Analyzing Trade Flows in Transportation Services Using the Gravity Model

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Results Report

1. **What are the descriptive characteristics of trade in Transportation Services (TSP) in 2015, and what proportion of countries engaged in non-zero trade in this sector?**

   a. The descriptive statistics of selected variables of the Transport Sector (TSP) is presented in Table 1:

Table 1. Descriptive Statistics of Selected Variables

Descriptive Statistics of Selected Variables

Statistic	N	Mean	St. Dev.	Min	Max
trade	1,948	221.62	617.53	0.005	8,145.00
dist	1,948	5,217.39	4,561.78	59.62	19,263.88
gdp_imp_M	1,948	760,744.10	1,831,018.00	1,898.58	10,936,700.00
gdp_exp_M	1,948	758,409.40	1,834,077.00	127.44	10,936,700.00
contig	1,948	0.05	0.23	0	1
comlang_off	1,948	0.07	0.26	0	1
comcol	1,948	0.02	0.14	0	1
colony	1,948	0.04	0.20	0	1

   b. Result from analysis revealed that in 2005, **91 countries** were involved in trading TSP, forming **1082 country pairs**. The share of countries who traded TSP is 45%.

2. **How do geographical distance and combined GDP influence bilateral trade in Transportation Services, and do factors like contiguity and common language enhance trade relationships?**

   a. Figure 1 shows correlation between trade and distance using scatter plot. The plot shows a weak negative relationship between trade and distance. This is further complemented by the correlation coefficient of – 0.153 between the two variables shown in Table 2. The weak relationship could be because there might be other factors beyond distance influencing trade. However, the basic intuition behind this result is that distance has been could be a barrier to trade. The further apart two countries are, the higher the transport cost, and hence, lower level of trade.

b. The scatter plot shown in Figure 2 shows a strong positive relationship between trade and combined GDP of importing and exporting countries. This is complemented by the coefficient in Table 2. The basic intution behind this is that larger economies are expected to trade more. These results align with the predictions of the gravity model of trade, which posits that trade between two countries is positively related to their economic size (GDP) and negatively related to the distance between them (see Figure 1)

c. The scatter plot in Figure 3 shows the correlation between trade and distance by contiguity. The plot revealed a positive relationship between contiguous countries (countries that share border) and negative for non-contiguous (countries that do not share border). The positive relationship between suggests that distance does not affect trade between contiguous countries, which could be due to specific regional trade agreements, economic policies, or other factors that promote trade over longer distances within contiguous regions. The negative relationship for non-contiguous countries suggests that trade decreases as distance increases due to higher transportation and transaction costs.

d. Figure 4 shows the relationship between trade and combined GDP of importing and exporting countries by contiguity. Both contiguous and non-contiguous country pairs show a positive relationship between trade and combined GDP, as indicated by the upward slope of both lines of best fit. This suggests that as the combined GDP of trading partners increases, trade volumes also increase. This supports the intuition that bigger economies tend to trade more. The blue line (contiguous countries) is above the red line (non-contiguous countries), indicating that for any given level of combined GDP, contiguous country pairs tend to trade more than non-contiguous pairs. This could be because contiguous countries benefit from reduced transportation costs and potentially stronger economic and cultural ties (from shared border) which facilitate higher trade volumes.

e. Countries with and without a common official language show a negative relationship between trade and distance, as indicated by the downward slope of both lines of best fit (see Figure 5). This means that trade decreases as distance increases. Also, the blue line (for countries with common official language) lies above the red line (countries with no common official language. This indicating that for any given distance, country pairs with a common official language tend to trade more.

f. Figure 6 shows a positive correlation between combined GDP and trade, indicating that countries with higher combined economic output tend to engage in more trade. The line for country pairs sharing a common official language is steeper compared to those that do not. This suggests that the presence of a common language enhances the positive impact of GDP on trade volumes. This suggests that country pairs that share an official language tend to trade more than those that don't, given the same level of combined GDP

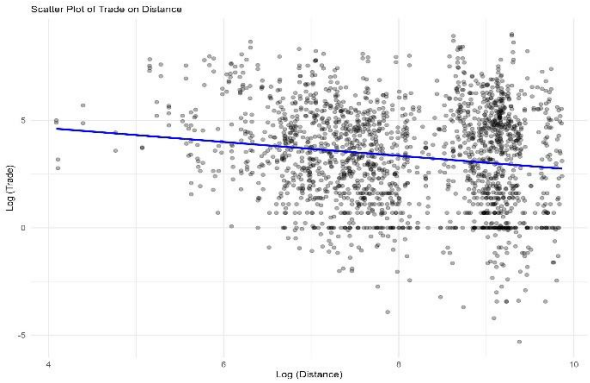

Figure 1. log(trade) vs log(distance)

