Abstract: This paper analyzes the relationship between freight transport, economic prosperity, carbon dioxide (CO₂) emissions, energy consumption, and urbanization for three top Asian economies, namely, Hong Kong, Singapore, and South Korea during 1995–2017. For this purpose, we use the augmented Dickey-Fuller test for the stationary of the series, Johansen co-integration approach, and fully modified ordinary least squares and Granger causality model to infer the causal relationship between the study variables. The results show that economic prosperity (GDP) and energy consumption (EC) have a significant impact on freight transport (FT) for all three economies. In addition, the results also manifest the existence of bidirectional causality between GDP and FT in Singapore but a unidirectional causality running from GDP to FT in the case of Hong Kong and South Korea. As a quick policy option, controlling fossil fuel energy consumption in the transport sector may result in a remarkable reduction in CO₂ emissions. The present study provides new insights to decision-makers for designing comprehensive energy and environmental policies for future sustainable freight transport growth in the long run.

Keywords: freight transport; economic prosperity; urbanization; carbon emissions; Granger causality model

1. Introduction

The transport sector is prominent because it plays a vital role in our daily lives and the country’s development. In addition, it helps the connection between the different locations which promotes trade and development. On the other hand, it is also a major source of fossil fuel energy consumption, which has a detrimental effect on the environment and has an enormous and increasing share of global carbon emissions [1]. As a result, there is an enormous amount of greenhouse gas (GHG) and CO₂ emissions, especially in Asian countries, which are alarming. The transport sector is one of the major sector for CO₂ emissions around the globe [1,2]. There is no doubt that transport is among the broadly growing economic sectors with substantial carbon emissions around the globe. Moreover, the upsurge in the number of highway automobiles is one reason for the rise in pollution. Presently, the number of
vehicles worldwide is estimated at around 1.2 billion, using around 13.5 billion barrels of petroleum fuel per year and emitting 6.1 billion tons of CO$_2$ per annum into the atmosphere [3]. Global CO$_2$ emissions are projected to grow by about 50% in 2030 to about 80% in 2050 as energy demand rises and the number of road vehicle numbers increases [2].

Asia is a region with varying levels of economic prosperity and the endowment of energy resources. Swift economic growth in the region is raising primary energy demand from 4025 Mtoe in 2005 to 7215 Mtoe by 2030. Asia’s transportation sector is growing hastily, and the annual energy consumption is expected to increase by 2.9 percent by 2030 [3]. China is the largest transportation user in Asia (12.3 quadrillions Btu), followed by India (3.3 quadrillions Btu). Like India and China, the other countries in this region also demonstrate a significant rise in the transportation energy demand from 5.5 quadrillions Btu in 2008 to 8.6 quadrillions Btu in 2017 [3]. The Asian region’s energy-related CO$_2$ emissions will rise from 10.065 billion tons in 2005 to 17.763 billion tons by 2030, with a yearly increase of 2.3 percent from the transport sector is increasing very rapidly with a growth rate of 2.8% per year [3]. This growth shows that the total CO$_2$ emissions will grow from 12.5% in 2005 to 13.7% in 2030 [3]. Therefore, the environmental impacts of transportation fuel consumption through CO$_2$ emissions were some of the primary concerns in recent sustainable transport policies in Hong Kong, Singapore, and South Korea. Consequently, significant consideration has been paid to decreasing energy use and restricting pollutant emissions to encourage environmental protection [4,5]. The majority of previous studies indicated that energy demand and economic prosperity are the two main factors of carbon emissions [6]. However, GDP and energy consumption (EC) alone may not reflect the correct result of carbon emissions [7,8]. Therefore, there is a great need to explore other variables that might affect carbon emissions. In the present study, we incorporate the transportation sector by including freight transport (FT) as a key factor through understanding its association with economic prosperity (GDP), energy consumption (EC), urbanization (URBN), and CO$_2$ emissions.

### 1.1. Literature Gap(s) and the Contribution of the Study

According to the International Energy Agency (IEA) estimates [9], global CO$_2$ emissions reached a historical high of 33.5 gigatonnes of CO$_2$ in 2018 due to increased growth in population and economic activity around the globe. Transportation is a major energy field that depends on oil and generates significant global CO$_2$ emissions. Besides, the freight transport sector is heavily dependent on fuel (oil and natural gas) consumption, resulting in serious oil security problems and environmental pressures in Asian countries. Moreover, the swift development of the economy and consequential urbanization has caused higher growth of CO$_2$ emissions [10]. Nevertheless, the previous studies [8,11] analyze the causality between FT, GDP, and CO$_2$ emissions together for economic analysis. Thus, we are strongly enthused to examine the long-term causal relationship between transportation, GDP, URBN, and transport CO$_2$ emissions, specifically in Hong Kong, Singapore, and South Korea.

The correlation among FT, GDP, EC, URBN, and CO$_2$ emissions have been addressed in three lines. (i) Initially, examine the interaction between GDP, energy consumption, and freight transportation. During the past few decades, connection/convergence among development and freight transport is studied and well handled in several studies [12–16]. (ii) In the second line, we noticed that improved GDP means more energy consumptioninduces greater pollutant emissions, mainly CO$_2$ emissions. Besides, economists utilized multiple methods and tools to analyze the implications of connections between GDP and environmental degradation (ED) under the Kuznets curve (EKC) hypothesis [17–19]. (iii) This research explores the causal connection between freight transport, urbanization, and CO$_2$ emissions. The orientation of the long-term causal relationship between variables also leads policymakers to make effective methods in developing better freight transport systems to enhance safety and sustainability for the future system. Furthermore, we consider the real effect of transportation and economic prosperity on country quality, which helps economists recognize whether economic development is more detrimental to the environmental quality or whether the transportation sector contributes more to CO$_2$ emissions.
For the economic analysis, we utilize the annual data of selected economies from 1995 to 2017. The approach allows simultaneous analysis of the interconnectedness determined by Johansen co-integration approach, fully modified ordinary least squares (FMOLS), and Granger causality model between freight transport, GDP, EC, URBN, and CO\textsubscript{2} emissions. This paper begins with an introduction accompanied by a conceptual analysis in which we summarize previous works concerning our subject. The method section is explained in Section 2. Then, Section 3 presents the results and analysis of the study. Finally, the conclusions and study implications are presented in the last section.

