Research Project on

Structural Gravity Model Estimation using India-CPTPP Trade Data and Counterfactual Analysis

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Group Members:

	Name	**Roll Number**
1.	Abhinav Agarwal	190024
2.	Abhinav Verma	190032
3.	Kshitiz Doon	190441
4.	Kush Daga	190451
5.	Siddharth Kumar Pandey	190839
6.	Siddharth Kumar Singh	190840

Abstract

In this paper, we have worked on the structural gravity model, which is an extended version of the basic gravity model based on a direct relationship of import value between two countries with their GDPs and indirect relationship with trade cost variable, namely distance. Structural gravity models include Multilateral Trade Resistance terms in the form of importer and exporter dummies to tackle the bias generated in normal OLS regression of the basic gravity model. In this paper, we have estimated our model using the CPTPP-India trade data employing three methodologies- Two way Fixed Effects, Poisson Pseudo Maximum Likelihood Estimation and Baier and Bergstrand Bonus Vetus OLS.We have used the software Stata for regression purpose. We took data on 5 different products for the year 2018, hence our work is a cross-sectional analysis. After the estimation, we moved to counterfactual analysis testing the relevance of the CPTPP alliance by considering two scenarios- if there is no CPTPP in 2025, and in the second case, if India Joins CPTPP in 2025.

Introduction

Gravity model is famously called, “The Empirical Workhorse of International Trade”. The basic gravity model connects the trade value with GDPs of trading countries and bilateral distance between them. But over the years, trade costs have been accounted for by tariffs, Non-Tariff Barriers and Multilateral Trade Resistance terms. These models are structural gravity models. With the increasing availability of data, it makes sense for us to include these variables to get more and more up-to-date and accurate estimations of models.

The purpose of this paper is to estimate the structural gravity model using trade flow data between India and CPTPP countries and infer the role of the Comprehensive and Progressive Agreement for the Trans-Pacific Partnership, popularly known as CPTPP, an FTA involving 11 countries, which was signed in the year 2018. The signatories are -

1. Australia
2. New Zealand
3. Canada
4. Chile
5. Brunei
6. Japan
7. Malaysia
8. Mexico
9. Peru
10. Singapore
11. Vietnam

The structural gravity model given by Anderson and Wincoop in their paper titled “Gravity with Gravitas: A Solution to the Border Puzzle” will be our basis for estimation. The equation is given as -

$$log(X_{ij}^{k}) = logY_{i}^{k} + logE_{j}^{k} - logY^{k} + (1 - \sigma_{k})[log\tau_{ij}^{k} - log\Pi_{i}^{k} - logP_{j}^{k}]$$

This equation and the different variables have been explored further in the model specification. Here, Π_{i}^{k} and P_{j}^{k} are multilateral trade resistance terms, and τ_{ij}^{k} represents the trade costs. We would estimate the structural gravity equation by using 3 different methodologies. Trade costs are accounted for using variables like distance, tariff rates and Non-tariff Barriers of the countries. The purpose of doing this is to analyze the effect that the CPTPP has had on the participant countries, as well as to predict the effect it may have on India’s trade flow if it were to be a member country. We would be using the Stata software to do our analysis.

Literature Review

Tinbergen (1962) gave the basic gravity equation, which was analogous to the law of Gravitation given by Newton. This basic and intuitive gravity model showed a direct relationship between the trade value between two countries with the product of their GDPs and an inverse relationship with trade costs involved. Trade costs were measured in terms of distance between the trading countries here.

McCallum (1995) used the traditional gravity model to study the US-Canada trade flows. This study highlighted the famous ‘Border puzzle’ in which disproportionate trade was observed among Canadian provinces compared to their trade with the US, even having a Free Trade Agreement and open borders for trade. Anderson and Wincoop (2003), in their landmark paper “Gravity with Gravitas: A Solution to the Border Puzzle”, gave the ‘structural’ gravity model in which they included the Multilateral Trade Resistance terms(both inward and outward) in the gravity model. The demand side of this model was a “love for variety” CES utility function and the production side involved producers employing the increasing returns to scale methodology just like Krugman’s (1980) model. This model solved most of the estimation issues faced by the traditional gravity model, and McCallum’s work was also improved upon by providing consistent estimates on cross-border US-Canada trade.