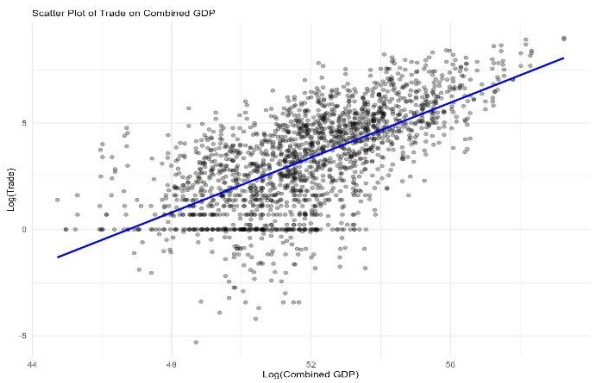

Figure 2. log(trade) vs log(GDP combined)

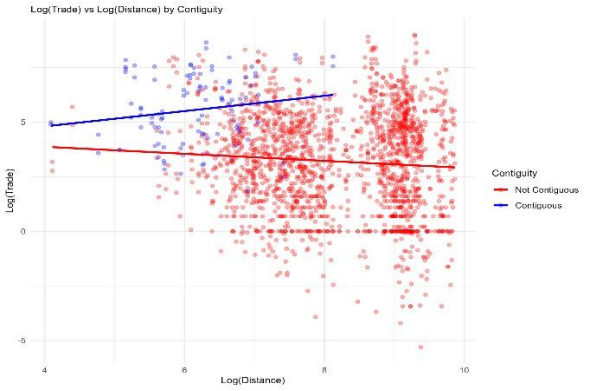

Figure 3. log(trade) vs log(distance) by contiguity

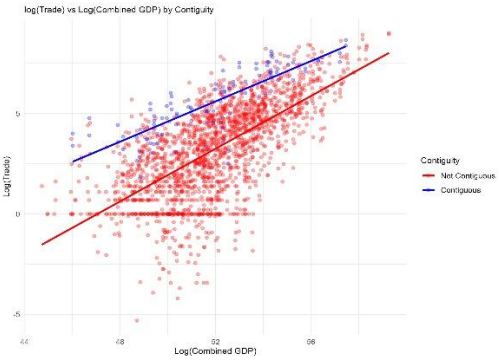

Figure 4. log(trade) vs log(GDP combined) by contiguity

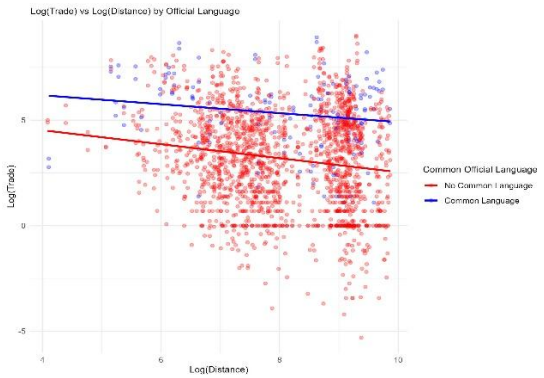

Figure 5. log(trade) vs log(distance) by official language

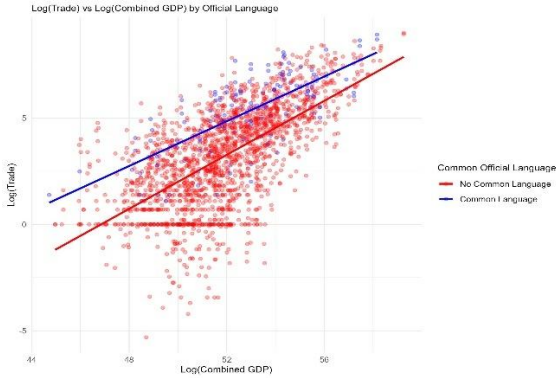

Figure 6. log(trade) vs log(GDP combined) by official language

Table 2. Correlation matrix of selected trade variables in TSP

Correlation Matrix of Trade Variables

	log_trade	log_distance	log_gdp_exp	log_gdp_imp	log_gdp_combined
log_trade	1	-0.153	0.474	0.424	0.648
log_distance	-0.153	1	0.214	0.241	0.328
log_gdp_exp	0.474	0.214	1	-0.039	0.707
log_gdp_imp	0.424	0.241	-0.039	1	0.679
log_gdp_combined	0.648	0.328	0.707	0.679	1