1.2. Literature Review

The transportation sector is considered as one of the major pollutant emissions sectors worldwide [20]. In addition, freight transport is still going to increase, requiring more energy in the future. Rail transport energy use (passenger and freight) is projected to rise by almost 72% in 2050, causing more CO\textsubscript{2} emissions in the future [21]. Currently, global policy developments have sought to lower transport fossil energy volumes. We aim to advance new resources’ performance, including biofuels, compressed natural gas (CNG), liquefied natural gas (LPG), and electricity. Drastically reducing CO\textsubscript{2} emissions and other common transportation air pollutants require enforcing sustainable transport strategies and environmentally friendly policies, including economic leverage and technological advancement. Steenhof et al. [22] used the decomposition analysis to the Canadian FT to analyze the important factors of GHG emissions. We recognize that, if the rise of freight transportation in Canada continues to rise, technological advancement becomes an insufficient option for growing GHG emissions. Sorrell et al. [23] in England assert that enhanced car transportation efficiency and decreased average passenger energy consumption are viable strategies that could reduce CO\textsubscript{2} pollution and improve environmental quality. In an analysis of Germany, Spain, France, Italy, and Britain, Gleave [24] revealed that the deterioration of the natural environment is influenced favorably by high volumes of CO\textsubscript{2} emissions and the elimination of freight traffic in these nations, by minimizing CO\textsubscript{2} emissions, helps environmental sustainability to be enhanced. Over recent years, Banister and Stead [25] have found strong links between transport activity, economic activity, and CO\textsubscript{2} emissions and their environmental impact. The close relationship between economic activity and transport considerably increases energy demand and CO\textsubscript{2} emissions. Hao et al. [26] have shown that freight transport is one of China’s leading causes of growing GHG emissions. In South Africa, transportation energy is a leading factor in the proliferation of GHG emissions [27]. Shahbaz et al. [28] investigated the connection between the transport sector CO\textsubscript{2} emissions, transportation sector energy demand in Tunisian transport systems. The findings reported that using the vector error correction model (VECM) analysis shows a link between EC and CO\textsubscript{2} emissions. Mustapa and Bekhet [29] have addressed some valuable strategy options to reduce Malaysia’s CO\textsubscript{2} emissions. The practical results derived using a linear programming method and sensitivity analysis have shown that 28% of the overall carbon dioxide emissions are produced in the transport industry.

For several years, the subject of coupling/decoupling between GDP and freight transport is studied and well handled in multiple studies [30–35]. For example, Hensher analyzed the effect of passenger transport and the consequent effects of freight transportation on growing GHG pollution in the Sydney Metropolitan Area and suggested various policy measures to reduce emissions of GHGs, including transport sector resilience, logistics capacity, and environmental qualities [36]. According to McKinnon [12], the number of foreign road freight companies, the fall in road transport’s share of the modal breakdown, and the rise in road freight cargo prices are the three main factors liable for two-thirds of UK decoupling. Kveiborg and Fosgerau [37] examined the correlation between economic growth and freight transport in Denmark, based on 19 industries and 26 commodity groups for the period 1981–1992. Their conclusions figure out that the differentiation between industries is a good idea that can enable robust and effective results to be achieved. Bennathan et al. [38] performed a bend-sectional analysis of a group of 33 countries at different stages of development and showed a very close relationship between GDP and freight transport.
Another group of articles examined transport demand using a number of techniques, including elasticity estimates. Most of these studies confirm the concept of a positive relationship between transportation and GDP. The co-integrating vector autoregressive (VAR) model was used in India by Kulsreshtha and Nag [39] to approximate the relationship between GDP and FT in the railways. Yao [40] examines the ties between FT, industrial production, and investment in inventory by using the causality test of Granger and the VAR system’s impulse response method. Both indicate an important feedback effect between freight movements and expenditure in output and inventory inputs. The logistics role as a critical factor in understanding the relationship between transport and GDP is included in the research [41,42]. By undertaking the analysis of the evolving demands of 88 major British producers on FT, McKinnon and Woodburn [42] suggest that control of transport infrastructure is a more important cause of the increase in freight traffic. McKinnon and Woodburn [42] also believe that producers forecast that their demand for road freight would increase substantially in line with profits and that road transport prices would generally remain unchanged at the rate currently proposed.

Many previous studies [43–45] have been concerned with urbanization impact on transport CO₂ emissions. Hasan et al. [44] result indicated that, with the increase of the urban population, CO₂ emissions from the New Zealand transport sector have increased. Liu et al. [46] refer to the ports as the center of human activities and they have implemented the three-dimensional risk management model to monitor port activities, which will allow for sustainable port development. Reckien et al. [45] results showed that the total built area and total traffic area are the leading factors for higher CO₂ emissions in Berlin city. Wang et al. [47] results also manifested that urban form is the main factor for transport CO₂ emissions.

Although the influential factor behind CO₂ emissions in the transport sector has been discussed in previous literature, few studies have evaluated the relationship between transport, urbanization, energy consumption, and CO₂ emissions. Saidi and Hammami [8] analyzed the transport, GDP, and environmental degradation using panel data. Similarly, Nadia and Rochdi [48] evaluated the relationship between FT, GDP, EC, and GHG emissions using the vector autoregressive (VAR) model in Tunisia. However, no recent study evaluates multiple factors such as FT, GDP, EC, urbanization, and CO₂ emissions, specifically in Hong Kong, Singapore, and South Korea. To fill this research gap, the current study investigates the relationship between freight transport energy consumption, urbanization, economic prosperity, and CO₂ emissions in Hong Kong, Singapore, and South Korea since these regions are already developed and utilize greater fossil fuel energy for freight transport as compared to other Asian countries. In this regard, certain empirical studies found that urbanization and energy consumption of transportation has an impact on carbon emissions [49]. Intriguingly, no study evaluates freight transport’s impact on urbanization, CO₂ emissions, and energy consumption for transportation policy implications. Therefore, in Hong Kong, Singapore, and South Korea, where well-developed freight transport and good accessibility are omnipresent, further investment in the transport sector could lead to marginal economic and long term environmental benefits. On the other hand, this research can help other Asian countries invest in the freight transport sector by adopting sustainable energy practices and promoting sustainability in the transport sector.

