STRUCTURAL GRAVITY MODEL ESTIMATION USING INDIA-CPTPP TRADE DATA AND COUNTERFACTUAL ANALYSIS

as part of the course

ECO412A : International Economics and Finance

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ABSTRACT

- In this paper, we have worked on structural gravity model estimation using India-CPTPP trade data.
- The estimation has been done using 3 different methodologies- Two way Fixed Effects, PPML and Bonus Vetus OLS. We have used Stata for estimation.
- The dataset includes trade data on 5 different products with simple average tariff and Prevalence score as the Non- Tariff Barrier.
- To model the MTR terms, we have used 12 importer and exporter dummies, a dummy for each country involved.
- Finally, counterfactual analysis is done to model two future scenarios- if there is no CPTPP in future and if India joins CPTPP in future.

INTRODUCTION

- ❖ Gravity equation is famously called the, 'Empirical Workhorse of Trade' due to its significance in explaining trade phenomena extensively.

- ❖ Gravity model has evolved from simple Tinbergen model analogous to Newton's law of Gravitation to structural gravity model involving multilateral trade resistance terms, some geographical as well as historical factors in trade costs to explain volume of trade.

- ❖ We apply structural gravity model to understand trade flows between India and CPTPP countries.

INTRODUCTION (CONTD…)

- The Comprehensive and Progressive Agreement for the Trans-Pacific Partnership, popularly known as CPTPP is a Free Trade Agreement involving 11 countries signed on 8 March 2018. The signatories are - Australia, New Zealand, Canada, Chile, Brunei, Japan, Malaysia, Mexico, Peru, Singapore and Vietnam.

- Trade costs would be accounted by variables like distance, tariff rates, non tariff barriers and some geographical factors, like common border, common language in our structural gravity model estimation.

- Finally, counterfactual analysis to understand importance of CPTPP would be done.

REVIEW OF LITERATURE

- ❖ Tinbergen(1962) formulated the basic model in which volume of trade between two countries was shown to be directly proportional to product of their GDPs and inversely proportional to trade costs (distance here).

- ❖ McCallum(1995) applied the basic gravity model in order to understand the US-Canada trade flows and was confronted with the famous 'Border Puzzle'.

- ❖ Anderson and Wincoop(2003), in their landmark paper,' Gravity with Gravitas: A Solution to the Border Puzzle', introduced Multilateral Trade Resistance terms to solve the border puzzle and gave the 'Structural Gravity Model'.

REVIEW OF LITERATURE (CONTD…)

- Anderson and Wincoop (2003) did the estimation of the structural gravity equation using the methodology of Structurally Iterated Least Squares.

- Baier and Bergstrand (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 modelling 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 modelling 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) Poisson Pseudo Maximum Likelihood estimation 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 analysing 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 in which the dependent variable is represented as a function of independent variables is -

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

MODEL ESTIMATION

- ❖ We would estimate our model using three methodologies. These are -
  (a) Two-way Fixed Effects Methodology
  (b) Poisson Pseudo Maximum Likelihood Estimation Methodology
  (c) Bonus Vetus OLS Methodology by Baier and Bergstrand (2009)

- ❖ We have 12*11= 132 observations for each product and since our analysis involves 5 products, we have 132*5= 660 observations in total.

- ❖ The 5 products included in the analysis are- Animal products, Computer Electronic and optical products, Motor vehicles and parts, Dairy products and Mineral products.

TWO-WAY FIXED EFFECTS ESTIMATION

- The Two-way Fixed Effects model would involve log-linearised form of dependent and independent variables with 12 importer and exporter dummies accounting for Multilateral Trade Resistance terms. The model is :-

$$\log X_{ij} = C + \alpha_1 \log Y_i + \alpha_2 \log Y_j + \alpha_3 \log t_{ij} + \alpha_4 \log d_{ij} + \alpha_5 \log NTB_i + \alpha_6 \log NTB_j + \\ \alpha_7 CPTPP + \alpha_8 CPTPP\_TD_1 + \alpha_9 CPTPP\_TD_2 + \alpha_{10} LANG_{ij} + \alpha_{11} COB_{ij} + \alpha_{12} LL_{ij} + \\ a_1 IMP_1 + a_2 IMP_2 + \dots + a_{12} IMP_{12} + b_1 EXP_1 + b_2 EXP_2 + \dots + b_{12} EXP_{12} + \varepsilon_{ij}$$

POISSON PSEUDO-MAXIMUM LIKELIHOOD METHOD

- The Poisson Pseudo-Maximum Likelihood Estimator is a generalised linear model and can be used to estimate the gravity model in its multiplicative form. The model 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

- The Bonus Vetus OLS methodology involves Taylor series expansion of trade cost terms in place of importer and exporter dummy terms. The model is :-

$$\log X_{ij}^{k} = \log Y_{i}^{k} + \log E_{j}^{k} - \log Y^{k} + (1-\sigma)\left[\log \tau_{ij}^{k^{*}}\right]$$

- The Baier and Bergstrand Taylor approximation of the MTR term (trade cost) :-

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

- Here, GDP share is given by

$$\theta_{i}^{k} = \frac{Y_{i}^{k}}{Y^{k}}$$

CODES

- Code for estimating structured gravity model using Two-way fixed effects methodology :-

```
regress log_imports log_gdp_imp log_gdp_exp log_dist
log_ntb_imp log_ntb_exp log_tariff cptpp_tc cptpp_td1 ll cob
imp_1 imp_2 imp_3 imp_4 imp_5 imp_6 imp_7 imp_8 imp_9 imp_10
imp_11 imp_12 exp_1 exp_2 exp_3 exp_4 exp_5 exp_6 exp_7 exp_8
exp_9 exp_10 exp_11 exp_12, vce(robust)
```

