Analyzing Trade Flows of GMO Crops under TPP in a Gravity Framework: An Application of the Heckman Selection Model

by

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Outline of Presentation

- Introduction
- Objective
- Methodology
- Results & Discussion
- Summary & Conclusion

Introduction

- Genetically modified organism (GMO) refers to crops or animals created for human and animal consumption using gene manipulations, to ensure they possess specific desirable characteristics (Zarrilli, 2005).

- GMOs started in 1980s when scientist discovered that DNA could be transferred from one organism to another with the first transgenic plant, a tobacco plant resistant to anti-biotics, created in 1983 (Cramer, 2001).

Introduction

- Globally, approximately 420 million acres of genetically engineered crops were planted in 28 countries in 2012 (International Service for the Acquisition of Agri-biotech Applications, 2012).

- U.S. is the lead country in the cultivation and trade of GMO foods (Clive, 2014).U.S. acreage accounts for approximately 41 percent of the acres planted.

- The three main GM crops in U.S. are corn, soybean and cotton with 93%, 94% and 96% adoption rates, respectively

Introduction

- About 88%, 93%, and 94% of corn, soybean and cotton produced in the U.S. are genetically modified. About 80% of these three crops are exported (USDA, 2014).

- Australia, Japan and New Zealand have comprehensive laws that require labeling GM foods. Also, eighty countries in Europe have banned the use of GMO seeds while Vietnam has shown some wariness towards GMO foods.

- However, with the impending Trans-Pacific Partnership (TPP) agreement, U.S. hopes to overcome these challenges and expand its trade to all TPP countries.

Objective

- The main purpose of this study is to analyze the trade flows of U.S. GMO corn, cotton and oilseed (soybean and cottonseed) to countries that are part of TPP trade agreement based on Gravity framework.

- The specific objective:
  - Develop an GMO risk index based on regulations
  - Evaluating the importance of GMO risk index along with traditional variables on trade flows using Heckman (1979) selection model.

Theoretical Framework of the Gravity Model

- The gravity model is a common knowledge in regional science for describing and analyzing spatial flows.

- It was pioneered in the analysis of international trade by Tinbergen (1962), Poyhonen (1963) and Linneman (1966).

- The basic gravity model begins with Newton's law of gravitational force (GFij) between two objects i and j (Reinert, 2006).

Theoretical Framework of the Gravity Model

- In an equation form, it is given as;

$$GF_{ij} = \frac{M_i M_j}{D_{ij}} \quad i \neq j \qquad (1)$$

where; M_i *and* M_j are the masses of the objects i and j while D_{ij} is the distance between the two objects.

- The gravity model of international trade introduced by Tinbergen (1962) replaces the gravitational force with trade flows between two countries or exports from country i to country j ($EX_{i,j}$).
- The mass in (1) can be associated with four different alternatives namely; the gross domestic product (GDP) of the two countries, both GDP and population of the two countries (POP), GDP per capita and a combination of GDP and GDP per capita.

Theoretical Framework of the Gravity Model

- In the first alternative, Reinert (2006) proposed the gravity model to be given as;

$$EX_{ij} = \frac{GDP_i GDP_j}{D_{ij}} \quad (2)$$

- Taking the natural logarithm of equation (2) gives

$$InEX_{ij} = \alpha + \beta_1 InGDP_i + \beta_2 InGDP_j - \beta_3 InD_{ij} \quad (3)$$

- For panel (countries over time) data equation (2) is written as

$$InEX_{ijt} = \alpha + \beta_1 InGDP_{it} + \beta_2 InGDP_{jt} - \beta_3 InD_{ijt} \quad (4)$$

Where; the α and the βs are the elasticities and GDP is the income of the two countries respectively.

Theoretical Framework of the Gravity Model

- Adding exchange rate variable to equation (4) to cater for currency differences gives;

$$InEX_{ijt} = \alpha + \beta_1 InGDP_{it} + \beta_2 InGDP_{jt} - \beta_3 InD_{ijt} + \beta_4 InER_{ijt} \quad (5)$$

where β_{4t} is expected to be greater than zero for more exports from country i to country j.

