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Evaluating the Relationship between Freight Transport, Economic Prosperity, Urbanization, and CO$_2$ Emissions: Evidence from Hong Kong, Singapore, and South Korea

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Abstract: This paper analyzes the relationship between freight transport, economic prosperity, carbon dioxide (CO$_2$) 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 CO$_2$ 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 CO$_2$ emissions, especially in Asian countries, which are alarming. The transport sector is one of the mjor sector for CO$_2$ 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_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_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_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_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_2 emissions and the elimination of freight traffic in these nations, by minimizing CO_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_2 emissions and their environmental impact. The close relationship between economic activity and transport considerably increases energy demand and CO_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_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_2 emissions. Mustapa and Bekhet [29] have addressed some valuable strategy options to reduce Malaysia's CO_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 CO_2 emissions. Hasan et al. [44] result indicated that, with the increase of the urban population, CO_2 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 CO_2 emissions in Berlin city. Wang et al. [47] results also manifested that urban form is the main factor for transport CO_2 emissions.

Although the influential factor behind CO_2 emissions in the transport sector has been discussed in previous literature, few studies have evaluated the relationship between transport, urbanization, energy consumption, and CO_2 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 CO_2 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 CO_2 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, CO_2 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 (CO_2) 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.

Table 1. Variables source and description.

Variable	Description	Unit	Source
FT	Freight transport by air	Million ton-kilometers	WDI
GDP	Gross domestic product	US$ based on purchasing power parity (PPP) 2005 price	WDI
CO_2	Total Carbon dioxide emissions from transport	% of total fuel combustion	WDI
EC	Energy consumption	Kg of oil equivalent per capita	EIA, WDI
URBN	Population in urban agglomerations of more than 1 million	% of the total population	WDI

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:

$$FT = f(GDP, CO_2, EC, URBN) \tag{1}$$

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

$$FT_t = \alpha'_0 + \alpha'_1 GDP_t + \alpha'_2 CO_{2t} + \alpha'_3 EC_t + \alpha'_4 URBN_t + \varepsilon'_t \tag{2}$$

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:

$$ln FT_t = \alpha_0 + \alpha_1 ln GDP_t + \alpha_2 ln CO_{2t} + \alpha_3 ln EC_t + \alpha_4 ln URBN_t + \varepsilon_t \tag{3}$$

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, α_0 and ε_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 α_1, α_2, α_3, and α_4, respectively. The expected sign for α_1 is positive; the sign for α_2 can be either positive or negative. While the sign for α_3 should be positive, the sign for α_4 should be positive or negative. The parameter α_0 permits for possible state fixed effect, and ε_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 stationery 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.

Table 2. Results of the augmented Dickey–Fuller (ADF) unit root test.

Sample	Variables	ADF Test Level		ADF Test Δ	
		Intercept	Intercept with Trend	Intercept	Intercept with Trend
Hong Kong	lnFT	−1.621595	−2.112267	−3.482117 **	−3.372594 ***
	lnGDP	1.793236	−0.836424	−3.752647 **	−5.684279 *
	$lnCO_2$	−1.746876	−1.833922	−2.770019 ***	−4.779845 *
	lnEC	−2.341277	−1.952472	−3.084842 ***	−4.124641 **
	lnURBN	−2.490371	−2.987367	−3.485382 **	−8.588034 ***
Singapore	lnFT	−2.637976	−0.927751	−3.173189 **	−4.933238 ***
	lnGDP	0.192578	−2.646660	−3.292680 **	−3.326197 ***
	$lnCO_2$	−0.575660	−2.190968	−4.022784 *	−3.968516 **
	lnEC	−0.938232	−1.654182	−5.009670 ***	−5.328170 ***
	lnURBN	−1.799816	−2.121417	−3.684012 **	−3.526451 ***
South Korea	lnFT	−1.929051	−2.724326	−6.477435 *	−6.373907 *
	lnGDP	−0.418006	−2.763469	−4.523819 *	−4.466164 *
	$lnCO_2$	−1.796247	−1.243045	−3.063300 *	−1.648152 ***
	lnEC	−0.706494	−1.863644	−6.577959 *	−6.248520 *
	lnURBN	−1.211805	−2.276505	−2.730032 ***	−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).

$$\Delta W_t = \alpha_0 + \alpha_1 t + \varphi_1 w_{t-1} + \varphi_2 w_{t-2} + \cdots + \varphi_K w_{t-k} + \varepsilon_t \tag{4}$$

