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An application of gravity models to freight data in Malaysia

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Background: Freight transport services and international trade are among important factors in pushing economies' transition forward. Malaysia's strategic location along key maritime routes positions it as a vital hub for international shipping and logistics, facilitating efficient trade between Asia, Europe and the Middle East.

Objectives: Despite extensive global studies on freight and trade, little specific research exists from Malaysia's perspective. Thus, this study aims to evaluate how factors such as economic size of trade partners and distance impact Malaysia's freight transport in international trade, using the gravity model, a tool for analysing bilateral trade flows.

Method: Three types of gravity models are employed to assess the impact of economic scale, infrastructure and demographic factors on freight transport. Then the validity of these relationships is further evaluated.

Results: The random effect model (REM) is found to be the best fitted model. The study identifies infrastructure and economic scale as pivotal factors influencing both freight export and import. The result showed the volume of container handled in ports is the main determinant in both export and import of freight, whereas air freight has significant impact to boost the export of freight. Distance is statistically significant, however, with marginally small impact.

Conclusion: Based on the analysis, we can conclude that the robust port infrastructure and efficient logistical facilities are important in reducing freight costs and enhancing Malaysia's international trade competitiveness.

Contribution: This study mainly contributes on providing empirical evidence and in-depth insight on Malaysia freight transport services through the application of gravity models.

Keywords: freight transport; gravity model; economic scale; infrastructure; machine learning.

Introduction

Over the last few decades, a significant surge in a global economic interaction has resulted in the exponential expansion of cross border economic activities (International Monetary Fund [IMF] 2008). The efficient movement of goods has become imperative for economic growth and development. Transportation systems are recognised as critical determinants of international trade flows (Rodrigue 2012). Freight transport services and international trade are critical in driving economic growth and development especially in facilitating Malaysia's economic transition and integration into global markets. Efficient logistics and freight transport services play a vital role in Malaysia's economy, particularly because of its abundant natural resources. As a leading exporter of liquefied natural gas (LNG), the largest producer of palm oil and significant producer of petroleum and rubber, Malaysia relies heavily on robust logistics infrastructure to facilitate the movement of these goods to global markets. This synergy between natural resources and logistics underscores the pivotal role of freight transport in driving economic growth and facilitating international trade for Malaysia.

According to UNCTAD (2021), transportation costs for commodities vary across countries according to route, direction and commodity. In addition, the distance between countries is not the only factor that affects the cost of freight transport. Previous studies emphasise that the factors determining the cost of freight transport differ systematically with the market structure of the transport sector (Hummels 2007), according to the transport route (Hafner, Kleinert & Spies 2022), bilateral trade imbalance (Behrens & Picard 2011; Jonkeren et al. 2011; Brancaccio, Kalouptsidi & Papageorgiou 2020) and port infrastructure of exporting and importing countries (Donaubauer et al. 2016).

The gravity model has become one of the most successful tools for estimating bilateral trade relations. The gravity model was widely used in determining the transport cost, and it includes works by Clark, Dollar and Micco (2004), Ganapati, Shapiro and Walker (2020), Martínez-Zarzoso and Wilmsmeier (2010), Pomfret and Sourdin (2008) and Wilmsmeier, Hoffmann and Sanchez (2006). The gravity model of trade is an economic model that estimates the volume of trade between two countries based on their economic size and distance. The gross domestic product (GDP) of trading countries is used as a measure of their economic size reflecting their capacity to produce and consume goods and services. Meanwhile, physical distance between the countries often measured in kilometres serve as a proxy for transportation cost and time. Besides that, other factors also influence international trade such as trade language, sharing common language and historical colonial relationships.

Researcher has adapted the gravity model to analyse freight transport by including additional variable that affect freight transport. The model helps in understanding how different factors influence the cost of moving goods between countries. For instance, Clark et al. (2004) examined the impact of trade volumes on transport costs, finding that routes with lower trade volumes have higher costs, indicating significant economies of scale. Ganapati et al. (2020) investigated how technological advancements and trade policies affect transportation costs, exploring the impact of energy costs and technological changes on manufacturing and transport expenses. Meanwhile, Martínez-Zarzoso and Wilmsmeier (2010) focused on the determinants of maritime transport costs, including factors such as distance, trade volume and port efficiency, providing insights into how these variables influence shipping costs. Pomfret and Sourdin (2008) studied the effects of infrastructure quality and the regulatory environment on transport costs, highlighting the importance of efficient logistics and supportive trade policies. Wilmsmeier et al. (2006) analysed regional differences in transport costs and their impact on trade flows, considering factors such as port characteristics and infrastructure, emphasising the role of regional infrastructure in shaping transport expenses. According to Fikru (2021), the effect of freight and other market competitiveness is measured with basic factors such as GDP, timelines, landlocked infrastructure and distance.

According to Malaysia External Trade Development Corporation (MATRADE), Malaysia achieved a significant milestone in international trade by surpassing RM2 trillion for the first time indicating robust performance in 2021. This was contributed to the increase in exports of transportation particularly in freight and support services. As published by Department of Statistics Malaysia (DOSM), exports of transportation jumped from RM10.3 billion in 2010 to RM16.5 billion in 2021 (Malaysia's International Trade in Services Statistics 2022). Despite the robust performance in international trade, Malaysia remains a net importer of services rendered by foreign providers. Over recent years, the rising trade deficit has become a significant concern for many countries, including Malaysia. The country's services trade balance, which is calculated as exports minus imports, has recorded a deficit for the past 11 consecutive years since 2012. This means that Malaysia has been importing more services than it exports. One of the primary contributors to this ongoing deficit in Malaysia's International Trade in Services is the transportation component particularly freight transport, where the costs of importing these services exceed the revenue generated from exporting.