- Due to the invariant nature and similarity to the GMO risk indices, the distance variable was dropped and dummies for GMO risk indices were included.

Theoretical Framework of the Gravity Model: GMO Risk Index

- A GMO risk index based on regulations was created for the 12 countries to measures the openness of a country to GMO trade, domestic production and consumption.
- The GMO risk index reflects the following four regulations
  - **Approval process,**
  - **Risk assessment,**
  - **Labeling policies and**
  - **Membership in international organization.**
- The specific indicators assessed for each of the four regulations and the scores assigned are presented in Table 1

Theoretical Framework of the Gravity Model: **GMO Risk Index**

GMO Regulatory Policy	Indicators	Scores
Approval Process	Absence of GMO approval procedures	**0**
	Mandatory approval process but far from enforcement	**1**
	Mandatory approval process adopting the principle of substantial equivalence	**2**
	Mandatory approval process adopting the precautionary principle	**3**
	GM-free country	**4**
Risk Assessment	Absence of GMO risk analysis	**0**
	Proposed risk assessment but far from enforcement	**1**
	Mandatory risk assessment	**2**
	GM-free country	**3**
Labeling Policies	Absence of labeling policies	**0**
	Voluntary GMO labeling	**1**
	Mandatory GMO label with threshold> 1%	**2**
	Mandatory GMO label with threshold </=3%	**3**
	GM-free country	**4**
Membership in International Agreement	No adherence to International agreements	**0**
	Adherence to a single international agreement	**1**
	Adherence to both international agreements	**2**

Theoretical Framework of the Gravity Model

- CODEX Aliment Arius International Food Standards and Cartagena Protocol on Biosafety were considered for membership of international organizations regulatory policy.

- The scores for each country were aggregated across all the indicators to give the total scores.

- The minimum expected score is zero (i.e. most open to GMO trade, production and consumption) and the maximum expected score is 20 (i.e. Not open to GMO trade, production or consumption).

- The total scores obtained by each country are summarized in Table 2.

Theoretical Framework of the Gravity Model

Table 2. Summary of GMO scores of each TPP Country

GMO Scores	Number of Countries (Frequency)	Countries
3	1	United States
6	2	Canada, Singapore
9	1	Australia
10	6	Chile, Japan, Malaysia, Mexico, New-Zealand, Vietnam
13	2	Brunei Darussalam, Peru

- The GMO scores for the TPP countries ranged from 3 to 13.
- U.S. had the least GMO score of 3 with Brunei Darussalam and Peru having the highest GMO score of 13.
- The GMO risk index for each country (i) was calculated as

$$GMO\_Index_i = |USA\ Score - Total\ Scores_i| \quad (6)$$

Data Source

- The study uses panel data from 1970 to 2014 for 11 countries - Australia, Brunei Darussalam, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, and Vietnam.

- Data on volume of U.S. corn, cotton and oilseed (soybean and canola oils) exports to 11 TPP countries as well as the export prices of the three commodities were obtained from the global agricultural trade systems (GATS) of the Foreign Agricultural Services (FAS) of USDA

- While data on real GDP and real exchange rate were obtained from the World Bank and International Monetary Fund (IMF).

Data Source
Dealing with Zero Trade Flows

- In our data set, there are 144 (29%), 143 (28%), and 62 (12.5%) zero-valued exports out of 495 for cotton, corn, and oilseeds, respectively.
- In this paper, using the Heckman selection model, the following two endogenous variables are estimated
  - **Trade flows (Yes or No) – Selection equation (Probit)**
  - **Magnitude of trade flows – Outcome equation (Tobit)**

Data Source: Endogenous and Exogenous Variables

- The exogenous variables include
  - GDP of U.S.
  - GDP of TPP countries
  - Export price (supply price)
  - Real exchange rate and
  - Newly developed GMO risk index.