Anderson and Wincoop (2003) did the estimation of the structural gravity equation using the methodology of Structurally Iterated Least Squares. Baier and Bergstarnd (2009) did the estimation of the gravity equation using Bonus Vetus OLs methodology in which there were no MTR terms but Taylor approximations of the trade cost terms.

Chaney and Helpman (2008) developed gravity-like equations modeling the heterogeneity in productivity by firms. Eaton and Kortum (2002) developed a sophisticated Ricardian model with firm heterogeneity, which involved a gravity-like equation for modeling bilateral trade.

Objectives

The objectives of our paper are-

1. To estimate the Structural Gravity Model using the trade flow data on India-CPTPP countries employing these three approaches -
    (a) Two-way fixed effects methodology
    (b) PPML methodology
    (c) Baier and Bergstrand Bonus Vetus OLS methodology
2. To do some counterfactual analysis using the estimates calculated to infer the role of the CPTPP agreement by analyzing trade flows in case of two scenarios-
    (a) If there is no CPTPP in the future.
    (b) If India joins the CPTPP in the future.

Model Specification

The functional form of our model where dependent variable is represented as a function of independent variables:-

$$X_{ij} = F(d_{ij}, Y_j, Y_i, NTB_i, NTB_j, CPTPP, IMP_1 \ldots IMP_{12}, EXP_1 \ldots EXP_{12}, CPTPP\_TD_1, CPTPP\_TD_2, COB_{ij}, LL_{ij}, t_{ij})$$

Where,

$X_{ij} :- \ Imports\ in\ country\ i\ from\ \ country\ j$

$d_{ij} :- \ The\ bilateral\ distance\ between\ country\ i\ and\ j$

$LL_{ij} :- \ Whether\ one\ of\ the\ countries\ i, j\ is\ Landlocked$

$COB_{ij} :- \ Whether\ the\ countries\ have\ a\ common\ border$

$t_{ij} :- \ Tariffs\ \ rate$

$NTB_i :- \ Non\ Tariff\ barrier\ of\ country\ i$

$NTB_j :- \ Non\ Tariff\ barrier\ of\ country\ j$

$IMP_k :-$ *Importer Dummy variable which takes value* 1 *when country k is importer for k* $\in [1, 12]$

$EXP_k :-$ *Exporter Dummy variable which takes value* 1 *when country k is exporter for k* $\in [1, 12]$

$Y_i :-$ *Importers GDP*

$Y_j :-$ *Exporters GDP*

$CPTPP :-$ *Trade Creation dummy* (*takes value* 1 *when both i and j are part of CPTPP*, 0 *otherwise*)

$CPTPP\_TD_1 :-$ *Trade Diversion dummy* (*if i is part of agreement and j is not then* 1, 0 *otherwise*)

$CPTPP\_TD_2 :-$ *Trade Diversion dummy* (*if i is not part of agreement and j is then* 1, 0 *otherwise*)

Here trade costs are represented in terms of a number of variables - the distance between the countries, the tariff rates, the non-tariff barriers, whether the countries share a common border, are part of whether one of them is landlocked or not. Importer's and Exporter's GDP are also included along with a trade creation dummy capturing the CPTPP trade alliance which equals one if both countries are part of the CPTPP alliance and zero otherwise. There are two trade diversion dummies, $CPTPP\_TD_1$, which equals 1 if i is part of the agreement and j is not, 0 otherwise and $CPTPP\_TD_2$, which equals 1 when i is not part of the agreement and j is, 0 otherwise.

Model Estimation

Model estimation is done using three methodologies. These are-

1. Two- way fixed effects methodology.
2. Poisson Pseudo Maximum Likelihood Estimation methodology.
3. Baier and Bergstrand Bonus Vetus OLS methodology.