Despite the importance of freight transport in Malaysia's trade and economy, there is a lack of comprehensive studies focusing on this sub sector's determinants and its impact on trade. The existing literature has primarily focused on logistics performance (Abu Bakar & Jaafar 2016), logistic services quality (Rahmat & Faisol 2014), logistics development (Zuraimi, Rafi & Dahlan 2013), issues and challenges in the logistics sector (Ong, Zailani & Kanapathy 2020), the contribution of dry ports (Jeevan et al. 2021; Zainuddin et al. 2010) and development of inland ports Nizamudin et. al., 2019). The study by Ong et al. (2020) suggested additional investigations focusing on a correlational analysis for freight logistics particularly examining key performance indicators in the Malaysian context. However, the determinants of freight transport costs and their implications for Malaysia's trade balance have not been thoroughly explored.

Therefore, this study attempts to close the gap in the empirical analysis by applying the gravity model to identify the impact of the determinants of freight transport. In the context of Malaysia, this application remains unexplored in terms of the bilateral freight transport data that represent a niche area in services. This study aims to analyse the impacts of the determinants of freight transport using the gravity model for the three main factors that is economic scale, infrastructure and demographic. The variables affecting freight transport categorised into three main factors comprises of economic scale, demography and infrastructure. The economic scale factors include total trade, trade imbalance, GDP and exchange rate. While demographic factors are represented by the distance between trading partners, the presence of a shared border and a common language. The infrastructure factor encompasses the volume of container handling at ports, airports and rail facilities. Malaysia is a net exporter country, and it will be interesting to understand how effective the gravity model explains the impact of freight transport with top trading partners. In the current environment, freight transport must adopt a more holistic approach to sustainability instead of its conventional approach to minimising operating expenses. Therefore, it is imperative to apply the models that embrace the impact of determinant freight transport in Malaysia's context.

Data and methodology

Data source and description

This study uses panel data compiled by the DOSM for the top 30 trading partners of Malaysia from 2010 to 2021. The choice of the study period is contingent upon the availability of freight data. It coincides with Malaysia's adoption of the *Manual Balance of Payments* Sixth Edition in 2012 with the inclusion of a back series commencing from 2010 (DOSM 2013). Meanwhile, the other economic indicators data were obtained from the World Bank database, Centre d'Études Prospectives et d'Informations Internationales (CEPII) and Ministry of Transport Malaysia (MOT).

Zero flow issues frequently arise in panel data analysis, particularly when dealing with export and import data that are log linearised. Treating zero values in trade flows can be challenging because simply removing them from the dataset may lead to the biased results. Therefore, this study adopts the approach utilised by Ismail (2008) and Levy-Yeyati, Stein and Daude (2003) whereby the dependent variables are transformed to log (1 + export) or log (1 + import) instead of taking the log of export and import directly.

According to Rodrigue (2012), the main factors that affect the transportation cost are geography, type of product, economies of scale, energy, trade imbalance, infrastructure, mode of transport, competition or regulation and surcharges. Therefore, in this study, the variables affecting freight transport are categorised into three main factors comprising of economic scale, demography and infrastructure. By organising these variables, the study aims to provide a comprehensive analysis of how these determinants influence freight transport costs in Malaysia's international trade context.

In this study, the gravity model will be fitted to two models, which is the exports and imports of freight. Table 1 summarises the variables, definitions and data source:

TABLE 1: List of variables.

Variable	Description	Unit	Source
Exp_Freight	Denotes as exports of freight between Malaysia and country j	USD	DOSM
Imp_Freight	Denotes as import of freight between Malaysia and country j	USD	DOSM
Distw	Measures the distance between Malaysia and country j	Kilometres	CEPII
Total Trade	Denotes the total trading volume of Malaysia	USD	World Bank
Trade Imbalance	Derives from total export of trade minus total import RM Mil	USD	Derive
Exchange	Average rate of currency per USD by countries	USD	World Bank
GDP Origin	Denotes the GDP of Malaysia	USD	World Bank
GDP Destination	Denotes the GDP of partner countries	USD	World Bank
Sea Container	Container volume handled by sea (TEU)	Tonne	MOT
Air Cargo	Cargo volume handled by air (Tonne)	Tonne	MOT
Rail Cargo	Cargo handled by rail (Tonne)	Tonne	MOT
Contig	Dummy for the neighbouring country	0 or 1 (dummy)	CEPII
Comlang	Dummy for sharing the common language	0 or 1 (dummy)	CEPII

DOSM, Department of Statistics Malaysia; CEPI, Centre d'Études Prospectives et d'Informations Internationales; MOT, Ministry of Transport Malaysia.

Gravity model

Researchers employ gravity models to understand the bilateral trade among the countries (Choudhri, Marasco & Nabi 2017; Magrini, Montalbano & Nenci 2017). It operates on the fundamental that trade between two countries is influenced by the magnitudes of their economic masses. In addition, it is inversely related to the distance that separates them. Notably, Tinbergen (1962) was a Dutch economist who first applied the gravity model according to Newton's universal law of gravitation to analyse foreign trade flows.