Empirical Model of Trade Flows

- The Heckman selection model of trade flows is specified as

$$EX_{ijt} = \alpha + \beta_1 lnGDP_{it} + \beta_2\ lnGDP_{jt} + \beta_3 lnER_{ijt} + \sum_{k=1}^{3} \beta^K\ GMO_{ijk}^K + \mu_{it} \quad (7a)$$

$$EX_{ijt}^* = \alpha + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnER_{ijt} + \beta_4 lnprice_{ijt} + \sum_{k=1}^{3} \beta_{4+K}^K\ GMO_{ijk}^K + \mu_{it} \quad (7b)$$

$$EX_{ijt} = \begin{cases} 1\ \ if\ \ EX_{ijt} > 0\ \ = EX_{ijt}^* \\ 0\ \ if\ EX_{ijt} \leq 0 \end{cases}$$

Where EX_{ijt} is a discrete choice between 0 and 1 and estimated using Probit model, while $ln\ EX_{ijt}^*$ is estimated using a lower zero censored Tobit model.

Empirical Model of Trade Flows

- The Heckman selection model of trade flows (7a and 7b) is estimated using maximum Likelihood (ML) for
  - Cotton --- not a feed or food
  - Corn --- is a feed or food
  - Oilseeds (soybean and cottonseed) --- is a feed or food

Results and Discussion

- Figures 1 and 2 report
  - U.S. exports of GMO corn, cotton and oilseed to all TPP countries, 1970 to 2014
  - GMO risk index