CODES (CONTD…)

❖ Code for estimating structured gravity model using Poisson Pseudo-Maximum Likelihood (PPML) estimator :-

```
ssc install ppml

ppml imp_value gdp_importer gdp_exporter distance ntb_importer
ntb_exporter simple_avg_tariff cptpp_tc cptpp_td1 ll cob imp_1
imp_2 imp_3 imp_4 imp_5 imp_6 imp_7 imp_8 imp_9 imp_10 imp_11
imp_12 exp_1 exp_2 exp_3 exp_4 exp_5 exp_6 exp_7 exp_8 exp_9
exp_10 exp_11 exp_12
```

CODES (CONTD…)

❖ Code for estimating structured gravity model using Baier and Bergstrand Bonus Vetus OLS methodology :-

```
. egen temp1 = mean(log_dist), by (product)

. egen temp2 = mean(log_dist), by (product)

. egen temp3 = sum(log_dist), by (product)

. gen log_dist_star = log_dist - temp1 - temp2 +
  (1/(9.70*9.70))*temp3
```

CODES (CONTD…)

- Code for estimating structured gravity model using Baier and Bergstrand Bonus Vetus OLS methodology (continued) :-

```
. egen temp4 = mean(log_tariff), by (product)

. egen temp5 = mean(log_tariff), by (product)

. egen temp6 = sum(log_tariff), by (product)

. gen log_tariff_star = log_tariff - temp4 - temp5 +
  (1/(9.70*9.70))*temp6
```

CODES (CONTD…)

- Code for estimating structured gravity model using Baier and Bergstrand Bonus Vetus OLS methodology (continued) :-

```
. egen temp14 = mean(log_ntb_imp), by (product)

. egen temp15 = mean(log_ntb_imp), by (product)

. egen temp16 = sum(log_ntb_imp), by (product)

. gen log_ntb_imp_star = log_ntb_imp - temp14 - temp15
  +(1/(9.70*9.70))*temp16
```

CODES (CONTD…)

- Code for estimating structured gravity model using Baier and Bergstrand Bonus Vetus OLS methodology (continued) :-

```
. egen temp17 = mean(log_ntb_exp), by (product)

. egen temp18 = mean(log_ntb_exp), by (product)

. egen temp19 = sum(log_ntb_exp), by (product)

. gen log_ntb_exp_star = log_ntb_exp - temp17 - temp18 +
  (1/(9.70*9.70))*temp19
```

CODES (CONTD…)

- Code for estimating structured gravity model using Baier and Bergstrand Bonus Vetus OLS methodology (continued) :-

```
regress log_imports log_dist_star log_tariff_star
log_ntb_imp_star log_ntb_exp_star cptpp_tc cptpp_td1
log_gdp_imp log_gdp_exp, vce(robust)
```

COUNTERFACTUAL ANALYSIS

We do some counterfactual analysis using the estimates we got for different independent variables to predict the trade flows in some future period of time in case of two possible scenarios. The data on explanatory variables would be interpolated for that future period of time (2025). Two scenarios would be considered. These are -

(a) If there is no CPTPP in 2025. Predicted future trade flows would be compared with present ones. Only applied for some selected pairs of countries in CPTPP.

(b) If India joins CPTPP in 2025. Again, future trade flows would be compared with present ones.

RESULTS

The results section would consist of the estimation results of three methodologies- Two way fixed effects, Poisson Pseudo Maximum Likelihood Estimation and Baier and Bergstrand Bonus Vetus OLS.

TWO WAY FIXED EFFECTS ESTIMATES

The summary of the parameters of regression are

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

TWO WAY FIXED EFFECTS ESTIMATES

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

TWO WAY FIXED EFFECTS ESTIMATES

log_imports	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
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

TWO WAY FIXED EFFECTS ESTIMATES

log_imports	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
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

TWO WAY FIXED EFFECTS ESTIMATES

log_imports	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
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

PPML ESTIMATES

Number of parameters	26
Number of observations	555
Pseudo log-likelihood	-1.661e+08
R-squared	.19771378
Option strict is	off

PPML ESTIMATES

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

PPML ESTIMATES

imp_value	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
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

PPML ESTIMATES

imp_value	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
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

PPML ESTIMATES

imp_value	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
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

BONUS VETUS OLS ESTIMATES

The summary of the parameters of regression are

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

BONUS VETUS OLS ESTIMATES

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

COUNTERFACTUALS

- ❖ 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.
- ❖ For the case of no CPTPP in 2025, 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.
- ❖ In case of India joining CPTPP in future, 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.

CONCLUSIONS

- As expected, the regression results using three methodologies showed a positive relationship between trade values and GDPs of the trading countries.
- The trade cost variables like distance, tariff rates, non-tariff barriers display a negative relationship with the import value.
- The trade creation dummy has a positive coefficient in all the estimating procedures showing the CPTPP alliance is surely trade creating.
- The importer and exporter dummies are included to display the multilateral trade resistance and most of the variables have a significant impact on import value.
- In case of counterfactuals, we find that CPTPP alliance is welfare inducing

DATA AND DATA SOURCES

SERIAL NO.	VARIABLES	SOURCE
1.	Importer's GDP	World Development Indicators - World Bank
2.	Exporter's GDP	World Development Indicators - 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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