Two way Fixed Effects Model-

The log linear model which we would be estimating under Two- way fixed effects methodology is-

$$\begin{aligned} log\, X_{ij} = C + \alpha_1 log\, Y_i + \alpha_2 log Y_j + \alpha_3 logt_{ij} + \alpha_4 logd_{ij} + \alpha_5 logNTB_i + \alpha_6 logNTB_j + \\ \alpha_7 \cdot CPTPP + \alpha_8 CPTPP\_TD_1 + \alpha_9 CPTPP\_TD_2 + \alpha_{10} LANG_{ij} + \alpha_{11} COB_{ij} + \alpha_{12} LL_{ij} + \\ a_1 IMP_1 + a_2 IMP_2 + \ldots\ldots + a_{12} IMP_{12} + b_1 EXP_1 + b_2 EXP_2 + \ldots\ldots + b_{12} EXP_{12} + \varepsilon_{ij} \end{aligned}$$

PPML Estimation-

The gravity model can also be estimated by Poisson Pseudo Maximum Likelihood Estimation methodology. This is done to account for count data, which can take zero values that cannot be estimated using the Fixed effects method. The model for this is given by -

$$log\,\lambda_{ij} = C + \alpha_i + \alpha_j + \beta_1 t_{ij} + \beta_2 d_{ij} + \beta_3 NTB_i + \beta_4 NTB_j + \beta_5 CPTPP + \beta_6 CPTPP\_TD_1 + \beta_7 CPTPP\_TD_2 + \beta_8 COB_{ij} + \beta_9 LL_{ij} + \beta_{10} LANG_{ij} + \varepsilon_{ij}$$

Baier and Bergstrand Bonus Vetus OLS methodology-

Another approach we would be adopting is the Baier and Bergstrand Approach, where multilateral trade resistance terms are not modeled using importer's and exporter's dummies but using the Taylor series approximation of MTR terms. The original structural gravity model is -

$$log(X_{ij}^k) = logY_i^k + logE_j^k - logY^k + (1 - \sigma_k)[log\tau_{ij}^k - log\Pi_i^k - logP_j^k]$$

The Baier and Bergstrand transformation for the model is-

$$logX_{ij}^k = logY_i^k + logE_j^k - logY^k + (1 - \sigma_k)[log\tau_{ij}^{k^*}]$$

By using the Baier and Bergstrand Taylor Approximation of MTR term (trade cost)-

$$log\tau_{ij}^{k^*} = log\tau_{ij}^k - \sum_{j=1}^{N} \theta_j^k log\tau_{ij}^k - \sum_{j=1}^{N} \theta_j^k log\tau_{ji}^k + \sum_{i=1}^{N}\sum_{j=1}^{N} \theta_i \theta_j log\tau_{ij}^k$$

Weighted by GDP shares-

$$\theta_i^k = \frac{Y_i^k}{Y^k}$$

We calculate log for each trade cost variable and then estimate the transformed Baier and Bergstrand model.

Results

Two- Way Fixed Effects:

Number of obs	471
F(24, 446)	16.02
Prob > F	0
R-squared	0.3413
Root MSE	1.4507

log_imports	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
log_gdp_imp	1.007291	0.1073051	9.39	0	0.7964046	1.218178
log_gdp_exp	1.421925	0.1784755	7.97	0	1.071168	1.772683
log_dist	-0.1525773	0.0767996	-1.99	0.048	-0.3035113	-0.0016434
log_tariff	-0.8118719	0.1766358	-4.6	0	-1.159014	-0.4647301
cptpp_tc	0.263552	0.2777483	-0.95	0.343	-0.80941	0.282306
cob	2.090188	0.4208284	4.97	0	1.263135	2.917241
imp_1	0.3241379	0.2236508	1.45	0.148	-0.1154023	0.7636781
imp_3	0.0445541	0.2424379	0.18	0.854	-0.4319084	0.5210166
imp_4	0.4900919	0.3053278	1.61	0.109	-0.1099681	1.090152
imp_7	0.4888894	0.3669583	1.33	0.183	-0.2322928	1.210072
imp_9	0.1243152	0.2482508	0.5	0.617	-0.3635714	0.6122018
imp_10	0.5137626	0.245319	2.09	0.037	0.0316378	0.9958873
imp_11	1.052857	0.2832254	3.72	0	0.496235	1.609479
imp_12	0.0487749	0.4033056	0.12	0.904	-0.7438404	0.8413903
exp_1	-0.1775645	0.3047587	-0.58	0.56	-0.7765058	0.4213769
exp_3	-0.0011267	0.3207821	0	0.997	-0.6315588	0.6293055
exp_4	-0.936045	0.3108256	-3.01	0.003	-1.54691	-0.3251802
exp_6	1.306574	0.3352875	3.9	0	0.6476346	1.965514
exp_7	0.4578902	0.4122367	1.11	0.267	-0.3522774	1.268058
exp_8	0.6231071	0.3079191	2.02	0.044	0.0179545	1.22826
exp_9	-0.8282785	0.3090345	-2.68	0.008	-1.435623	-0.2209338
exp_10	0.8220872	0.3466171	2.37	0.018	0.1408817	1.503293
exp_11	1.102076	0.3546257	3.11	0.002	0.4051308	1.79902
exp_12	-0.419884	0.334084	-1.26	0.209	-1.076458	0.2366903
_cons	-17.33447	1.846426	-9.39	0	-20.96324	-13.70569