Figure 1. Trends in U.S. Exports

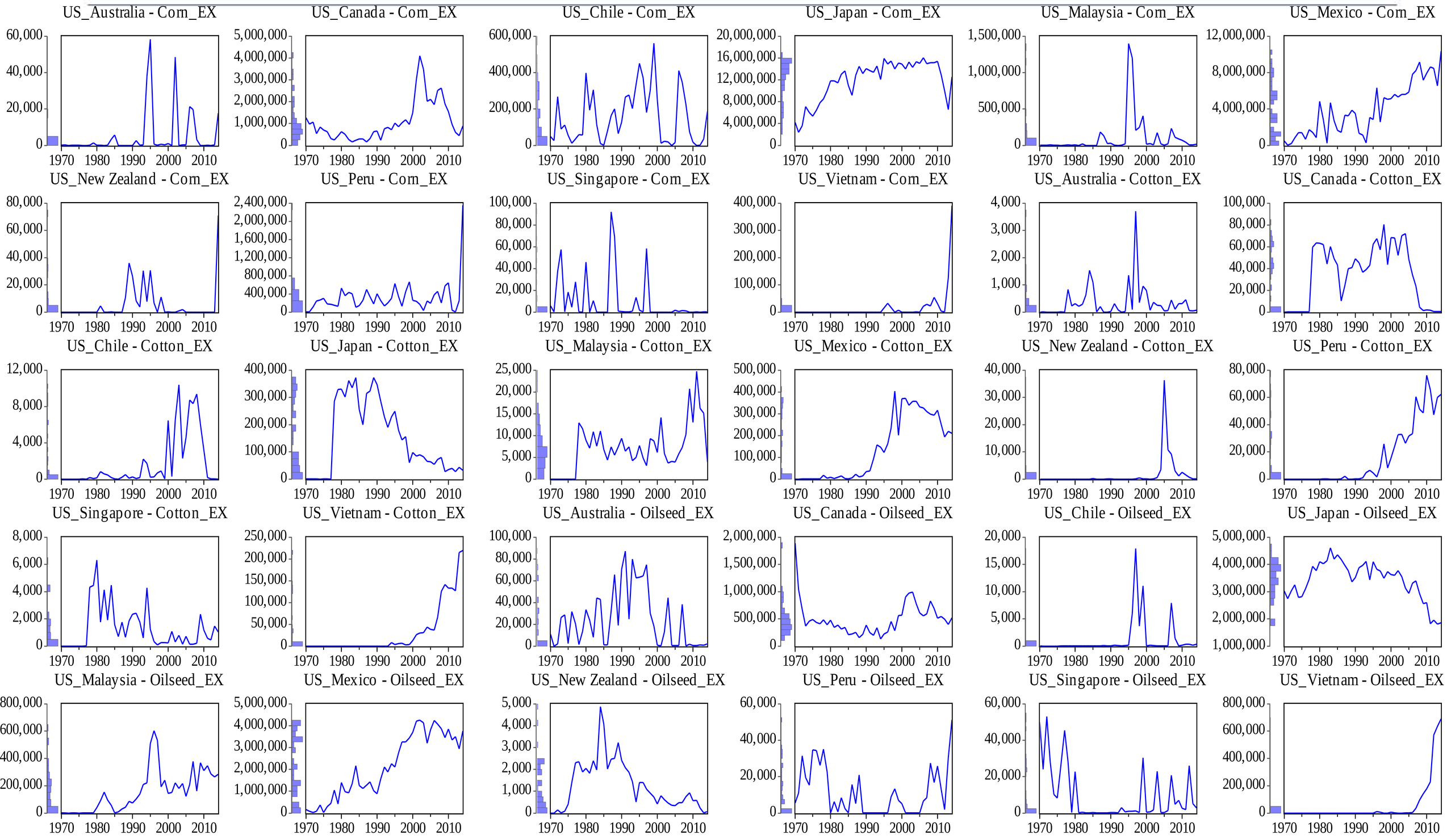
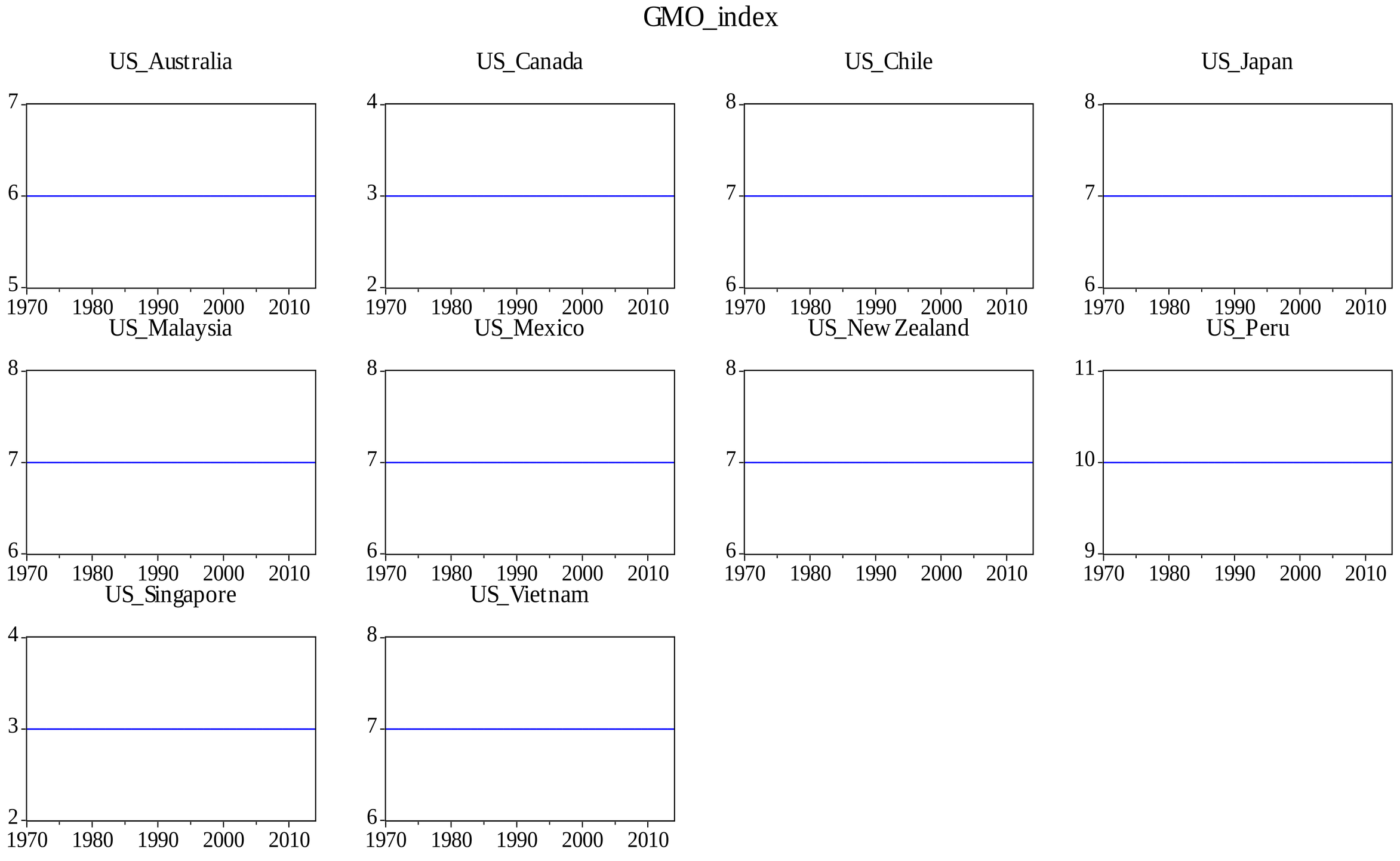


