS test technique, the result is insignificant at level in CADF test technique.

**Table 6:** Results for Pesaran (2007) CIPS and CADF panel unit root test techniques

| Variable | CADF   |                            | CIPS     |                            |
|----------|--------|----------------------------|----------|----------------------------|
|          | Level  | 1 <sup>st</sup> Difference | Level    | 1 <sup>st</sup> Difference |
| LNLCF    | -1.266 | -8.630***                  | -2.320** | -5.695***                  |
| LNGDP    | -0.291 | -3.482***                  | -1.914   | -3.956***                  |
| LNNRR    | -0.761 | -10.422***                 | -1.853   | -4.604***                  |
| LNREC    | 3.735  | -5.927***                  | -0.904   | -4.978***                  |
| LNHC     | 0.114  | -3.488***                  | -1.813   | -4.348***                  |
| LNGFC    | -0.964 | -5.491***                  | -1.939   | -4.342***                  |

The subscript \*\*\*, \*\* and \* represent 1%, 5% and 10% levels of significance, respectively.

After confirming that all variables are stationary at 1<sup>st</sup> difference, the study applies Westerlund (2007) panel cointegration test techniques including Gt, Ga, Pt and Pa tests to observe whether the variables have the long run cointegration relationship among each other. The results provided in table 6 show that the null hypothesis of no cointegration among variables is rejected in Gt, Ga and Pt tests while the null hypothesis is not rejected in Pa test. Therefore, the overall results indicate that there exists the long run cointegration relationship among variables. While the result obtained from Gt test shows that the result is valid at 1% significant level, the result obtained from Ga and Pt show that the results are valid at 5% significant level.

**Table 7:** Results for Westerlund (2007) panel cointegration test techniques

|    | LNLCF as a dependent variable |         |          |                |
|----|-------------------------------|---------|----------|----------------|
|    | Value                         | Z-value | P-value  | Robust P-value |
| Gt | -3.878                        | -4.288  | 0.000*** | 0.000***       |
| Ga | -14.057                       | 0.369   | 0.644    | 0.010**        |
| Pt | -10.279                       | -2.229  | 0.013**  | 0.020**        |
| Pa | -8.542                        | 1.104   | 0.865    | 0.470          |

The subscript \*\*\*, \*\* and \* represent 1%, 5% and 10% levels of significance, respectively.

After confirming that there exists the long run cointegration relationship among variables, the study decided to go through the empirical analysis where the study uses the Powell (2022) panel long run estimation techniques. The results that are provided in table 7 indicate that economic growth, natural resource rent and renewable energy consumption have positive impacts to increase the load capacity factor. As all the variables were transformed into logarithmic forms, the effect can be analyzed based on the percentage basis. For instance, on average, 1% increase in economic growth, natural resource rent and renewable energy consumption cause the load capacity factor to increase by around 0.29%, 0.34% and 0.42% where the effects are relatively higher in higher quantiles. This implies that economic growth, natural resource rent and renewable energy consumption can contribute more to increasing the load capacity once these factors become higher. The highest positive effect of renewable energy consumption to the load capacity factor in all quantiles indicates that renewable energy is the most potential factor to raise load capacity.

As it has been mentioned that human capital and gross fixed capital were used as control variables, the results showed that these two variables cause negative effects to the load capacity factor. The results indicate that the average effect of human capital is around 11% which can almost be totally inelastic while the average effect of gross fixed capital is around 31%. This indicates that the selected countries

are not capable to utilize human resources and capital assets in enhancing the load capacity. While the negative effect of human capital was found to be quite higher at upper quantile, the study shows that the negative effect of gross fixed capital is lower at upper quantile. This implies that gross fixed capital becomes relatively less harmful at upper quantile in reducing the load capacity factor.