3. **What is the impact of distance, GDP, contiguity, and common language on bilateral trade in Transportation Services, as estimated by the intuitive Gravity Model?**

   This part is answered using Table 3

   a. **Overall quality of model:** The model has an adjusted R-squared of 0.6004, indicating that approximately 60% of the variation in trade in TSP is explained by the model (having accounted for the number of variables). This suggests a strong fit of the model. The F-stat is significant ($p<0.05$), indicating that the overall model is statistically significant (at least one of the variables is a good predictor of trade).

   b. **Effect of distance on trade:** The coefficient for distance is negative (-0.8083) and significant ($p<0.01$). This indicates that as 1% increase in distance between trading partners is associated with a decrease of about 0.81% in trade volume. Overall, this result suggests that an increase in the distance between trading partners will result in a decrease in the logarithm of trade

volumes. This finding is consistent with the gravity model of trade, which predicts that trade between two countries decreases with distance**.**

c. **Relevance of trade partners to have a common border:** From the regression result, the positive coefficient (0.3734) for contiguity (that is, having a common border) is statistically significant ($p<0.01$) suggests that neighboring countries trade more than those that are not contiguous (those that do not share common border). This finding further reflects the relevance of proximity in trade. This could be because countries sharing a border are likely to have lower transportation and transaction costs, stronger economic linkages, and hence, more frequent cross-border interactions.

d. **Relevance of trade partners to speak the same language:** The coefficient for common official language is positive and significantly associated with trade ($p<0.001$). The result from the regression attests those countries sharing a common official language trade more. This could be attributed to reduced communication barriers, increased trust, and cultural similarities.

e. **Relevance of trade partners to have been in some sort of colonial relationship with the same colonizing nation:** The effect of colonial relationship on trade is shown by common colonizer variable. These two variables have positive coefficients and significantly associated with trade. This result suggests that historical ties such as colonial relationships, enhance trade volumes. These ties might facilitate trade through shared institutional and possibly legal frameworks, business practices, established trade routes, and potentially preferential trade agreements.

f. **The effect of GDP on trade, for both importer's and exporter's GDP:** The coefficients of the importers and exporters GDP are positive and significantly associated with trade. This suggests that a higher GDP of the importing country causes greater demand for goods and services, leading to increased trade volumes while a higher GDP of the exporting country suggests a greater capacity to produce and export goods, resulting in higher trade volumes while a higher GDP of the exporting country suggests a greater capacity to produce and export goods, resulting in higher trade volumes. This finding supports the gravity model that larger economies tend to engage in more trade due to their increased capabilities and needs.

g. Do the dichotomous variables (e.g., contiguity, common language, colonial relationships) collectively have a statistically significant impact on bilateral trade in Transportation Services, and what are the implications of this finding for the explanatory power of the Gravity Model?

$$H_0 : \beta(contig) = \beta(comcol) = \beta(comlang\_official) = 0$$

$$H_1 : \beta(contig) \neq \beta(comcol) \neq \beta(comlang\_official) \neq 0$$

The p-value of the F-test is less than 0.05, hence, the null hypothesis (claim) is rejected since there is sufficient evidence to establish that at least one of the dichotomous variables (common official language, contiguity, common colony) significantly affects trade (see Figure 7). his indicates that at least one of these variables significantly affects trade flows.