2. Materials and Methods

Data Sources

The purpose of this study is to analyze the impact of freight transport (FT) on economic prosperity (GDP), carbon dioxide (CO₂) emissions, energy consumption (EC), and urbanization (URBN) for Hong Kong, South Korea, and Singapore. The data source for the series is mined from World Development Indicators (WDI) and Energy Information Administration (EIA) database and annual data from 1995–2017 [50,51]. The information of all variables with their source is illustrated in Table 1.
Multiple recent studies [28, 52–54] have jointly observed the nexus of energy consumption and economic growth. Based on the Cobb–Douglas production function, the econometric model in which the various explanatory variables such as economic growth, carbon dioxide emissions, energy consumptions, and urbanization, trade openness can be used [52, 55–57]. The current study investigates the impact of freight transport (FT) on economic prosperity (GDP), carbon dioxide emissions (CO$_2$), and energy consumption (EC) by taking urbanization (URBN) as an additional variable. However, no current study comprehensively investigates the linkage of freight transport and economic prosperity, EC, URBN, with CO$_2$ emissions, especially in Asian countries. To cover the research gap, the present study investigates the linkage of transportation and economic prosperity with carbon dioxide emissions for Hong Kong, Singapore, and South Korea. Moreover, our model uniquely incorporated disaggregated energy consumption, urbanization, carbon dioxide emissions and economic prosperity as explanatory variables. The functional form and econometric model specification are as follows:

$$FT = f(GDP, CO_2, EC, URBN)$$

(1)

The linear form of Equation (1) can be re-written to include error terms and presented as follows:

$$FT_t = a'_0 + a'_1GDP_t + a'_2CO_2t + a'_3EC_t + a'_4URBN_t + \epsilon'_t$$

(2)

The data is transformed into a natural logarithm for reliable and consistent results. The log-linear form of Equation (2) is presented in Equation (3) as follows:

$$lnFT_t = a_0 + a_1lnGDP_t + a_2lnCO_2t + a_3lnEC_t + a_4lnURBN_t + \epsilon_t$$

(3)

Here, ln is the natural logarithm, $t$ is the time, FT indicates the freight transport, GDP denotes the economic prosperity, CO$_2$ is the carbon dioxide emissions, EC is the energy consumption, and URBN is the urbanization, $a_0$ and $\epsilon_t$ indicates the constant and classical error term. The estimated coefficients for freight transport with respect to economic prosperity, carbon dioxide emissions, energy consumption, and urbanization are $a_1$, $a_2$, $a_3$, and $a_4$, respectively. The expected sign for $a_1$ is positive; the sign for $a_2$ can be either positive or negative. While the sign for $a_3$ should be positive, the sign for $a_4$ should be positive or negative. The parameter $a_0$ permits for possible state fixed effect, and $\epsilon_t$ denotes normally distributed error term.

For econometric methodology, the first step is to determine the existence of a unit root in each variable to find the order of integration. For this, we will use the augmented Dickey-Fuller (ADF) test [58], if the variables are integrated of order one I(1). Next, this study will use Johansen test to identify the long-run equilibrium relationship in the data. After the cointegration test, this study will utilize the fully modified ordinary least square (FMOLS) method to determine whether GDP, CO$_2$ emissions, EC, and URBN positively or negatively influence FT. Finally, our study will apply the Granger causality test to infer the direction of causality between series.
3. Empirical Results and Discussion

3.1. Unit Root Test Results

In the econometric analysis, the variables stationarity is crucial to avoid spurious regression results. Therefore, the ADF standard time series unit root test is applied in this study to ensure the robustness of the series for each economy. This can be done by including a constant term and a time trend in the ADF equation of the unit root test when determining it at the level and first difference. The lag length is selected according to the Schwarz information criterion (SIC). The expected outcomes for this test are that the series will be I(0) at levels and I(1) at their first difference because the precondition for testing the Johansen co-integrating test requires that the variables should be in the same order I(1), i.e., stationary at first difference. The null hypothesis of the ADF unit root test is that data is non-stationary in order of integration I(0), where the alternative hypothesis is that the data contains no unit root. The results of the ADF unit root test are summarized in Table 2. The study considers the estimation under the intercept with trend to exploit potential hidden features. The ADF method fails to reject the null hypotheses that all the variables are non-stationary at levels for three economies, while rejecting the null hypotheses that all the variables are non-stationary at first difference for three economies. It shows strong and consistent outcomes that series contains unit root at levels, but they have no unit root at their first difference; however, the series are integrated in the same order I(1) for each economy. Since the ADF test results show that variables are non-stationary, we precede Johansen co-integration test to analyze the long-run equilibrium relationship amid the variables.

| Sample       | Variables | ADF Test Level | ADF Test Δ |
|--------------|-----------|----------------|------------|
|              |           | Intercept      | Intercept  |
|              |           | Intercept with Trend | Intercept with Trend |
| Hong Kong    | lnFT      | -1.621595      | -3.482117 ** | -3.372594 *** |
|              | lnGDP     | 1.793236       | -3.752647 ** | -5.684279 *    |
|              | lnCO₂     | -1.746876      | -2.770019 ***| -4.779845 *     |
|              | lnEC      | -2.341277      | -3.084842 ***| -4.124641 **    |
|              | lnURBN    | -2.490371      | -3.485382 ***| -8.588034 ***   |
| Singapore    | lnFT      | -2.637976      | -3.173189 ** | -4.933238 ***   |
|              | lnGDP     | 0.192578       | -3.292680 ** | -3.326197 ***   |
|              | lnCO₂     | -0.575660      | -4.022784 *  | -3.968516 **    |
|              | lnEC      | -0.938232      | -5.009670 ***| -5.328170 ***   |
|              | lnURBN    | -1.799816      | -3.684012 ** | -5.326451 ***   |
| South Korea  | lnFT      | -1.929051      | -6.477435 *  | -6.373907 *     |
|              | lnGDP     | -0.419006      | -4.523819 *  | -4.466164 *     |
|              | lnCO₂     | -1.796247      | -3.063300 *  | -1.648152 ***   |
|              | lnEC      | -0.706494      | -6.577959 *  | -6.248520 *     |
|              | lnURBN    | -1.211805      | -2.730302 ***| -2.224946 **    |

*, **, *** indicate significance at 1%, 5%, 10% level, respectively.