**Table 8:** Results for Powell (2022) panel long run estimation techniques

| Quantile                  | LNLCF as a dependent variable |                        |                       |                        |                        |
|---------------------------|-------------------------------|------------------------|-----------------------|------------------------|------------------------|
|                           | LNGDP                         | LNNRR                  | LNREC                 | LNHC                   | LNGFC                  |
| 10 <sup>th</sup> Quantile | 0.2816***<br>(0.0014)         | 0.3384***<br>(0.0006)  | 0.4094***<br>(0.0011) | -0.1134***<br>(0.0082) | -0.3424***<br>(0.0036) |
| 20 <sup>th</sup> Quantile | 0.2460***<br>(0.0021)         | 0.3351***<br>(0.0002)  | 0.3959***<br>(0.0020) | 0.0096<br>(0.0083)     | -0.3369***<br>(0.0073) |
| 30 <sup>th</sup> Quantile | 0.2900***<br>(0.0015)         | 0.3347***<br>(0.0001)  | 0.4143***<br>(0.0005) | -0.1738***<br>(0.0093) | -0.3140***<br>(0.0007) |
| 40 <sup>th</sup> Quantile | 0.2776***<br>(0.0021)         | 0.3408***<br>(0.0002)  | 0.4058***<br>(0.0006) | -0.0671***<br>(0.0079) | -0.3429***<br>(0.0014) |
| 50 <sup>th</sup> Quantile | 0.2841***<br>(0.0001)         | 0.3369***<br>(0.00003) | 0.4019***<br>(0.0001) | -0.1649***<br>(0.0009) | -0.3555***<br>(0.0007) |
| 60 <sup>th</sup> Quantile | 0.2814***<br>(0.0001)         | 0.3322***<br>(0.0000)  | 0.4080***<br>(0.0001) | -0.1051***<br>(0.0006) | -0.3454***<br>(0.0003) |
| 70 <sup>th</sup> Quantile | 0.2835***<br>(0.0003)         | 0.3356***<br>(0.0000)  | 0.4158***<br>(0.0001) | -0.1199***<br>(0.0009) | -0.3250***<br>(0.0001) |
| 80 <sup>th</sup> Quantile | 0.2879***<br>(0.0001)         | 0.3368***<br>(0.0000)  | 0.4194***<br>(0.0000) | -0.1028***<br>(0.0003) | -0.3247***<br>(0.0001) |
| 90 <sup>th</sup> Quantile | 0.2841***<br>(0.0000)         | 0.3345***<br>(0.0000)  | 0.4147***<br>(0.0000) | -0.1168***<br>(0.0001) | -0.3184***<br>(0.0001) |

The subscript \*\*\*, \*\* and \* represent 1%, 5% and 10% levels of significance, respectively.

After analyzing the panel long run estimation, the study conducts panel causality test techniques to see whether the variables have causal relationships among each other. Examining causal relationship among variables is important in the sense that it helps to show whether one variable can cause others. As the panel data that for the current study has cross-sectional dependence relationship among variables, the panel causality results indicate whether one variable in one country can cause other variables in other countries. The results for panel causal test are provided in table 8. The results indicate unidirectional causality from economic growth to the load capacity factor and from the load capacity factor to natural resource rent whereas the results indicate unidirectional causality between the load capacity factor and renewable energy consumption. The unidirectional causality from economic growth to the load capacity factor implies that economic growth is a potential factor in raising the load capacity while unidirectional causality from the load capacity factor to natural resource rent implies that the load capacity can increase natural resource rent. Moreover, the bidirectional causality relationship between the load capacity factor and renewable energy consumption implies that both the load capacity and renewable energy can contribute each other to increase.

The study also analyzed the causal relationship among the main independent variables. For instance, the study found the unidirectional causal relationship from economic growth to natural resource rent and from economic growth to renewable energy consumption while the study found the bidirectional causal relationship between renewable energy consumption and natural resource rent. The unidirectional causal relationship from economic growth to natural resource rent and from economic growth to renewable energy consumption implies that economic growth can contribute to raising both renewable energy consumption and natural resource rent. On the other hand, the bidirectional causal relationship between renewable energy consumption and natural resource rent implies that both renewable energy consumption and natural resource rent contribute each other to raise each factor together.

The unidirectional causal relationship from economic growth to the load capacity is inconsistent with study of Musah et al. (2024) on G-10 countries and Sun et al. (2024b) on APAC-17 countries where the bidirectional causality relationship between economic growth and the load capacity was found to exist in these studies. This implies that economic growth in developed economies doesn't only enhance load capacity, the load capacity further contributes to enhance economic growth. Therefore, developed economies have capability to ensure both economic and environmental sustainability. On the other hand, the unidirectional causality relationship from economic growth to renewable energy consumption for the current study that is inconsistent with the bidirectional causality between economic growth and renewable energy consumption from Sun et al. (2024b) indicates that renewable energy in developed economies can contribute to enhance economic growth as well. However, the bidirectional causality relationship between renewable energy consumption and natural resource rent from the current study indicates that renewable energy in selected Asian countries can replace fossil energy for which it can ensure both economic and environmental sustainability in the long run.