Table 3. Determinants of trade (intuitive model)

```
##
## Regression Results (Determinants of Trade)
## ============================================================
##                              Dependent variable:
##                          ---------------------------------------
##                                    Log(Trade)
##                                       OLS                coefficient
##                                                            test
##                                   Model 1 (SE)         Model 2 (RSE)
##                                       (1)                   (2)
## ------------------------------------------------------------------
## Log(GDP Importer)                  0.7489***              0.7489***
##                                     (0.0212)               (0.0197)
##
## Log(GDP Exporter)                  0.7818***              0.7818***
##                                     (0.0203)               (0.0211)
##
## Log(Distance)                      -0.8083***             -0.8083***
##                                     (0.0356)               (0.0366)
##
## Contiguity                          0.3734**              0.3734***
##                                     (0.1683)               (0.1263)
##
## CommLang(Official)                 0.9162***              0.9162***
##                                     (0.1429)               (0.1371)
##
## Colony                             1.3337***              1.3337***
##                                     (0.2415)               (0.1993)
##
## Comcol                             0.7484***              0.7484***
##                                     (0.1794)               (0.1378)
##
## Constant                          -30.0402***            -30.0402***
##                                     (0.7577)               (0.7468)
##
## ------------------------------------------------------------------
## Observations                          1,948
## R2                                    0.6019
## Adjusted R2                           0.6004
## Residual Std. Error       1.4732 (df = 1940)
## F Statistic           418.9855*** (df = 7; 1940)
## ============================================================
## Note:                                *p<0.1; **p<0.05; ***p<0.01
```

```
Linear hypothesis test:
contig = 0
comlang_off = 0
comcol = 0

Model 1: restricted model
Model 2: log_trade ~ log_gdp_imp + log_gdp_exp + log_distance + contig +
    comlang_off + comcol + colony

  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1   1943 4435.3
2   1940 4210.2  3    225.07 34.569 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 7. F-test for joint hypothesis of dichotomous variables

h. Is the elasticity of trade with respect to the GDPs of importing and exporting countries equal to 1, or does trade respond disproportionately to changes in GDP?

The F-stat has a pvalue of less tha 0.05, hence we reject the null hypothesis. We conclude that the elasticity of trade with respect to the GDPs of importing and exporting countries is not unity. This implies that a 1% increase in the GDPs of the importer or exporter does not translate to a 1% increase in trade volumes. (see Figure 8).

H_0 : $\beta(\text{log\_gdp\_imp}) = \beta(\text{log\_gdp\_exp}) = 1$

H_1 : At least one $\neq 1$

```
Linear hypothesis test:
log_gdp_exp = 1
log_gdp_imp = 1

Model 1: restricted model
Model 2: log_trade ~ log_gdp_imp + log_gdp_exp + log_distance + contig +
    comlang_off + comcol + colony

  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1   1942 4700.6
2   1940 4210.2  2    490.38 112.98 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 8. F-test for unit elasticity of GDP on trade

4. **How does OECD membership influence bilateral trade in Transportation Services, and does the augmented Gravity Model provide additional explanatory power compared to the intuitive model?**

Figure 9 shows a flat or no correlation between trade and distance for non-OECD members. This indicates that trade volumes among non-OECD countries are less sensitive to changes in distance. On the other hand, the line for OECD countries shows a negative relationship (correlation), indicating that trade decreases among OECD members as distance increases.

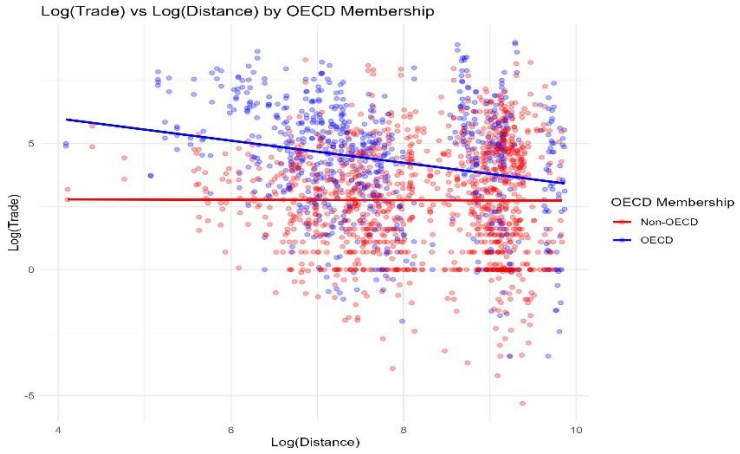

Figure 9. log(trade) vs log(distance) by OECD membership

a. **Overall quality of Model**: The model has an R-squared value of 0.6024, which implies that approximately 60% of the variability in trade is explained by the variables included in the model. This is a relatively high value and indicates a good fit. Similarly, the adjusted R-squared is 0.6008 indicating that approximately 60% of the variation in trade is explained by the model (having accounted for the number of variables).

b. **Effect of OECD membership on trade:** The coefficient for OECD membership is -0.1261 with a p-value greater than 0.05. Although not statistically significant, it exhibits a negative relationship with trade. This suggests that, all else being equal, trade volume between OECD member countries are lower than between non-member countries.