Where Δ is the difference operator, the endogenous variable W_t is an $n \times 1$ vector, φ_k 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 ε_t indicates the random disturbance error terms. The coefficients estimations are φ_1, φ_2, φ_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
			H_0	H_1	Trace	5%	Max-Eigen	5%	
Hong Kong	1995–2017	1	r = 0 r ≤ 1	r > 0 r > 1	109.1362 54.99742 27.14683 8.069588 0.910491	69.81889 47.85613 29.79707 15.49471 3.841466	54.13882 27.85060 19.07724 7.159097 0.910491	33.87687 27.58434 21.13162 14.26460 3.841466	Trace test indicates 2 cointegrating equations at the 0.05 level Max-eigenvalue test indicates 2 cointegrating equations at the 0.05 level
Singapore	1995–2017	1	r = 0 r ≤ 1	r > 0 r > 1	92.95562 46.45274 26.18081 11.00769 2.171486	69.81889 47.85613 29.79707 15.49471 3.841466	46.50288 20.27193 15.17312 8.836204 2.171486	33.87687 27.58434 21.13162 14.26460 3.841466	Trace test indicates 1 cointegrating equation at the 0.05 level Max-eigenvalue test indicates 1 cointegrating equation at the 0.05 level
South Korea	1995–2017	1	r = 0 r ≤ 1	r > 0 r > 1	98.36770 57.25285 25.21879 12.37046 0.022893	69.81889 47.85613 29.79707 15.49471 3.841466	41.11485 32.03406 12.84833 12.34756 0.022893	33.87687 27.58434 21.13162 14.26460 3.841466	Trace test indicates 2 cointegrating equations at the 0.05 level Max-eigenvalue test indicates 2 cointegrating equations at the 0.05 level

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.

Dependent Variable *ln*FT						
Sample	lnGDP	lnCO$_2$	lnEC	lnURBN	R^2	Adj-R^2
Hong Kong	0.979376 *	0.779005	1.697001 **	11.87148	0.83	0.81
Singapore	0.428509 *	2.173917 *	0.340190 *	7.250403 **	0.65	0.57
South Korea	0.482706 *	1.175235 *	1.274457 *	8.535497 *	0.82	0.77

* and ** indicate significance at 1%, 5% level, respectively. GDP = Gross Domestic Product, FT = Freight transport, CO_2 = 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_2 emissions increase because the effect is positive and significant. The significant coefficient indicates that FT increases by 2.17% if CO_2 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_2 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 increase by 1%. The coefficients of 1.17 and 1.27 indicate that FT increases by 1.17% and 1.27% if CO_2 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 β, φ a, and γ in this study, and ε_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_2 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_2 emissions in Singapore. The pairwise Granger causality confirms that there is a relationship that exists among freight transport, GDP, urbanization and CO_2 emissions for these selected economies. In addition, there is a unidirectional causality running from EC to FT in all three economies.

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	0.0378 **	GDP→FT
		FT does not Cause GDP	0.61626	0.5523	
		CO_2 does not Cause FT	1.75135	0.2152	FT→CO_2
		FT does not Cause CO_2	2.71448	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_2	12.0554	0.0006 *	GDP→ CO_2
		CO_2 does not Cause GDP	0.40146	0.6759	
		URBN does not Cause CO_2	9.15104	0.0022 *	URBN→ CO_2
		CO_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_2 does not Cause FT	0.50776	0.4848	FT→ CO_2
		FT does not Cause CO_2	3.98627	0.0604 ***	
		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→URBN
		FT does not Cause URBN	4.11550	0.0361 **	
		GDP does not Cause CO_2	11.8325	0.0027 *	GDP↔ CO_2
		CO_2 does not Cause GDP	7.22831	0.0145 **	
		URBN does not Cause CO_2	3.18001	0.0905 ***	URBN→CO_2
		CO_2 does not Cause URBN	0.32960	0.5726	
		URBN does not Cause GDP	4.68480	0.0250 **	URBN↔ GDP
		GDP does not Cause URBN	4.96431	0.0210 **	
South Korea	2	GDP does not Cause FT	3.27051	0.0864 ***	GDP→FT
		FT does not Cause GDPCO2	0.68637	0.4177	
		does not Cause FT	0.47439	0.0699 ***	CO_2→ FT
		FT does not Cause CO_2	2.99148	0.4993	
		EC does not Cause FT	1.71035	0.0999 ***	EC→FT
		FT does not Cause EC	0.95653	0.2065	
		URBN does not Cause FT	4.71228	0.3404	FT→URBN
		FT does not Cause URBN	1.57714	0.0428 **	
		GDP does not Cause CO_2	0.01810	0.2007	GDP~CO_2
		CO_2 does not Cause GDP	0.65539	0.8944	
		URBN does not Cause CO_2	0.43036	0.4282	URBN~CO_2
		CO_2 does not Cause URBN	0.05279	0.8204	
		URBN does not Cause GDP	4.13482	0.0357 **	URBN→GDP
		GDP does not Cause URBN	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_2 = carbon dioxide Emissions, EC = Energy consumption, URBN = Urbanization.