3.2. Co-Integration Test Results

The Johansen co-integration method is used to test the presence of a long-run equilibrium relationship between series [59]. This test contains two likelihood statistics, namely trace statistics and the maximum Eigenvalue statistics. Both trace and maximum Eigenvalue test statistics indicate the number of co-integrating vectors of equations (r). As the Johansen co-integration test suggested choosing the optimal lag length for the vector autoregressive (VAR) selected using the Schwarz information criterion (SIC). The co-integration exists if both trace test and maximum Eigenvalue statistical test shows one co-integrating vector at a 5% significance level. The Johansen co-integration equation can be calculated as Equation (4).

\[
\Delta W_t = \alpha_0 + \alpha_1 t + \varphi_1 W_{t-1} + \varphi_2 W_{t-2} + \cdots + \varphi_k W_{t-k} + \epsilon_t
\]  

(4)
Where $\Delta$ is the difference operator, the endogenous variable $W_t$ is an $n \times 1$ vector, $\varphi_1$ is the number of regressors, the parameters $\alpha_0 + \alpha_1$ for the deterministic term representing the constant and time trend $(t)$ variables. The residual $\varepsilon_t$ indicates the random disturbance error terms. The coefficients estimations are $\varphi_1$, $\varphi_2$, $\varphi_k$, which contains the long-run relationship information amid the series in the $W_t$ vector. The summary of results from the Johansen co-integration test is further illustrated in Table 3. The outcomes indicate that all the variables for the individual sample groups are co-integrated since no co-integration hypothesis is rejected at a 5% significance level. However, the results of our study give a stronger proof of co-integration amid the studied variables. Thus, we can conclude that the series being analyzed embrace a long-run relationship.

### Table 3. Results of the Johansen co-integration test.

| Samples     | Years       | Lags | Hypothesis | Johansen Test Statistics | Note                                      |
|-------------|-------------|------|------------|---------------------------|-------------------------------------------|
|             |             |      |            | H₀          | H₁          | Trace  | 5%      | Max-Eigen | 5%       |                           |
| Hong Kong   | 1995–2017   | 1    | $r = 0$    | 109.1362    | 69.81889   | 54.13882| 33.87687 |           |           | Trace test indicates 2 cointegrating equations at the 0.05 level |
|             |             |      | $r > 0$    | 54.99742    | 47.85613   | 27.85060| 27.58434 |           |           | Max-eigenvalue test indicates 2 cointegrating equations at the 0.05 level |
|             |             |      | $r > 1$    | 27.14683    | 29.79707   | 19.07724| 21.13162 |           |           |                           |
|             |             |      | $r \leq 1$ | 8.069588    | 15.49471   | 7.159097| 14.26460 |           |           |                           |
|             |             |      |            | 0.910491    | 3.841466   | 0.910491| 3.841466 |           |           |                           |
| Singapore   | 1995–2017   | 1    | $r = 0$    | 92.95562    | 69.81889   | 46.50288| 33.87687 |           |           | Trace test indicates 1 cointegrating equation at the 0.05 level |
|             |             |      | $r > 0$    | 46.45274    | 47.85613   | 20.27193| 27.58434 |           |           | Max-eigenvalue test indicates 1 cointegrating equation at the 0.05 level |
|             |             |      | $r > 1$    | 26.18081    | 29.79707   | 15.17312| 21.13162 |           |           |                           |
|             |             |      | $r \leq 1$ | 11.00769    | 15.49471   | 8.836204| 14.26460 |           |           |                           |
|             |             |      |            | 2.171486    | 3.841466   | 2.171486| 3.841466 |           |           |                           |
| South Korea | 1995–2017   | 1    | $r = 0$    | 98.36770    | 69.81889   | 41.1485 | 33.87687 |           |           | Trace test indicates 2 cointegrating equations at the 0.05 level |
|             |             |      | $r > 0$    | 57.25285    | 47.85613   | 32.03406| 27.58434 |           |           | Max-eigenvalue test indicates 2 cointegrating equations at the 0.05 level |
|             |             |      | $r > 1$    | 25.21879    | 29.79707   | 12.8433 | 21.13162 |           |           |                           |
|             |             |      | $r \leq 1$ | 12.37046    | 15.49471   | 12.34756| 14.26460 |           |           |                           |
|             |             |      |            | 0.022893    | 3.841466   | 0.022893| 3.841466 |           |           |                           |

**Notes:** All the variables are with logarithms.

### 3.3. Fully Modified Ordinary Least Squares (FMOLS) Regression Outcomes

Since the variables are co-integrated, we then implemented the FMOLS tactic, which shows the long run FMOLS estimation of explanatory variables. This method was initially proposed by Pedroni for assorted co-integration vectors [60]. This study prefers FMOLS because it considers the indigeneity, serial correlation problem [61], and the most appropriate method to be used for small sample size [62]. Table 4 contains the results of three top economies; for the case of Hong Kong, the outcomes indicate that GDP is a positive and statistically significant influence on FT in the long run at a 1% level. The positive and significant coefficient of GDP indicates that there is a strong relationship between FT and GDP. A magnitude of 0.97 implies that freight transport increases by 0.97% when there is an increase of 1% in the GDP in Hong Kong. Also, we found that URBN have a positive but insignificant effect on FT. While EC is a positive and significant effect on FT, the coefficient of 1.69 reveals that FT increases by 1.69% if the EC volume increases by 1%.

### Table 4. Summary of fully modified ordinary least square (FMOLS) regression results.

| Sample       | lnGDP       | lnCO₂    | lnEC     | lnURBN | $R^2$ | Adj-$R^2$ |
|--------------|-------------|----------|----------|--------|------|-----------|
| Hong Kong    | 0.979376 *  | 0.779005 | 1.697001 | 0.83   | 0.81 |
| Singapore    | 0.428509 *  | 2.173917 | 0.340190 | 0.65   | 0.57 |
| South Korea  | 0.482706 *  | 1.175235 | 1.274457 | 0.82   | 0.77 |

* and ** indicate significance at 1%, 5% level, respectively. GDP = Gross Domestic Product, FT = Freight transport, CO₂ = carbon dioxide emissions, EC = Energy consumption, URBN = Urbanization.
For the Singapore case, economic prosperity positively affects freight transport at a 1% significance level. A magnitude of 0.42 indicates that freight transport may increase by 0.42% if the GDP increases by 1%. It is also found that FT increases if the CO<sub>2</sub> emissions increase because the effect is positive and significant. The significant coefficient indicates that FT increases by 2.17% if CO<sub>2</sub> emissions increase by 1%. Similarly, for the EC, we found that the effect of EC is positive and statistically significant at 1% level. Finally, the findings of South Korea indicate that FT is strongly accelerated by the GDP, CO<sub>2</sub> emissions, and EC. The magnitude of these indicators is positive and statistically significant at 1% level. For the GDP, the coefficient of 0.48 indicates that FT augments by 0.48% if the GDP increases by 1%. The coefficients of 1.17 and 1.27 indicate that FT increases by 1.17% and 1.27% if CO<sub>2</sub> emissions and EC increase by 1%.