The gravity model, traditionally used in modelling the international trade of goods, has been expanded to include international trade in services particularly in the context of freight transport (Bektas 2017; Ghisolfi et al. 2022; Tavasszy & De Jong 2013). This adaptation allows for a more comprehensive analysis of the factors influencing freight transport and trade flows in services. It provides valuable insights into the dynamics of international logistics and transportation networks. The gravity equation can be considered a short-hand representation of supply and demand forces (Head 2003). The earliest gravity model constructed was as follows (Equation 1):

$$Y_{ij} = \propto \frac{X_i^{\beta 1}\ X_j^{\beta 2}}{\mathcal{D}_{ij}^{\beta 3}} \qquad \text{[Eqn 1]}$$

where Y_{ij} is the exports or imports of freight transport from country i to country j, $\propto$ is a constant; X_i and X_j represent the economic mass of the exporting or importing countries, respectively, and D_{ij} is the distance between the countries. The logarithmic transformation of the previous equation translates in the following linear function (Equation 2):

$$\log\ (Y_{ij}) = log\ (\propto \frac{X_i^{\beta 1}\ X_j^{\beta 2}}{\mathcal{D}_{ij}^{\beta 3}}) \qquad \text{[Eqn 2]}$$

$$\log\ (Y_{ij}) = log\left(\propto\right) + \beta_1 \log\ (X_i) + \beta_2 \log\left(X_j\right) - \beta_3 \log\ (D_{ij})$$

Let log ($\propto$) as a new constant $\propto$:

$$\log\ (Y_{ij}) = \propto + \beta_1 \log\ (X_i) + \beta_2 \log\left(X_j\right) - \beta_3 \log\ (D_{ij})$$

To account for unexplained variability, an error term is directly incorporated into the linearised equation, where $\propto$ denotes the intercept (Equation 3):

$$\log Y_{ij} = \propto + \beta_1 \log X_i + \beta_2 \log X_j - \beta_3 \log D_{ij} + \varepsilon_{ij} \qquad \text{[Eqn 3]}$$

The gravity model has a range of different theoretical micro foundations and has proven to be very flexible to wide range of specifications (Chaney 2008; Helpman, Melitz & Rubinstein 2008; Melitz & Ottaviano 2008). A gravity equation operates on a bilateral basis including a dependent variable through the amalgamation of macroeconomies factors such as country size, income level, exchange rates, prices and a comprehensive market access indicator applicable for both countries involved.

Descriptive statistics

Descriptive statistics as summarised in the Table 2 provide crucial insights into the characteristics of log-transformed variables. The transformation to logarithmic form was performed to present the relationship of the variables in the gravity model in a linear form. The mean values reveal central tendencies across different variables such as LogTot_Trade indicating higher total trade volumes with a mean of 8.436. Standard deviations and variances highlight the dispersion and variability within each dataset; this is essential for understanding the consistency and spread of data points. For instance, LogImbalance exhibits a high standard deviation (0.976) and variance (0.953) indicating the significant variability in trade imbalances, which is crucial in assessing economic stability and trade dynamics. Additionally, the range from minimum to maximum values underscores the breadth of data distribution as seen in LogDistw ranging from 3.087 to 9.205, depicting wide variations in distances between trading partners.

The descriptive statistics presented above are based on log-transformed variables. Log transformation was applied to normalise the data, reduce heteroscedasticity and facilitate linear regression analysis.

Model evaluation

This study employs three econometric models, that is.. pooled ordinary least squares (POLS), fixed effects and random effects models to analyse the impacts of the determinants of freight transport in Malaysia's international trade**.**

Pooled ordinary least square

According to Gómez-Herrera (2013), gravity model has traditionally been linearised and estimated through ordinary least square techniques. The POLS model makes the assumption that each individual has the same connection between the independent and dependent variables. This approach is applied under the assumption of homoskedasticity, where the variance of the error is considered constant across all observation. Pooling or combination all observation can be written as (see Equation 4):

TABLE 2: Descriptive statistics of variables.

Variable	Min	Max	Mean	SD	Variance
logExp_Freight	4.61	6.90	6.17	0.57	0.32
logImp_Freight	4.69	6.89	6.23	0.49	0.24
logTot_Trade	6.96	9.19	8.44	0.60	0.36
logImbalance	3.72	8.52	7.50	0.98	0.95
logGDP_o	9.25	13.80	12.85	0.84	0.71
logGDP_d	10.17	13.80	12.89	0.91	0.83
logExchange	-1.62	1.60	0.69	0.81	0.66
logDistw	3.09	9.20	8.10	1.20	1.44
logAir_Cargo	2.64	6.90	5.88	0.97	0.95
logSea_Container	2.63	6.88	5.95	0.92	0.85
logRail_Cargo	3.13	6.90	5.95	0.80	0.65

SD, standard deviation.

$$Y_{ij} = \beta_0 + \beta_1 X_{1ij} + \beta_2 X_{2ij} + \ldots\ldots + \beta_9 X_{9ij} + \varepsilon_{ij} \quad \text{[Eqn 4]}$$

$i = 1,2,3,4 \ldots . N$

$j = 1,2 \ldots \ldots .. T$

where Y_{ij} is the dependent variable for entity *i* at time *j*. X_{1ij}, X_{2ij}, X_{9ij} are the independent variables, β_0, $\beta_1 \ldots . \beta_9$ are the coefficients and ε_{ij} is the error term. The POLS estimating model would not account for the endogeneity problem. Endogeneity occurs when an explanatory variable is correlated with the error term. The presence of endogeneity can lead to bias and inconsistent parameter estimates and undermining the validity of the model (Wooldridge 2010). Baier and Bergstrand (2007) stated one way to account for endogeneity bias is to use the fixed effects model (bilateral fixed effects and country-and-time effects).

Fixed effect model

Estimating gravity equations with fixed effects is a widely adopted and recommended approach by prominent empirical trade economists (Head & Mayer 2013). A fixed entity refers to a characteristic or factor that remains constant over a period or across observations. Having a fixed entity in econometrics typically implies that the entity-specific effects are constant and not influenced by other factors or variables. These fixed effects are often used to control for unobserved heterogeneity and capture the unique characteristics of entities that may affect the outcome being analysed.