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_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_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

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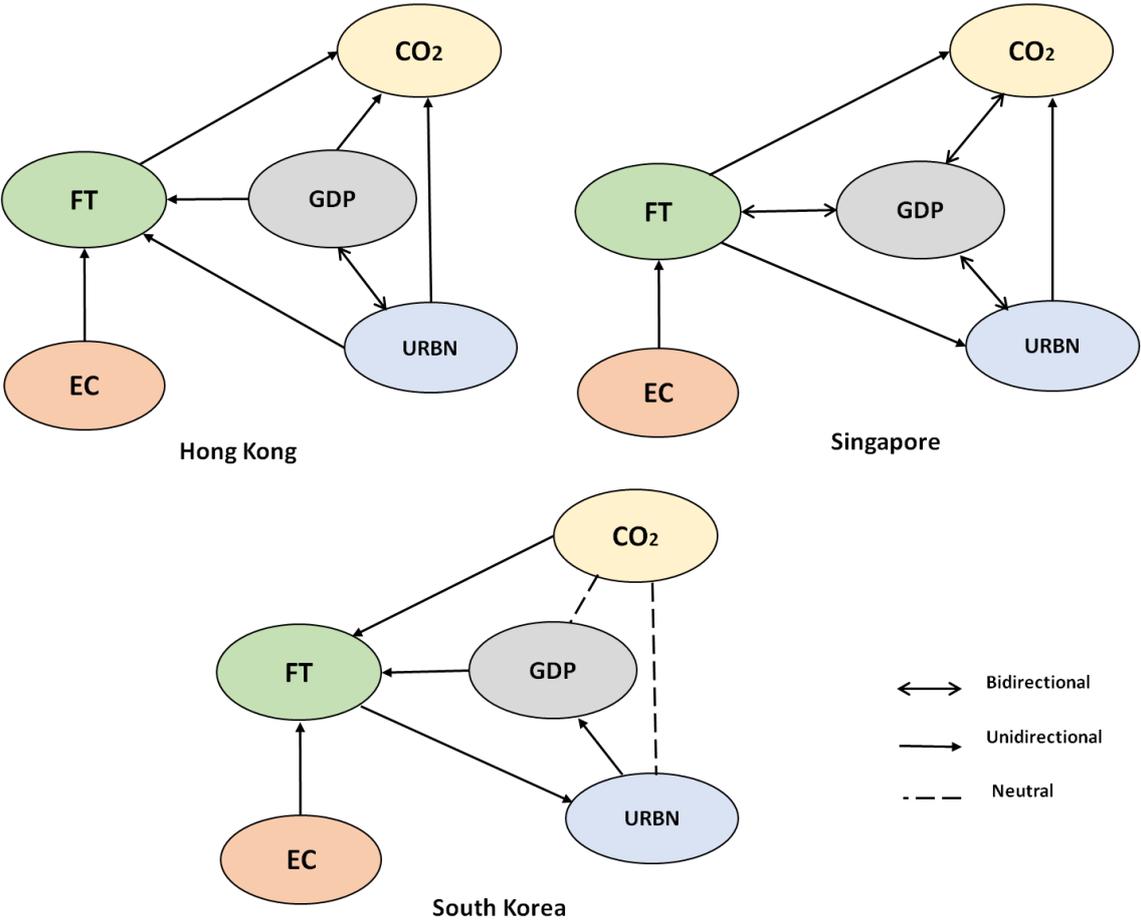
Figure 1. Summary of the Granger causalities in Hong Kong, Singapore, and South Korea.

4. Conclusions

The purpose of this study is to investigate the relationship between freight transport (FT), economic prosperity (GDP), carbon dioxide (CO_2) 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 CO_2 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 CO_2 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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