**Table 9:** Results for Dumitrescu & Hurlin (2012) panel causality tests

| Null Hypothesis                          | W-Stat. | Z-Stat. | Prob.  |
|------------------------------------------|---------|---------|--------|
| LNGDP does not homogeneously cause LNLCF | 5.00008 | 8.05483 | 0.0000 |
| LNLCF does not homogeneously cause LNGDP | 1.51275 | 0.89482 | 0.3709 |
| LNNRR does not homogeneously cause LNLCF | 1.54536 | 0.96177 | 0.3362 |
| LNLCF does not homogeneously cause LNNRR | 4.72080 | 7.48143 | 0.0000 |
| LNREC does not homogeneously cause LNLCF | 3.43574 | 4.84300 | 0.0000 |
| LNLCF does not homogeneously cause LNREC | 4.30812 | 6.63412 | 0.0000 |
| LNHC does not homogeneously cause LNLCF  | 6.81689 | 11.7850 | 0.0000 |
| LNLCF does not homogeneously cause LNHC  | 2.20702 | 2.32025 | 0.0203 |
| LNGFC does not homogeneously cause LNLCF | 2.60319 | 3.13365 | 0.0017 |
| LNLCF does not homogeneously cause LNGFC | 2.68406 | 3.29968 | 0.0010 |
| LNREC does not homogeneously cause LNGDP | 1.45674 | 0.77983 | 0.4355 |
| LNGDP does not homogeneously cause LNREC | 7.92291 | 14.0558 | 0.0000 |
| LNREC does not homogeneously cause LNNRR | 5.84934 | 9.79849 | 0.0000 |
| LNNRR does not homogeneously cause LNREC | 2.59469 | 3.11621 | 0.0018 |

## 5. CONCLUSION AND DISCUSSION

The current study attempts to examine the effects of economic growth, natural resource rent and renewable energy consumption on the load capacity factor in selected 11 Asian countries for the period between 1990-2021. While the study used economic growth, natural resource rent and renewable energy consumption as the main independent variables to examine their effects on the load capacity factor, the study also used human capital and gross fixed capital as the control variables. Khan et al., (2023) and Roy, (2024) found human capital to contribute to enhancing load capacity, none of the study was found where the effect of human capital on the load capacity factor was examined. For this reason, the study examined whether human capital has any effect on the load capacity factor. As gross fixed capital is the main factor of economic growth along with human capital, the study also decided to use this variable to examine its effect on the load

capacity factor. In fact, the above literature review various past studies where the variables including industrial value added and foreign direct investment were used to examine whether they have any effects in determining the load capacity factor. While method of moment quantile regression (MMQR) panel regression estimation Machado and Silva (2019) was used in past literature review, Powell (2022) panel long-run estimation technique was not found in any of these studies. Therefore, the current study is among the new ones where this model is used to examine the factors that determine the load capacity factor.

By applying Powell (2022) panel long run estimation technique, the study revealed that both economic growth, natural resource rent and renewable energy consumption never to increase the load capacity factor in the selected country group. While panel long run estimation technique indicated that economic growth, natural resource rent and renewable energy consumption have positive effects on the load capacity factor, all these variables are less efficient to increase the load capacity despite the result being the highest positive in the highest quantile. The fact is that most of the selected countries are underdeveloped in the selected panel group. However, the overall positive effects of these variables on the load capacity implies that both economic and environmental sustainability are possible in the selected Asian countries. In fact, the developed countries including Singapore, Japan, South Korea, China and Malaysia can help other lower income countries to ensure both environmental and economic sustainability. As the panel data analysis revealed that there exists cross-sectional dependence relationship among variables, the study implies that the developed countries can help developing countries to ensure both economic and environmental sustainability.

Moreover, the study examined causal relationship among variables by applying Dumitrescu & Hurlin (2012) panel causality test techniques. The results revealed unidirectional causality relationship from economic growth to the load capacity factor and natural resource rent, from economic growth to natural resource rent and renewable energy consumption, and the bidirectional causality relationship between the load capacity factor and renewable energy consumption and between renewable energy consumption and natural resource rent implies that economic growth can play significant role in ensure both economic and environmental sustainability by increasing load capacity, renewable energy development and raising income level from natural resource rent. Moreover, the causality test results imply that renewable energy development can ensure increasing the load capacity while the increasing load capacity can contribute positively to increase renewable energy development. On the other hand, natural resource rent can develop renewable energy while renewable energy development can contribute to enhance income from natural resource rent.

While the study confirmed that economic growth, natural resource rent and renewable energy consumption never economic and environmental sustainability by increasing the load capacity factor, the study also showed that both human capital and gross fixed capital doesn't never in enhancing the load capacity factor in selected Asian countries. As it has been mentioned earlier that most of the selected Asian countries are underdeveloped, they might not be able to develop strong human resource and capital assets that can contribute positive roles in enhancing the load capacity factor. The result is consistent with the findings of Roy, (2024) where human capital was found to contribute to enhancing the load capacity factor only in developed economies. Moreover, the developed economies can have opportunities to enhance more investment through trade and foreign direct investment (FDI) that may favor to enhance the load capacity. To increase the efficiency of economic growth, natural resource rent and renewable energy consumption in

enhancing the load capacity factor at a faster rate, policymakers should pay attention in improving technological progress for their efficiency. In this case, the developed economies including Japan, South Korea, China and Singapore can play positive role to make necessary investment in other underdeveloped Asian countries that may help to enhance technology and therefore ensure both economic and environmental sustainability.

| ETİK BEYAN ve KATKI ORANLARI                                                                                                               |                                                                                                                                                         |
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