3.4. Granger Causality Results

To infer the direction of causal association amid the variables, the Granger 1969 was the first to test for causality from X to Y and Y to X in a clear and straightforward term [63]. According to the Granger causality test, if the past value of variable X leads to the current value of variable Y and provides statistically significant information about Y’s future values, then the causality exists from X to Y. The following Equation of the Granger causality test is used to evaluate the direction of causality between variables:

\[
X_t = \sum_{j=1}^{m} \beta_j X_{t-j} + \sum_{j=1}^{m} \varphi_j Y_{t-j} + \varepsilon_{1t} \tag{5}
\]

\[
Y_t = \sum_{j=1}^{m} \alpha_j Y_{t-j} + \sum_{j=1}^{m} \gamma_j X_{t-j} + \varepsilon_{2t} \tag{6}
\]

where, \(X_t\) and \(Y_t\) represent observed values at time \(t\), \(m\) shows the number of lags, the estimated coefficients are \(\beta, \varphi, \alpha, \gamma\) in this study, and \(\varepsilon_t\) is an error term. Equation (5) is used to test the null hypothesis that \(Y\) does not Granger-causes \(X\) (\(\varphi_1 = \varphi_2 = \ldots = \varphi_m = 0\)) using t-test. If the null hypothesis is rejected, the alternative hypothesis \(H_1\) is in favor, indicating that at least one \(\varphi_i \neq 0\). Similarly, Equation (6) is used to test the null hypothesis that \(X\) does not Granger-causes \(Y\). The equations above can be set as the causal relationship between series \(X\) and \(Y\).

The econometric models are useful to find out the causality relationship between different variables such as EC, GDP, CO<sub>2</sub> emissions [64–66]. Table 5 summarizes the Granger causality test results of three Asian economies, whereas Figure 1 presents the causality direction amid all variables. According to the empirical results, we found that FT is driven by the GDP and energy consumption for all three economies. Also, bidirectional causality between GDP and FT exists in Singapore, indicating that GDP causes freight transport and as a result, freight transport causes GDP, which supports the feedback effect. In the case of Hong Kong and South Korea, GDP contributes significantly to freight transport, while the effect is insignificant in the opposite direction. The results follow the previous studies of Saidi and Hammami [8], Arvin et al. [67], Achour and Belloumi [68], who argue that a high level of GDP augments transport and vice versa. Concerning the causal relationship between URBN and GDP, we found bidirectional causality between the two series in Hong Kong and Singapore. The results also show bidirectional causality between GDP and CO<sub>2</sub> emissions in Singapore. The pairwise Granger causality confirms that there is a relationship that exists among freight transport, GDP, urbanization and CO<sub>2</sub> emissions for these selected economies. In addition, there is a unidirectional causality running from EC to FT in all three economies.
providing specific financing mechanisms. The results also manifest that the Korean government must

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According to our results, we can say that there is a significant relationship between economic prosperity and freight transport in the three economies. The results indicate that freight transport and economic prosperity increase transport CO\textsubscript{2} emissions in Hong Kong and Singapore. Thus, it is crucial to improve and develop sustainable freight transport (air, rail, and road), improve infrastructure, increase transportation ease and overall productivity of production units. The results of our study show that the freight transport causes environmental degradation. Thus, these findings recommend should encourage the use of green and sustainable practices (green fuel) in freight transport sector by providing specific financing mechanisms. The results also manifests that the Korean government must develop strategies to establish and encourage the development of rail (utilizing the biofuels) for good transportation. For example, to achieve future CO\textsubscript{2} emissions reduction targets, these three economies are suggested to reduce freight transport’s dependency on fossil fuels. The government should upgrade the freight industry from a traditional one to a modern one that can enhance transportation and energy efficiency. Besides, these economies should optimize the energy structure and freight transportation

Table 5. Results of pairwise Granger causality test.

| Sample    | Optimal Lag | Null-Hypothesis               | F-Statistics | P-Value | Causality |
|-----------|-------------|--------------------------------|--------------|---------|-----------|
| Hong Kong | 2           | GDP does not Cause FT          | 4.04714      | 0.0578 **| GDP→FT    |
|           |             | FT does not Cause GDP          | 0.61626      | 0.5523  |           |
|           |             | CO\textsubscript{2} does not Cause FT | 1.75135      | 0.2152  | FT→CO\textsubscript{2} |
|           |             | FT does not Cause CO\textsubscript{2} | 2.73448      | 0.0913 ***|           |
|           |             | EC does not Cause FT           | 2.78494      | 0.0917 ***| EC→FT    |
|           |             | FT does not Cause EC           | 0.61255      | 0.5542  |           |
|           |             | URBN does not Cause FT         | 8.20787      | 0.0035 *| URBN→FT   |
|           |             | FT does not Cause URBN         | 1.64829      | 0.2234  |           |
|           |             | GDP does not Cause CO\textsubscript{2} | 12.0554      | 0.0006 *| GDP→CO\textsubscript{2} |
|           |             | CO\textsubscript{2} does not Cause GDP | 0.40146      | 0.6759  |           |
|           |             | URBN does not Cause CO\textsubscript{2} | 9.15104      | 0.0022 *| URBN→CO\textsubscript{2} |
|           |             | CO\textsubscript{2} does not Cause URBN | 1.83883      | 0.1911  |           |
|           |             | URBN does not Cause GDP        | 4.30323      | 0.0320 **| URBN→GDP  |
|           |             | GDP does not Cause URBN        | 4.81873      | 0.0230 **|           |

| Singapore | 2           | GDP does not Cause FT          | 5.19789      | 0.0182 **| GDP→FT    |
|           |             | FT does not Cause GDP          | 3.71778      | 0.0472 **|           |
|           |             | CO\textsubscript{2} does not Cause FT | 0.50776      | 0.4848  |           |
|           |             | FT does not Cause CO\textsubscript{2} | 3.86827      | 0.0604 ***| FT→CO\textsubscript{2} |
|           |             | EC does not Cause FT           | 12.5516      | 0.0005 *| EC→FT    |
|           |             | FT does not Cause EC           | 0.00684      | 0.9932  |           |
|           |             | URBN does not Cause FT         | 0.50822      | 0.6110  |           |
|           |             | FT does not Cause URBN         | 4.11550      | 0.0361 **| FT→URBN   |
|           |             | GDP does not Cause CO\textsubscript{2} | 11.8325      | 0.0027 *| GDP→CO\textsubscript{2} |
|           |             | CO\textsubscript{2} does not Cause GDP | 7.22831      | 0.0145 **|           |
|           |             | URBN does not Cause CO\textsubscript{2} | 3.18001      | 0.0905 ***| URBN→CO\textsubscript{2} |
|           |             | CO\textsubscript{2} does not Cause URBN | 0.32960      | 0.5726  |           |
|           |             | URBN does not Cause GDP        | 4.68480      | 0.0250 **|           |
|           |             | GDP does not Cause URBN        | 4.96431      | 0.0210 **| URBN→GDP  |