c. **Effect of distance on trade:** After including OECD variable in the model, the coefficient for distance is negative (-0.8276) and significant ($p<0.01$). This indicates that as 1% increase in distance between trading partners is associated with a decrease of about 0.83% in trade volume. Overall, this result suggests that an increase in the distance between trading partners will result in a decrease in the logarithm of trade volumes. This finding is consistent with the gravity model of trade, which predicts that trade between two countries decreases with distance**.**

Table 4. Determinants of trade (Augmented Model with OECD Variable)

Determininants of Trade (Augmented Model)

	Dependent variable:	
	Log(Trade)	
	OLS	coefficient test
	Model 3 (SE)	Model 4 (RSE)
	(1)	(2)
Log(GDP Importer)	0.7612***	0.7612***
	(0.0226)	(0.0217)
Log(GDP Exporter)	0.7936***	0.7936***
	(0.0216)	(0.0225)
Log(Distance)	-0.8276***	-0.8276***
	(0.0376)	(0.0402)
Contiguity	0.3737**	0.3737***
	(0.1682)	(0.1259)
CommLang(Official)	0.9147***	0.9147***
	(0.1429)	(0.1369)
Commcol	1.3145***	1.3145***
	(0.2417)	(0.1995)
Colony	0.7381***	0.7381***
	(0.1794)	(0.1370)
OECD Membership	-0.1261	-0.1261
	(0.0793)	(0.0789)
Constant	-30.4631***	-30.4631***
	(0.8028)	(0.7979)
Observations	1,948	
R2	0.6024	
Adjusted R2	0.6008	
Residual Std. Error	1.4726 (df = 1939)	
F Statistic	367.2165*** (df = 8; 1939)	

5. What are the effects of distance and OECD membership on trade in Transportation Services when using a structural Gravity Model with importer and exporter fixed effects, and how do these results compare to the augmented model?

a. **Overall quality of model:** The structural model with fixed effect (see column3, Table 5) has a R-squared and adjusted R-squared value of 0.79 and 0.77 respectively. This is a good fit for the model as the variables included in the model account for approximately 80% variation in trade. The F-statistics for the model is NA.

b. Why should variables measuring GDP be excluded from the econometric model when importer and exporter fixed effects are included, and what additional variables might be captured by these fixed effects?

Including GDP variables in a model with fixed effects is redundant because the fixed effects already account for country-specific economic size. This could lead to perfect multicollinearity or over-specification since these economic sizes (GDP) are already captured by the fixed effects of each country.

c. How do the estimated parameters of the structural Gravity Model with fixed effects compare to those of the augmented model (from question 4), and what differences, if any, are observed in the effect of the OECD variable on bilateral trade in Transportation Services?

Yes, any variable that is country-specific and does not vary over time would also be captured by fixed effects.

d. What differences, if any, are observed in the estimated parameters of the structural Gravity Model without the OECD dummy compared to the intuitive model (from question 3), and how does the effect of distance on bilateral trade in Transportation Services vary between the two models?

The results reveal that OECD membership is not statistically significant in both models. In the augmented model (Model 2), the coefficient for OECD membership is negative and statistically insignificant. This suggests that there is no strong evidence to support that trade volumes are higher between OECD member countries compared to non-members. Contrasting with the augmented model, the fixed effects model shows a positive coefficient for OECD membership, though it remains statistically insignificant. This implies a positive association between being OECD members and higher trade volumes, suggesting that when controlling for unobserved heterogeneity specific to each importer and exporter (fixed effects), OECD membership might facilitate trade.

- **Removing the OECD variable**: Recall, in Model 3, which is the structural model of fixed effect with OECD variable, the OECD variable has no significant effect on trade as seen in Model 3 of Table 5. The structural model without the OECD variable is the Model 4 in Table 5. In this model, removing the OECD variable did not significantly affect the regression estimates and the goodness of fit.

- **Effect of distance in Model 3 and Model 4**: In Table 5, Model 3 is the structural model with OECD variable and Model 4 is a structural model without OECD. The coefficient of log of distance is -1.15 in both Model 3 and 4 and statistically significant at 1% ($p < 0.01$). This further supports that removing the OECD produced no significant changes in the estimates of both models. The result however indicates that 1% increase in distance between two trading countries is associated with an 1.15% decrease in trade between trading partners.