The fixed effects estimator is more sensitive to heteroskedasticity and serial correlation in the idiosyncratic errors (Wooldridge 2010). The within estimator is illustrated as follows (Equation 5):

$$Y_{ij} - \overline{Y}_c = \left(X_{it} - \overline{X}_c \right) \beta + \left(\varepsilon_{it} - \overline{\varepsilon}_c \right) \quad \text{[Eqn 5]}$$

where Y_{ij} is the dependent variable for country c at time t, $\overline{Y}_c$ is the mean of the dependent variable for country c across all years, X_{it} is a vector of independent variable for country *c* at time t, $\overline{X}_c$ is the mean of independent variables for country c across all years, β is vector coefficient to be estimate, ε_{it} is the error term for country *c* at time t and $\overline{\varepsilon}_c$ is the mean of error term for country *c* across all years.

The fixed effect model (FEM) is (Equation 6):

$$Y_{ij} - \overline{Y}_c = \beta_1 \left(X_{it1} - \overline{X}_{c1} \right) + \cdots + \beta_k \left(X_{itk} - \overline{X}_{ck} \right), t = 1,2,\ldots.T \quad \text{[Eqn 6]}$$

where *i* denotes the entity (country), *t* refers to years, *c* represents the entity-specific average and *k* indicates the specific independent variables.

However, the within estimator has several disadvantages such as data transformation as within estimation wipes out all-time in-variant variables that do not vary within an entity, has a large degree of freedom for errors, R^2 is not correct because the intercept term is suppressed and does not report dummy coefficient. As argued by Nguyen (2020), using FEM with the basic gravity model faces the problem of lost information on time-invariant variables such as distance, sharing common border and language.

Random effect model

Compared to the FEM that estimates parameters for each level of a categorical variable, the random effect model (REM) estimates parameters for random effects that represent unobserved heterogeneity. The REM assumes that these random effects are drawn from a population distribution and are uncorrelated with the independent variables. The REM is estimated by generalised least square (GLS) when the covariance structure is known and by feasible generalised least square (FGLS) when the covariance structure of composite errors is unknown (Greene 2008; Kmenta 1997).

In FGLS, the estimation process involves estimating the parameters θ of the model while also estimating the variance components $\hat{\sigma}_u^2$ and $\hat{\sigma}_v^2$ of the random effects and residual errors, respectively. These estimated variances are then used to construct the covariance matrix Σ for use in the estimation procedure (Ceesay & Moussa 2022). In particular, the transformation parameter is (Equation 7):

$$\theta = 1 - \sqrt{\frac{\hat{\sigma}_u^2}{T\hat{\sigma}_u^2 + \hat{\sigma}_v^2}} = 1 - \sqrt{\frac{\hat{\sigma}_u^2}{T\hat{\sigma}_{between}^2}} \quad \text{[Eqn 7]}$$

The REM is (Equation 8):

$$Y_{ij} - \theta\bar{Y}_c = \beta_0\left(1-\theta\right) + \beta_1\left(X_{it1} - \theta\bar{X}_{c1}\right) + \cdots + \beta_9\left(X_{it9} - \theta\bar{X}_{c9}\right) + \left(v_{it} - \theta\bar{n}_i\right) \quad \text{[Eqn 8]}$$

where $X_{it1} \ldots X_{it9}$ is the 9 independent variables for country i at time t, $\bar{X}_{c1} \cdots \bar{X}_{c9}$ is the average values of the independent variables for all countries, while θ represents the parameter that indicates weight given to between-group variation versus within-group variation and V_{it} represents error term for country i at time t.

As highlighted by Hsiao (2003), REM offers advantages such as increased efficiency, smaller standard errors and enhanced statistical power to detect effect summaries. As stated by Mundlak (1978), the REM operates under the assumption that omitted variables are uncorrelated with the included time-varying covariates.

The REM is preferable when there is a belief that some omitted variables may remain constant over time. The study by Ahmad, Jaini and Zamzamir@Zamzamin (2015) stated that the advantage of both the FEM and REM is that they allow control over all unmeasured time-invariant variables that may have an impact on the dependent variable. The REM eliminates the problem of FEM, which is having too many parameters because of the individual-specific effects (Greene 2008). This modelling choice accommodates scenarios where certain factors are expected to show consistency within cases or across time but not necessarily both.

Testing the model

According to Breusch and Pagan (1980), FEM is evaluated by the F-test while REM is examined by Lagrange multiplier (LM) test. The F-test is a statistical test used to determine whether the fixed effects in the FEM significantly enhance the model's explanatory power compared to the POLS model. In this test, the null hypothesis is that all dummy parameters except for one dropped are all zero and the alternative hypothesis is that at least one dummy parameter is not zero. If the null hypothesis is rejected (at least one group or time specific intercept μ_i is not zero), it is suggesting the presence of significant fixed effects in the FEM. This implies that FEM, which accounts for individual/group-specific effects, is more appropriate than POLS assuming these effects are absent or constant across groups. This may conclude that there is a significant fixed effect in FEM.

Meanwhile, the LM is used to test the significance of the variance of individual-specific effects. The null hypothesis is that the variance is zero versus alternative hypothesis that the variance is non-zero, $H_o: \sigma_u^2 = 0$ and $H_o: \sigma_u^2 \neq 0$. Baltagi (2005) presents the LM statistics follows the chi-squared distribution as follows (Equation 9):

$$LMu = \frac{nT}{2\left(T-1\right)}\left[\frac{\Sigma\left(\Sigma e_{it}\right)^2}{\Sigma\Sigma e_{it}^2} - 1\right]^2 = \frac{nT}{2\left(T-1\right)}\left[\frac{\left(\Sigma T\bar{e}_i\right)^2}{\Sigma\Sigma e_{it}^2} - 1\right]^2 \sim \chi^2\left(1\right) \quad \text{[Eqn 9]}$$

where T is the number of time periods in the panel data, n represents the number of cross-sectional units, e_{it} is residual from estimated model and $\bar{e}_i$ is the average residual for the i^{th} the cross-sectional unit.