| South Korea | 2           | GDP does not Cause FT          | 3.27051      | 0.0864 ***| GDP→FT    |
|             |             | FT does not Cause GDP          | 0.68637      | 0.4177  |           |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 0.47439      | 0.0699 ***|           |
|             |             | FT does not Cause FT           | 2.99148      | 0.4993  |           |
|             |             | FT does not Cause FT           | 1.71035      | 0.0999 ***| FT→URBN   |
|             |             | FT does not Cause EC           | 0.95653      | 0.2065  |           |
|             |             | URBN does not Cause FT         | 4.71228      | 0.3404  |           |
|             |             | FT does not Cause URBN         | 1.57714      | 0.0428 **| FT→URBN   |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 0.01810      | 0.2007  | GDP→CO\textsubscript{2} |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 0.65539      | 0.8944  |           |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 0.43036      | 0.4282  | URBN→CO\textsubscript{2} |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 0.05279      | 0.6204  |           |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 4.15482      | 0.0357 **| URBN→CO\textsubscript{2} |
|             |             | GDP does not Cause GDP CO\textsubscript{2} | 2.36175      | 0.1263  |           |

* * ** indicates 1%, 5%, and 10% significance levels respectively. → indicates unidirectional causality, ↔ denotes bidirectional causality, ~ means no causality. GDP = Gross Domestic Product, FT = Freight transport, CO\textsubscript{2} = carbon dioxide Emissions, EC = Energy consumption, URBN = Urbanization.
structure. Energy structure plays a significant role due to the heavy oil consumption. Therefore, effective and sustainable development (i.e., sustainable fuels) in the transport sector could enhance its sustainability. Moreover, urbanization growth is indispensable for the freight transport sector; therefore, governments should develop new ecological industry cities and well-planned compact cities. The main implication of our study is that improving economic prosperity and freight transport is a very challenging issue, and the impact of micro, as well as macro-level factors such as logistics and economic policies, should not be neglected for a comprehensive analysis.

Figure 1. Summary of the Granger causalities in Hong Kong, Singapore, and South Korea.

4. Conclusions

The purpose of this study is to investigate the relationship between freight transport (FT), economic prosperity (GDP), carbon dioxide (CO₂) emissions, energy consumption (EC), and urbanization (URBN) for three top Asian economies, namely Hong Kong, South Korea, and Singapore, in a multivariate framework using annual data from 1995 to 2017. The empirical findings indicate that GDP and EC have positive and significant effects on freight transport for all three economies. It is found that freight transport is mainly influenced by GDP and energy consumption. Besides, there is unidirectional causality from FT to CO₂ emissions in Hong Kong and Singapore. The main results note the existence of bidirectional causality between GDP and FT in Singapore but a unidirectional causality running from GDP to FT in the case of Hong Kong and South Korea. Concerning the relationship between GDP and CO₂ emissions, there is bidirectional causality in the case of Singapore. Moreover, the results also show bidirectional causality between GDP and URBN for Hong Kong and Singapore.
This present study provides important policy implications and contributes to accelerating the current literature. First, the significant impact of GDP on freight transport suggests the vital role of the transport sector in economic development. It represents that the nexus between freight transport and GDP may be affected by technological advancements. However, the literature suggests that efficient and sustainable technologies in the transportation sector can enhance sustainability over the long term in Asian countries. Freight transport mainly influences energy consumption (fossil fuels); thus, the usage of green technologies in the transport sector intensifies energy efficiency. These policies allow a greater significant role of transport in the global economic activity. On the other hand, some instruments (such as fiscal, economic, regulatory, and technological factors) should be adopted, because the amendment of energy efficiency in the transport sector depends on these factors. Simultaneously, energy efficiency and environmental influence of transport are impacted by several useful transport planning decisions, land usage, taxes, prices, fuel quality, subsidies, and investment in innovations. Further, to mitigate transport energy consumption, the government should implement environmental regulatory policies to deal with energy consumption and road emissions reduction, especially for the commercial freight transport sector. Finally, urban areas play an essential role in increasing the freight transport sector; therefore, they need to implement sustainable urbanization growth policies and reduce the unplanned urban sprawls.

However, there are also some limitations that future studies could pay more attention. As this study only used freight transport by air for the analysis, a future study could include data of freight transport by road and rail. Moreover, as Hong Kong and Singapore freight transport include significant portions of international freight, future research could include the overall CO\(_2\) emissions, including international aviation carbon emissions. By conducting further research in these directions, an improved understanding of the causal relationship between freight transport, CO\(_2\) emissions, energy consumptions and GDP will be obtained, and the planning of future transport systems will be conducted under proper advice.

Besides, Maziarz [69] stated that the Granger causality is not necessarily a true causality. For future research, all micro-level factors, as well as macro-level ones (i.e., oil types, future energy policies, vehicle types, and advancement and incentives for green technologies, etc.) which directly and indirectly impact the freight and economic prosperity should be included for comprehensive policy implications in the transport sector.

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**References**

1. Timilsina, G.R.; Shrestha, A. Transport sector CO\(_2\) emissions growth in Asia: Underlying factors and policy options. *Energy Policy* **2009**, *37*, 4523–4539. [CrossRef]

2. International Energy Agency (IEA). *Key World Energy Statistics 2017 Energy Statistics*; International Energy Agency: Paris, France, 2017.