As we can see from the table of estimates, most of our independent variables got significant estimates and signs of estimates were also on expected lines with GDPs of trading countries having positive relationship with trade value and trade cost variables like distance, tariff rates and Non TariFF Barriers having a negative relationship with import value. The trade creation dummy also is positive and significant showing that CPTPP is indeed trade creating among member countries.

PPML Methodology:

No. of parameters - 26
No. of observations - 555
Pseudo Log-Likelihood - -1.661e+08
R-squared - 0.19771378

imp_value	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
gdp_importer	1.25E-10	1.03E-10	1.21	0.224	-7.66E-11	3.26E-10
gdp_exporter	1.68E-10	9.81E-11	1.71	0.087	-2.46E-11	3.60E-10
distance	-0.0001593	0.0000409	-3.9	0	-0.0002395	-0.0000792
ntb_importer	-0.0215588	0.1763788	-0.12	0.903	-0.3672549	0.3241372
ntb_exporter	-0.2377033	0.1356012	-1.75	0.08	-0.5034767	0.0280701
simple_avg_tariff	-0.0456434	0.0204676	-2.23	0.026	-0.0857591	-0.0055277
cptpp_tc	0.2402937	0.8710167	0.28	0.783	-1.466868	1.947455
cptpp_td1	2.91861	0.9270605	3.15	0.002	1.101605	4.735615
cob	3.066383	0.7086968	4.33	0	1.677363	4.455403
imp_1	0.2204633	0.6160833	0.36	0.72	-0.9870377	1.427964
imp_2	-4.315691	0.5466602	-7.89	0	-5.387125	-3.244257
imp_3	0.9346806	0.4961776	1.88	0.06	-0.0378095	1.907171
imp_7	1.905373	0.6895849	2.76	0.006	0.5538118	3.256935
imp_9	-1.115229	0.5409607	-2.06	0.039	-2.175493	-0.0549656
imp_10	0.4869956	0.5626944	0.87	0.387	-0.6158651	1.589856
imp_12	0.6148517	1.003983	0.61	0.54	-1.352918	2.582621
exp_1	-2.88663	0.4626978	-6.24	0	-3.793502	-1.979759
exp_2	-8.743604	0.7856944	-11.13	0	-10.28354	-7.203671
exp_3	-1.9255	0.5039242	-3.82	0	-2.913173	-0.9378265
exp_4	-6.293941	0.7021833	-8.96	0	-7.670195	-4.917687
exp_6	0.210266	0.516702	0.41	0.684	-0.8024514	1.222983
exp_8	-2.085074	0.4660981	-4.47	0	-2.99861	-1.171539
exp_9	-6.827555	0.715301	-9.55	0	-8.229519	-5.42559
exp_10	-0.3250607	0.5380713	-0.6	0.546	-1.379661	0.7295397
exp_12	-3.828036	0.5333763	-7.18	0	-4.873435	-2.782638
_cons	14.24793	1.270962	11.21	0	11.75689	16.73897

The PPML estimates were calculated on a count dataset where zero values of import values were also included in our analysis. The estimates were again on expected lines for independent variables with most of them being significant and the trade creation dummy again being positive, indicating the relevance of this alliance for the member nations.