If the null hypothesis rejected, the REM is more appropriate than POLS. The REM is able to deal with heterogeneity better than the POLS.

Lastly, the Hausman test is conducted for selecting between REM and FEM. This test compares fixed effect and random effects under the null hypothesis that individual effects are uncorrelated with any regressor in the model (Hausman 1978). If the null hypothesis of no correlation is rejected, it suggests that there is significant correlation between the individual effects μ_i and at least one of the regressors in the model. Consequently, this finding implies that the random effects model may not be suitable in the study.

R-squared and Akaike information criteria

The R-squared value is used to gauge the variation in the dependent variables that can be explained by the independent variables or regressors. A higher R-squared value indicates a better fit of the model. Furthermore, a good model is the one that has a minimum AIC among all the models. The AIC is a measure used in statistical modelling to assess the relative quality of different models. It balances the trade-off between the goodness of fit of the model and the complexity of the model. Akaike information criteria is derived from information theory and is based on the likelihood function of the model and adjusted for the number of parameters estimated. The AIC is obtained from the calculation of 2k-2 (log-likelihood), where k is the number of variables in the model including intercept and the log-likelihood is a measure of fit. Thus, the approach choosing the lowest AIC helps in selecting the most appropriate model that accurately captures the underlying relationships in the data while avoiding excessive complexity that could lead to overfitting and poor out-of-sample prediction performance.

Multicollinearity checking

According to Sahoo (2019), a threshold correlation of 80% is used to determine multicollinearity. If the correlation exceeds 80%, it suggests that variables should be eliminated. The correlation matrix is presented in Table 3.

Table 3 shows various degrees of relationships between the independent variables. The strong negative correlation between Sea Container and Rail Cargo (-0.66) indicates a significant substitution effect with increased reliance on one mode reducing the usage of the other. Conversely, the relatively strong positive correlation between Air Cargo and Rail Cargo (0.52) suggests a complementary relationship, where these modes are often used together or similar logistical purposes. The weak correlations among most other variables indicate a lack of strong linear relationships, highlighting the complexity and potentially multifaceted nature of trade dynamics that might not be fully captured by pairwise linear correlations alone.

Regression specification error test

The regression specification error test (RESET) proposed by Ramsey (1969) serves as a comprehensive misspecification test. It aims to identify instances of omitted variables and inappropriate functional forms in a regression model. The test relies on the Lagrange multiplier principle and is typically conducted using critical values from the F-distribution. In practical terms, the RESET test assesses whether additional non-linearities in the model have been overlooked or omitted. By utilising the F-distribution's critical values, the test helps to determine whether the inclusion of additional variables or a different functional form would significantly enhance the model's explanatory power.

The null hypothesis for the Ramsey RESET states that the model does not suffer from misspecification errors suggesting that there are no omitted variables or non-linearity. The exports model showed *p*-value is 0.005, and the imports model is 0.000; there is evidence to reject the null hypothesis. This indicates that the model maybe mis-specified. Hence, the non-linear method may improve the model.

Results and discussion

This section presents the statistical analysis of the findings. In this study, we employed two distinct R packages for the analysis. The panel data analysis was conducted using the plm package (Croissant & Millo 2008), which allowed for the estimation of fixed effects and random effects models to account for both cross-sectional and time-series dimensions in the dataset. This approach allowed for the control of individual-specific effects and the exploration of dynamic relationships over time. Additionally, gravity models were estimated using the gravity package (Santos Silva & Tenreyro 2006), which facilitated the modelling of bilateral flows between entities based on factors such as economic size and geographic distance. Gravity models are widely utilised in economics and international trade to predict and understand bilateral interactions.

Table 4 presents the export estimation results based on the POLS, FEM and REM. Model 1 examines freight exports and encompasses an analysis incorporating all variables considered in this study through three distinct models, which are POLS, FEM and REM. Meanwhile, Model 2 is analysing only significant variables.

Based on Table 4, the R-squared values for export models range between 0.47 and 0.52, indicating that these models explain up to 52% of the variation in the dependent variable. Although R-squared provides some insights into the explanatory power, it may not be the most suitable measure in the context of panel data regression. The adjusted R-squared values that are corrected for the number of predictors range from 0.459 to 0.501, and this offers a slightly more accurate measure of the goodness of fit. The lowest AIC value of 1143.672 is observed for the REM, suggesting that it is the best-fitting model among those considered. This aligns with the Hausman Test results, which favour the REM over the FEM (*p*-value > 0.05). The inclusion of MSE values ranging from

TABLE 3: Correlation matrix of the independent variable.

Variables	Tot_Trade	Imbalance	GDP_d	GDP_o	Exchange	Distw	Sea Container	AirCargo	Rail Cargo
Tot_Trade	1.00	-	-	-	-	-	-	-	-
Imbalance	-0.09	1.00	-	-	-	-	-	-	-
GDP_d	0.41	-0.13	1.00	-	-	-	-	-	-
GDP_o	0.18	0.03	0.07	1.00	-	-	-	-	-
Exchange	0.29	-0.02	-0.11	0.01	1.00	-	-	-	-
Distw	0.19	-0.01	-0.29	0.00	0.25	1.00	-	-	-
Sea_Container	-0.02	0.03	0.00	0.04	-0.01	0.00	1.00	-	-
Air_Cargo	0.23	-0.03	0.06	0.79	0.02	0.00	-0.22	1.00	-
Rail_Cargo	-0.13	-0.04	-0.03	-0.45	-0.02	0.00	-0.66	0.52	1.00

GDP, gross domestic product.