3. Nasreen, S.; Mbarek, M.B.; Atiq-ur-Rehman, M. Long-run causal relationship between economic growth, transport energy consumption and environmental quality in Asian countries: Evidence from heterogeneous panel methods. *Energy* **2020**, *192*, 116628. [CrossRef]

4. Herold, D.M.; Lee, K.H. The influence of internal and external pressures on carbon management practices and disclosure strategies. *Australas. J. Environ. Manag.* **2019**, *26*, 63–81. [CrossRef]
5. Herold, D.M.; Farr-Wharton, B.; Lee, K.H.; Groschopf, W. The interaction between institutional and stakeholder pressures: Advancing a framework for categorising carbon disclosure strategies. *Bus. Strateg. Dev.* 2019, 2, 77–90. [CrossRef]

6. Begum, R.A.; Sohag, K.; Abdullah, S.M.S.; Jaafar, M. CO$_2$ emissions, energy consumption, economic and population growth in Malaysia. *Renew. Sustain. Energy Rev.* 2015, 41, 594–601. [CrossRef]

7. Ozturk, I.; Acaravci, A. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Econ.* 2013, 36, 262–267. [CrossRef]

8. Saidi, S.; Hammami, S. Modeling the causal linkages between transport, economic growth and environmental degradation for 75 countries. *Transp. Res. Part D Transp. Environ.* 2017, 53, 415–427. [CrossRef]

9. IEA. CO$_2$ Emissions from Fuel Combustions: Overview; International Energy Agency: Paris, France, 2020; p. 3.

10. Anwar, A.; Mustafa, Y.; Inayat, U. Impact of urbanization and economic growth on CO$_2$ emission: A case of far east Asian countries. *Intern. J. Environ. Res. Pub. Health* 2020, 17, 2531. [CrossRef]

11. Zhang, C.; Nian, J. Panel estimations for transport sector CO$_2$ emissions and its affecting factors: A regional analysis in China. *Energy Policy* 2013, 63, 918–926. [CrossRef]

12. McKinnon, A.C. Decoupling of road freight transport and economic growth trends in the UK: An exploratory analysis. *Transp. Rev.* 2007, 27, 37–64. [CrossRef]

13. Alises, A.; Vassallo, J.M. Comparison of road freight transport trends in Europe. Coupling and decoupling factors from an Input-Output structural decomposition analysis. *Transp. Res. Part A Policy Pract.* 2015, 82, 141–157. [CrossRef]

14. Wu, H.M.; Xu, W. Cargo Transport Energy Consumption Factors Analysis: Based on LMDI Decomposition Technique. *IERI Procedia* 2014, 9, 168–175. [CrossRef]

15. Pérez, A.A.; Magro, J.M.V.; Valderrama, A.F.G. Road freight transport decoupling: A comparative analysis between the United Kingdom and Spain. *Transp. Policy* 2014, 32, 186–193.

16. Chandran, V.G.R.; Tang, C.F. The impacts of transport energy consumption, foreign direct investment and income on CO$_2$ emissions in ASEAN-5 economies. *Renew. Sustain. Energy Rev.* 2013, 24, 445–453. [CrossRef]

17. Koilo, V. Evidence of the Environmental Kuznets Curve: Unleashing the Opportunity of Industry 4.0 in Emerging Economies. *J. Risk Financ. Manag.* 2019, 12, 122. [CrossRef]

18. Dogan, E.; Turkekul, B. CO$_2$ emissions, real output, energy consumption, trade, urbanization and financial development: Testing the EKC hypothesis for the USA. *Environ. Sci. Pollut. Res.* 2016, 23, 1203–1213. [CrossRef]

19. Narayanan, P.K.; Narayan, S. Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. *Energy Policy* 2010, 38, 661–666. [CrossRef]

20. Linton, C.; Grant-Muller, S.; Gale, W.F. Approaches and techniques for modelling CO$_2$ emissions from road transport. *Transp. Rev.* 2015, 35, 533–553. [CrossRef]

21. IEA. *The Future of Rail Opportunities for Energy and the Environment*; International Energy Agency: Paris, France, 2019.

22. Steenhof, P.; Woudsma, C.; Sparling, E. Greenhouse gas emissions and the surface transport of freight in Canada. *Transp. Res. Part D Transp. Environ.* 2006, 11, 369–376. [CrossRef]

23. Sorrell, S.; Lehtonen, M.; Stapleton, L.; Pujol, J.; Champion, T. Decomposing road freight energy use in the United Kingdom. *Energy Policy* 2009, 37, 3115–3129. [CrossRef]

24. Gleave, S.D. *Freight Transport Intensity of Production and Consumption: Report no EUR 20864EN*; Institute for Prospective Technological Studies, Joint Research Centre: Seville, Spain, 2003.

25. Banister, D.; Stead, D. Reducing transport intensity. *Eur. J. Transp. Infrastruct. Res.* 2002, 2, 161–178.

26. Hao, H.; Geng, Y.; Li, W.; Guo, B. Energy consumption and GHG emissions from China’s freight transport sector: Scenarios through 2050. *Energy Policy* 2015, 85, 94–101. [CrossRef]

27. Tongwane, M.; Piketh, S.; Stevens, L.; Ramotubei, T. Greenhouse gas emissions from road transport in South Africa and Lesotho between 2000 and 2009. *Transp. Res. Part D Transp. Environ.* 2015, 37, 1–13. [CrossRef]

28. Shahbaz, M.; Khraief, N.; Jemaa, M.M. Ben On the causal nexus of road transport CO$_2$ emissions and macroeconomic variables in Tunisia: Evidence from combined cointegration tests. *Renew. Sustain. Energy Rev.* 2015, 51, 89–100. [CrossRef]

29. Mustapa, S.I.; Bekhet, H.A. Analysis of CO$_2$ emissions reduction in the Malaysian transportation sector: An optimisation approach. *Energy Policy* 2016, 89, 171–183. [CrossRef]
30. Beyzatlar, M.A.; Karacal, M.; Yetkiner, H. Granger-causality between transportation and GDP: A panel data approach. *Transp. Res. Part A Policy Pract.* **2014**, *63*, 43–55. [CrossRef]

31. Iacono, M.; Levinson, D. Mutual causality in road network growth and economic development. *Transp. Policy* **2016**, *45*, 209–217. [CrossRef]

32. Mraihi, R. Transport Intensity and Energy Efficiency: Analysis of Policy Implications of Coupling and Decoupling. In *Energy Efficiency—The Innovative Ways for Smart Energy, the Future Towards Modern Utilities*; Eissa, M., Ed.; BoD—Books on Demand: Norderstedt, Germany, 2012.

33. Lee, M.K.; Yoo, S.H. The role of transportation sectors in the Korean national economy: An input-output analysis. *Transp. Res. Part A Policy Pract.* **2016**, *93*, 13–22. [CrossRef]

34. Herold, D.M.; Lee, K.H. A three-dimensional risk management model of port logistics for hazardous goods. *Marit. Policy Manag.* **2017**, *44*, 221–241. [CrossRef]

35. Nasreen, S.; Saidi, S.; Ozturk, I. Assessing links between energy consumption, freight transport, and economic growth: Evidence from dynamic simultaneous equation models. *Environ. Sci. Pollut. Res.* **2018**, *25*, 16825–16841. [CrossRef]

36. Hensher, D.A. Climate change, enhanced greenhouse gas emissions and passenger transport—What can we do to make a difference? *Transp. Res. Part D Transp. Environ.* **2008**, *13*, 95–111. [CrossRef]

37. Kveiborg, O.; Fosgerau, M. Decomposing the decoupling of Danish road freight traffic growth and economic growth. *Transp. Policy* **2007**, *14*, 39–48. [CrossRef]

38. Bennathan, E.; Fraser, J.; Thompson, L.S. What Determines Demand for Freight Transport; World Bank Publications: Washington, DC, USA, 1992.