Bonus Vetus OLS Methodology:

Number of obs	471
F(8, 462)	21.11
Prob > F	0.0000
R-squared	0.2453
Root MSE	1.5257

log_imports	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
log_dist_star	0.1864795	0.0601129	3.1	0.002	0.068351	0.304608
log_tariff_star	-0.1151762	0.1582544	-0.73	0.467	-0.4261637	0.1958114
log_ntb_imp_star	0.9503602	0.388351	2.45	0.015	0.1872069	1.713513
log_ntb_exp_star	1.728905	0.3820994	4.52	0	0.9780365	2.479773
cptpp_tc	0.665968	0.2714721	2.45	0.015	0.132495	1.199441
cptpp_td1	-0.1038463	0.3568719	-0.29	0.771	-0.8051395	0.5974469
log_gdp_imp	0.6628781	0.1182456	5.61	0	0.4305122	0.8952439
log_gdp_exp	0.9613515	0.159006	6.05	0	0.648887	1.273816
_cons	-11.3959	1.804246	-6.32	0	-14.94144	-7.850351

The Bonus Vetus OLS had the Taylor series expansion of the trade cost variables, namely distance, tariff and non tariff barriers of importers and exporters. The estimates we got were mostly significant and again the trade creation dummy was positive indicating the positive impact of this alliance on participating members. But, the signs of estimates of tariff and both non tariff barriers were positive, indicating a departure from the usual notion of negative impact of these variables on trade. It may be due to the quality of products traded where the quantity of trade is insignificant in front of the quality of products traded.

Counterfactual Analysis

We did counterfactual analysis using the estimates we got from PPML regression. The reason for using the estimates of PPML was simply because it can be applied for count data models, hence the estimates obtained are more accurate with lesser bias in case of PPML. Now, the future scenario we consider here is the year 2025. We extrapolate the data on dynamic variables- namely GDP and tariff rates, while distance and NTBs (Prevalence Score) would be the same. The summary of the two scenarios considered are-

Scenario 1- If there is no CPTPP in future.
In this scenario, we took data of independent variables for 2025 on all the 5 products between three pairs of CPTPP countries- Australia and Canada, Singapore and Japan, Mexico and New Zealand. We put the values of CPTPP_TC trade creation dummy value zero and trade diversion dummies were also kept zero. The import values were calculated and the results showed that without CPTPP agreement, the trade values are expected to fall in 2025. The fall is not very significant.

Scenario 2- If India joins CPTPP in future.
In this scenario, we took data of independent variables for 2025 on all the 5 products between three CPTPP countries and India- Australia and India, India and Japan, India and New Zealand. We put the values of CPTPP_TC trade creation dummy value of 1 now, and trade diversion dummies were also modified accordingly.. The import values were calculated and the results showed that with India joining CPTPP agreement, the trade values are expected to increase marginally, by the amount of estimate of trade creation dummy, which was not much significant but still a possible improvement in trade values can be expected.

Conclusion

We did the structural gravity model estimation using three methodologies and also presented a brief summary of counterfactual analysis. Our results were mostly in line with expectations. The trade value was positively related to GDPs of the trading countries and negatively related to the trade cost variables like distance, tariffs rates, the non tariff barriers, namely the Prevalence score. The work on counterfactual analysis was brief and concise and only involved altering the dummies and using the extrapolated data for that future period of time. The results we got in two scenarios of counterfactual analysis were also in line with our expectations, but the magnitude of changes were not so significant, as we were only modifying dummies here, hence the changes were along margins of estimates of dummies. But it can give a useful insight that CPTPP is indeed welfare inducing for member countries and India can benefit by joining it.

Data and Data Sources

	VARIABLES	SOURCE
1.	Importer's GDP	WDI - World Bank
2.	Exporter's GDP	WDI - World Bank
3.	Distance	CEPII
4.	Non-tariff barriers of importer	UNCTAD
5.	Non-tariff barriers of exporter	UNCTAD
6.	Tariff Rate	WITS - TRAINS
7.	Import value	WITS - TRAINS

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