TABLE 4: Estimation result for exports of freight transport.

Variable	Category	Export					
		Model 1			Model 2		
		POLS	FE	RE	POLS	FE	RE
logTot_Trade	Coefficient	3.420***	1.635	4.722***	3.417***	1.634	4.744***
	p-value	0.000	0.281	0.000	0.000	0.281	0.000
logImbalance	Coefficient	0.191	0.015	0.000	-	-	-
	p-value	0.334	0.932	0.997	-	-	-
logGDP_d	Coefficient	-0.276	-3.462*	-1.523***	-0.303***	-3.467*	-1.538***
	p-value	0.265	0.078	0.439	0.218	0.077	0.000
logGDP_o	Coefficient	9.135*	-	10.727*	9.487*	-	10.743*
	p-value	0.051	-	0.017	0.042	-	0.045
logDistw	Coefficient	0.891***	-	0.838***	0.883***	-	0.835***
	p-value	0.000	-	0.000	0.000	-	0.000
logExchange	Coefficient	-0.175	2.962	-0.395***	-0.176	2.965	-0.397***
	p-value	0.103	0.237	0.000	0.100	0.236	0.000
logSea_Container	Coefficient	-8.036**	-	-11.760**	-8.487*	-	-11.817*
	p-value	0.062	-	0.005	0.005	-	0.016
logAir_Cargo	Coefficient	-9.926*	-	-10.158*	-9.684*	-	-10.167*
	p-value	0.036	-	0.037	0.040	-	0.061
logRail_Cargo	Coefficient	-3.965*		-4.530*	-4.206*		-4.535*
	p-value	0.094		0.063	0.074		0.093
Comlang1	Coefficient	-	-	-4.402***	-	-	-4.433***
	p-value	-	-	0.000	-	-	0.000
Contig1	Coefficient	-	-	-2.948**	-	-	-2.971**
	p-value	-	-	0.002	-	-	0.002
Constant	Coefficient	0.146	-	39.999	4.096	-	40.564
	p-value	0.999	-	0.676	0.965	-	0.703
Observation	-	360	360	360	360	360	360
F-statistics	-	34.824***	2.094*	-	39.066***	2.798*	-
Chi square	-	-	-	370.252***	-	-	369.873***
R^2	-	0.472	0.510	0.515	0.471	0.511	0.515
Adjusted R^2	-	0.459	0.485	0.500	0.459	0.486	0.501
AIC	-	1180.337	1762.522	1148.206	1180.301	1761.53	1143.672
MSE	-	25.815	15.445	25.661	25.884	15.445	23.250

POLS, pooled ordinary least squares; FE, fixed effect; RE, random effect; AIC, Akaike information criteria; MSE, mean squared error.
*, significant level at 10%; **, significant level at 5%; ***, significant level at 1%.

15.445 to 25.884 provides additional context for model comparison. The REM's MSE of 23.250 while higher than some other models still support its selection as the best model when considering the trade-off between complexity and fit.

The determinants of export were analysed using the nine variables, with the results indicating that eight of these variables are significant. The only variable that did not show significance is Trade Imbalance. The results indicate that the exports of freight are influenced by factors related to infrastructure, economic scale and demography. The findings of this study are supported by established theoretical frameworks in the field of international trade and transport. Economic size measured by GDP and total trade is a primary determinant of freight transport, as larger economies tend to engage in more trade because of their higher production and consumption capacities (Anderson 1979). In addition, efficient infrastructure significantly reduces transportation costs and enhances trade by improving connectivity and minimising delays, which is essential for increasing the volume of freight transport (Limão & Venables 2001). Furthermore, cultural and historical ties such as shared language and colonial history play a vital role in enhancing trade by reducing transaction costs and fostering trust and cooperation. These factors are often included in gravity models as dummy variables to capture their effects (Melitz & Ottaviano 2008).

The significant levels for these factors vary with some being significant at the 1% level while others at the 5% level and a few at the 10% level. This suggests that while all these factors are important determinants of freight exports, their degrees of influence in these relationships differ. Specifically, the factors significant at the 1% level have the strongest evidence of a relationship with freight exports, followed by those significant at the 5% and 10% levels. This is in line with the study by Oruangke (2020), which investigated the impact of logistics performance on the Association of Southeast Asian Nations (ASEAN) trade. The GDP of country origin, total trade and distance are variables that tend to increase freight export. The positive relationship of GDP country origin suggests that 1% increase leads to a 10.743% increase in freight export. This highlights the importance of the economic scale of trading partners in influencing freight exports. Similarly, a 1% increase in total trade is associated with a 4.744% increase in freight export. The coefficient for distance is 0.835, which is significant at the 1% level (*p*-value = 0.000). This indicates that a 1% increase in the distance between trading partners corresponds to a 0.835% increase in freight export.

On the contrary, the negative sign showed for the Sea_Container, Air_Cargo and Rail_Cargo indicates that increasing the volume of handling container and cargo will decrease the cost of freight. This relationship underscores the significance of expanding port and airport capacities to enhance competitiveness.

In terms of magnitude, the main factors that determine the export of freight is infrastructure mainly the port and airport capacity. Hence, the finding provides the evidence that infrastructure plays an important role in improving the attraction of port and airport services as well as facilitated the trade flow. The study by Ahmad et.al. (2015) on the impact of infrastructure on international trade in Malaysia also indicates that infrastructures are important to enhance Malaysia trade to greater heights. In order to boost the export of freight, infrastructure needs to be carefully considered not just on ports. Another mode of transportation such as air freight has more impact on exports.