39. Kulsreshtha, M.; Nag, B. Structure and dynamics of non-suburban passenger travel demand in Indian railways. *Transportation* **2000**, *27*, 221–241. [CrossRef]

40. Yao, V.W. The Causal Linkages Between Freight and Economic Fluctuations. *Int. J. Transp. Econ.* **2005**, *32*, 143–159.

41. Hayaloglu, P. The impact of developments in the logistics sector on economic growth: The case of OECD countries. *Int. J. Econ. Financ. Issues* **2015**, *5*, 523–530.

42. McKinnon, A.C.; Woodburn, A. Logistical restructuring and road freight traffic growth: An empirical assessment. *Transportation* **1996**, *23*. [CrossRef]

43. Sun, H.; Li, M.; Xue, Y. Examining the factors influencing transport sector CO$_2$ emissions and their efficiency in central China. *Sustainability* **2019**, *11*, 4712. [CrossRef]

44. Hasan, M.A.; Frame, D.J.; Chapman, R.; Archie, K.M. Emissions from the road transport sector of New Zealand: Key drivers and challenges. *Environ. Sci. Pollut. Res.* **2019**, *26*, 23937–23957. [CrossRef]

45. Beckien, D.; Ewald, M.; Edenhofer, O.; Lüdeke, M.K.B. What parameters influence the spatial variations in CO$_2$ emissions from road traffic in Berlin? Implications for urban planning to reduce anthropogenic CO$_2$ emissions. *Urban. Stud.* **2007**, *44*, 339–355. [CrossRef]

46. Liu, J.; Zhou, H.; Sun, H. A three-dimensional risk management model of port logistics for hazardous goods. *Marit. Policy Manag.* **2019**, *46*, 715–734. [CrossRef]

47. Wang, S.; Fang, C.; Guan, X.; Pang, B.; Ma, H. Urbanisation, energy consumption, and carbon dioxide emissions in China: A panel data analysis of China’s provinces. *Appl. Energy* **2014**, *136*, 738–749. [CrossRef]

48. Benali, N.; Feki, R. Evaluation of the relationship between freight transport, energy consumption, economic growth and greenhouse gas emissions: The VECM approach. *Environ. Dev. Sustain.* **2018**, *22*, 1039–1049. [CrossRef]

49. Saidi, S.; Shahbaz, M.; Akhtar, P. The long-run relationships between transport energy consumption, transport infrastructure, and economic growth in MENA countries. *Transp. Res. Part A Policy Pract.* **2018**, *111*, 78–95. [CrossRef]

50. World Development Indicators Database: 2017; World Bank Group: Washington, DC, USA, 2017.

51. *Annual Energy Outlook 2019 with Projections to 2050*; US Energy Information Administration: Washington, DC, USA, 2019.

52. Omri, A.; Daly, S.; Rault, C.; Chaibi, A. Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. *Energy Econ.* **2015**, *48*, 242–252. [CrossRef]

53. Zoundi, Z. CO$_2$ emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach. *Renew. Sustain. Energy Rev.* **2017**, *72*, 1067–1075. [CrossRef]
54. Sarker, S.A.; Wang, S.; Adnan, K.M.M. Energy Consumption and Economic Growth Nexus in Bangladesh. *J. Syst. Sci. Inf.* 2019, 7, 497–509. [CrossRef]
55. Lotfalipour, M.R.; Falahi, M.A.; Ashena, M. Economic growth, CO₂ emissions, and fossil fuels consumption in Iran. *Energy* 2010, 35, 5115–5120. [CrossRef]
56. Lee, J.W. The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. *Energy Policy* 2013, 55, 483–489. [CrossRef]
57. Shahbaz, M.; Solarin, S.A.; Mahmood, H.; Arouri, M. Does financial development reduce CO₂ emissions in Malaysian economy? A time series analysis. *Econ. Model.* 2013, 35, 145–152. [CrossRef]
58. Dickey, D.A.; Fuller, W.A. Distribution of the estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc.* 1979, 74, 427–431.
59. Johansen, S. Statistical analysis of cointegration vectors. *J. Econ. Dyn. Control.* 1988, 12, 231–254. [CrossRef]
60. Pedroni, P. Purchasing power parity tests in cointegrated panels. *Rev. Econ. Stat.* 2001, 83, 727–731. [CrossRef]
61. Bashier, A.; Siam, A.J. Immigration and economic growth in Jordan: FMOLS approach. *Int. J. Humanit. Soc. Sci. Educ.* 2014, 1, 85–92.
62. Mensah, C.N.; Long, X.; Boamah, K.B.; Bediako, I.A.; Dauda, L.; Salman, M. The effect of innovation on CO₂ emissions of OECD countries from 1990 to 2014. *Environ. Sci. Pollut. Res.* 2018, 25, 29678–29698. [CrossRef]
63. Granger, C.W.J. Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica* 1969, 37, 424. [CrossRef]
64. Mahadevan, R.; Asafu-Adjaye, J. Energy consumption, economic growth and prices: A reassessment using panel VECM for developed and developing countries. *Energy Policy* 2007, 35, 2481–2490. [CrossRef]
65. Pao, H.-T.; Yu, H.-C.; Yang, Y.-H. Modeling the CO₂ emissions, energy use, and economic growth in Russia. *Energy* 2011, 36, 5094–5100. [CrossRef]
66. Ang, J.B. Economic development, pollutant emissions and energy consumption in Malaysia. *J. Policy Model.* 2008, 30, 271–278. [CrossRef]
67. Arvin, M.B.; Pradhan, R.P.; Norman, N.R. Transportation intensity, urbanization, economic growth, and CO₂ emissions in the G-20 countries. *Util. Policy* 2015, 35, 50–66. [CrossRef]
68. Achour, H.; Belloumi, M. Investigating the causal relationship between transport infrastructure, transport energy consumption and economic growth in Tunisia. *Renew. Sustain. Energy Rev.* 2016, 56, 988–998. [CrossRef]
69. Maziarz, M. A review of the Granger-causality fallacy. *J. Philos. Econ. Reflect. Econ. Soc. Issues* 2015, 8, 86–105.

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