Table 5. Determinants of Trade

	Model 1	Model 2	Model 3	Model 4
(Intercept)	-30.04 ***	-30.46 ***	8.70 ***	8.65 ***
	(0.75)	(0.80)	(0.47)	(0.45)
log_gdp_imp	0.75 ***			
	(0.02)			
log_gdp_exp	0.78 ***			
	(0.02)			
log_distance	-0.81 ***			
	(0.04)			
contig	0.37 **	0.37 **	0.36	0.37
	(0.13)	(0.13)	(0.21)	(0.21)
comlang_off	0.92 ***	0.91 ***	0.10	0.10
	(0.14)	(0.14)	(0.17)	(0.17)
comcol	1.33 ***	1.31 ***	0.32	0.35
	(0.20)	(0.20)	(0.39)	(0.38)
colony	0.75 ***	0.74 ***	0.77 ***	0.77 ***
	(0.14)	(0.14)	(0.19)	(0.19)
log(gdp_imp)		0.76 ***		
		(0.02)		
log(gdp_exp)		0.79 ***		
		(0.02)		
log(dist)		-0.83 ***	-1.15 ***	-1.15 ***
		(0.04)	(0.06)	(0.06)
OECD_dummy		-0.13	0.07	
		(0.08)	(0.16)	
Country Imp/Exp FE	NO	NO	YES	YES
R^2			0.79	0.79
Adj. R^2			0.77	0.77
DF Resid.			1068.00	1068.00
nobs			1948	1948

Note: robust standard errors

**Model 1: intuitive model*
**Model 2: augmented model*
**Model 3: structural model with OECD*
**Model 4: structural model without OECD*

6. What challenges arise when estimating the intuitive or structural Gravity Model, particularly regarding the policy variable OECD, and can these models provide causal insights into the determinants of trade in Transportation Services?

a. Problems/Challenges in Estimating the Impact of OECD Membership

- **Endogeneity and Reverse Causality:** OECD membership might be endogenous to trade, meaning countries with higher trade volumes or greater economic openness are more likely to join the OECD. This creates a risk of reverse causality, where high trade levels lead to OECD membership rather than the other way around. Without addressing this endogeneity, the model might incorrectly estimate the effect of OECD membership on trade, reflecting selection bias rather than a causal relationship.

- **Omitted Variable Bias:** There could be other factors, such as trade policies, regulatory standards, or economic stability, that influence both OECD membership and trade but are not included in the model. If these omitted variables are correlated with both OECD membership and trade volume, they can bias the estimated effect. For instance, more economically developed or trade-oriented countries might both trade more and join the OECD, complicating the isolation of the OECD membership effect.

- **Self-Selection and Heterogeneity:** Countries self-select into the OECD based on characteristics like economic stability, trade openness, and political alignment, which introduces selection bias. OECD countries may differ from non-members in ways that influence trade, making it challenging to separate the effect of OECD membership from these inherent characteristics. The observed differences in trade volumes might reflect pre-existing economic and institutional differences rather than the impact of OECD membership.

- **Limited Variation Over Time:** OECD membership status does not change frequently, especially in cross-sectional or short time-series data. This limited variation makes it difficult to identify a causal effect. Without sufficient temporal variation, techniques like difference-in-differences become less effective.

- **Multicollinearity with Country Fixed Effects:** When using country fixed effects in the structural gravity model, the effect of OECD membership can be partially absorbed by these fixed effects, especially if OECD membership is highly correlated with country-specific characteristics. This complicates the interpretation of the OECD coefficient, as the trade-related benefits of OECD membership might already be captured by other country-level factors included in the fixed effects.

b. Can We Draw a Causal Effect from the Models?

No, we cannot confidently draw a causal effect from these gravity models due to several reasons:

- **Correlation vs. Causation:** The models primarily show correlations between OECD membership and trade, not causation. Even if OECD membership is associated with higher trade, this does not imply that OECD membership itself causes the increase in trade.

- **Instrumental Variables:** To establish causation, an instrumental variable that is correlated with OECD membership but not directly with trade is needed. However, finding a valid instrument is challenging, as most factors influencing OECD membership, such as economic openness or institutional quality, also affect trade. Without a valid instrument, causality cannot be definitively attributed to OECD membership.

- **Fixed Effects and Unobserved Factors:** While fixed effects help control for unobserved, time-invariant country characteristics, they do not address endogeneity related to OECD membership itself. Time-varying factors that could influence both trade and OECD membership, such as policy changes, remain a source of potential bias.

- **Selection Bias in OECD Membership:** OECD countries are likely different from non-OECD countries in ways that affect trade. This selection bias means that comparing OECD and non-OECD members may not provide an accurate measure of OECD membership's causal impact on trade, as differences in trade might reflect these underlying characteristics rather than the membership itself.