The estimation of distance is statistically significant but not strongly affected the export of freight. Furthermore, the study by Mohd Hassan et al. (2020), which utilised the gravity model to investigate the exports performance of Malaysia's palm-based oleochemicals found that distance was not a significant factor. In addition, Figueiredo De Oliveira (2014) also proved that distance impact is insignificant when estimating outward freight rates.

Additionally, the exchange rate was found to be statistically significant with a negative coefficient. This negative relationship suggests that a 1% increase in the exchange rate (indicating a stronger domestic currency) leads to a 0.397% decrease in freight transport exports. This is consistent with the notion that a stronger domestic currency makes exports more expensive and less competitive in international markets. The result is consistent with the study by Chi (2016) that the exchange rate is a significant factor affecting freight flows from China to the United States. The study also found that the impact of the bilateral exchange rate and transport cost varies across different industries and commodity levels.

Table 5 presents the estimation results for freight imports. Similar to the export estimation, Model 1 encompasses all variables considered in this study across three models (POLS, FEM and REM). Meanwhile, Model 2 focuses solely on the significant variables for analysis.

TABLE 5: Estimation result for imports of freight transport.

Variable	Category	Import					
		POLS	FE	RE	POLS	FE	RE
logTot_Trade	Coefficient	1.047***	1.219***	1.004***	1.043***	1.227***	0.979***
	p-value	0.000	0.000	0.000	0.000	0.000	0.000
logImbalance	Coefficient	-0.024	-0.006	-0.030	-	-	-
	p-value	0.229	0.528	0.124	-	-	-
logGDP_d	Coefficient	0.076**	0.063	0.138**	0.082***	-0.013	0.163***
	p-value	0.002	0.546	0.000	0.000	0.888	0.000
logGDP_o	Coefficient	1.372**	-	1.320**	1.216**	-	1.150*
	p-value	0.004	-	0.003	0.005	-	0.015
logDistw	Coefficient	-0.037*	-	-0.030*	-0.036*	-	-0.030*
	p-value	0.037	-	0.072	0.038	-	0.072
logExchange	Coefficient	-0.005	0.223*	-0.009	-	-	-
	p-value	0.671	0.094	0.431	-	-	-
logSea_Container	Coefficient	-2.999***	-	-2.897***	-2.623***	-	-2.484***
	p-value	0.000	-	0.000	0.000	-	0.000
logAir_Cargo	Coefficient	-0.035	-	-0.011	-	-	-
	p-value	0.941	-	0.981	-	-	-
logRail_Cargo	Coefficient	-0.282	-	-0.279	-	-	-
	p-value	0.233	-	0.222	-	-	-
Comlang1	Coefficient	-	-	-0.121	-	-	-
	p-value	-	-	0.203	-	-	-
Contig1	Coefficient	-	-	0.512***	-	-	0.507***
	p-value	-	-	0.000	-	-	0.000
Constant	Coefficient	9.641	-	8.364	2.686	-	1.339
	p-value	0.299	-	0.350	0.730	-	0.874
Observation	-	360	360	360	360	360	360
F-statistics	-	269.885***	62.492***		377.566***	122.936	
Chi square	-			2650.01***			2692.6***
R^2	-	0.874	0.442	0.884	0.873	0.437	0.884
Adjusted R^2	-	0.871	0.366	0.880	0.871	0.362	0.882
AIC	-	-475.704	-351.520	-503.080	-476.277	-349.906	-509.289
MSE	-	0.259	0.044	0.239	0.262	0.043	0.238

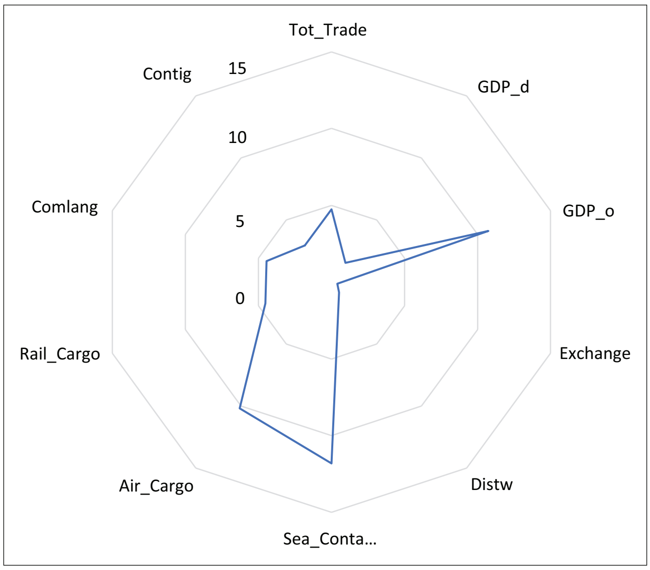
POLS, pooled ordinary least squares; FE, fixed effect; RE, random effect; AIC, Akaike information criteria; MSE, mean squared error.
*, Significant level at 10%; **, Significant level at 5%; ***, Significant level at 1%.

Consistent with the exports model, the results of Hausman test showed (p-value >0.05) indicate REM is the best fit model. However, R-squared can be misleading in models with many predictors or in a complex panel data context. Thus, MSE assesses the average square difference between observed and predicted values indicating better predictive accuracy. The MSE values range from 0.043 to 0.238 across the models with REM having the lowest MSE. The lowest AIC value is observed in REM with the value of -509.29. Contrasting to the export model, the significant variables for import are Tot_Trade, GDP_d, GDP_o, Distw, Sea_Container and Contig.

A decrease in Sea_Container by 1% automatically increases the cost of freight import by 2.48%. The result indicates that maritime transport is the most important mode of transport for Malaysia's trade. The study on the Singapore Port by Mindur (2020) stated that strategic collaboration among government and maritime partners contributed to the highly advanced port infrastructures and the latest technologies. In addition, shipowners use larger container ships capable of carrying enormous quantities of cargo in order to reduce shipping cost. According to the study by Hanafiah et al. (2020), one of the critical issues of Malaysia's maritime industries is business operation. The low cargo rate disadvantages the shipping companies causing loss of profits and making it difficult to sustain the industry as well as to be competitive.

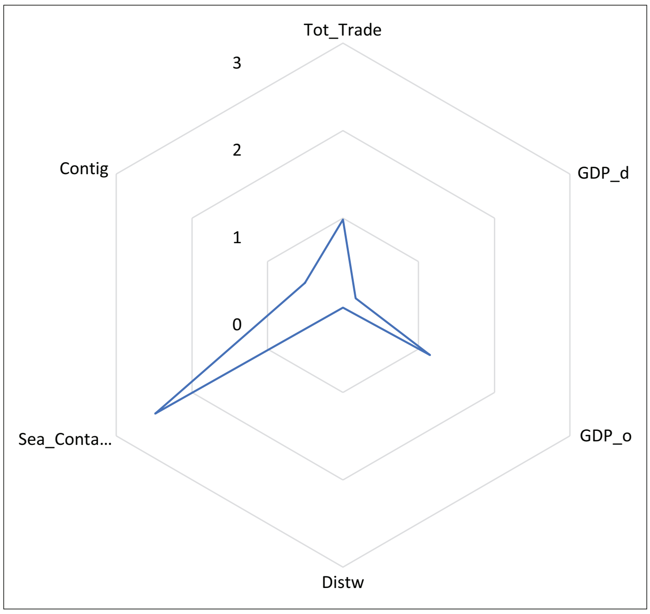
Besides that, the economic scale comprises of total trade, GDP_d and GDP_o is statistically significant with positive signs. An increase in those variables will increase the imports of freight transport. The coefficient of GDP_o and Tot-Trade is close to 1, which indicates that the one per cent changes in both will change import of freight by one per cent. This is in line with the logic behind gravity model for aggregated trade flow, whereby higher income (GDP) level of importing and exporting countries, the greater capacity to produce or supply and hence it enhances the trade level (Abafita & Tadesse 2021). Meanwhile, distance is not a strong factor that influences the imports of freight transport. This is consistent with the study by Borchert and Yotov (2016), whereby the effect of distance on international trade has fallen over time, possibly reflecting the impact of new technologies or production fragmentation, commonly associated with globalisation.

Therefore, the coefficients derived from the analysis of export and import freight models are depicted in Figure 1 and Figure 2, serving as a paradigm for understanding the relationships within the respective models.



GDP, gross domestic product.

FIGURE 1: Export's model paradigm.



GDP, gross domestic product.

FIGURE 2: Import's model paradigm.

Conclusion

The main focus of this study was to analyse the impact of freight transport on international trade involving Malaysia with a specific focus on its impact on bilateral trade relations with major trading partners. A gravity equation has been employed on panel data for the period 2010–2021. The sharp rise in international trade resulted in pressure to have efficient freight transport services as well as competitive logistics sectors in Malaysia.

The research identifies economic scale and infrastructure as pivotal factors influencing both freight transport exports and imports. The analysis underscores the significant impact of these variables on the dynamics of international trade. Infrastructure encompassing ports and logistical facilities emerges as a critical determinant of a nation's ability to facilitate efficient and cost-effective freight movement. Investment in port and airport capacities is essential to improve competitiveness and policymakers should prioritise infrastructure development to support trade expansion. Strengthening economic relations with major trading partners and expanding the scale of production and consumption will boost trade. Additionally, maintaining a competitive exchange rate is crucial for the competitiveness of the export freight. Strategic collaborations between the government and maritime partners can lead to advancements in port infrastructure and technology. Other than that distance has a less significant impact on exports and imports of freight transport. This is aligning with Borchert and Yotov (2016) that suggest the reduced effect of distance because of technological advancements and production fragmentation. The widening imbalance in freight transport where imports are growing at a faster rate than exports suggest a growing reliance on imported goods influenced by domestic consumption patterns, global supply chains and market demands. This represents diversification of Malaysia's economy and demonstrates the country's deeper integration into global supply chains.

Overall, the results of this study are expected to give value to the government, especially to the transport sector in formulating the country's economic development policy. Reflecting to the result of this study, it is suggested for the future study to further explore on freight cost by commodities, services delivery performances and regulation. Other than that, further study on non-linear estimation also needs to provide greater flexibility in representing a wide range of relationship. This preliminary findings will be used as a basis to explore further on freight transport in Malaysia. Enhancing Malaysia's export competitiveness and optimising freight transport efficiency are crucial for achieving sustainable economic growth and maintaining balanced trade dynamics in the global marketplace. Improving these areas will not only boost Malaysia's economic resilience and growth potential but also ensure that the country remains a key player in international trade. By focusing on these priorities, Malaysia can better leverage its strategic advantages, streamline logistics operations and adapt to global economic shifts ultimately fostering a more robust and dynamic economy.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

A.A. was responsible for the formal analysis, investigation, writing and data curation. Z.H.Z. was responsible for the conceptualisation, methodology, project administration, validation, writing and supervision, with N.H.M. responsible for the methodology, resources, writing and supervision.

Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

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Data availability

The data used in this study are strictly confidential as provided by the Department of Statistics Malaysia.

Disclaimer

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