Figure 2. GMO Risk Index



Results and Discussion

- Table 3 reports the results of the selection and outcome equation of the Heckman selection model

- The Heckman selection model is estimated for each of the three crops – Cotton, Corn and Oilseeds

- Here are the results

Results and Discussion: Selection Equation

Variables	Cotton	Corn	Oilseed
Selection Equation			
Intercept	-15.0951***	17.9438***	16.8483***
R_GDP_TPP	0.7495***	1.7274***	2.0726***
R_GDP_US	2.2170***	-1.4390***	-2.0241***
GMO_Risk Index 1	-1.5731**	-3.8314***	0.2503
GMO_Risk Index 2	-4.6356***	-9.1227***	-2.7155***
GMO_Risk Index 3	-0.3985	-2.0890***	0.376

Results and Discussion: Outcome Equation

Variables	Cotton	Corn	Oilseed
Outcome Equation			
Intercept	-28.8767***	20.2110***	-22.6609***
R_GDP_TPP	0.4120***	1.1778***	2.1084***
R_GDP_US	2.5707***	-2.0724***	1.9347***
Exchange Rate	0.0382		-0.2712***
Export Price	0.8299***	0.1398	
GMO_Risk Index 1	1.5503***	-6.1811***	6.5621
GMO_Risk Index 2	0.3111	-8.1240***	-5.0846***
GMO_Risk Index 3	0.455	-5.5944***	-1.1203**

Results and Discussion

- Tables 4 presents the results of the marginal effects of the outcome model.

Results and Discussion

Table 4: Marginal Effects of Outcome Model

	Australia	Brunei	Canada	Chile	Japan	Malaysia	Mexico	New Zealand	Peru	Singapore	Total
						Cotton					
GDP_TPP	0.672	0.743	0.736	0.749	0.740	0.746	0.746	0.745	0.720	0.740	0.733
GDP_US	1.989	2.198	2.176	2.215	2.190	2.208	2.207	2.204	2.129	2.188	2.169
GMO_index_3	-1.411	-1.560	-1.544	-1.571	-1.554	-1.567	-1.566	-1.564	-1.511	-1.553	-1.539
GMO_index_6	-4.159	-4.596	-4.550	-4.630	-4.579	-4.616	-4.614	-4.608	-4.452	-4.575	-4.536
GMO_index_7	-0.358	-0.395	-0.391	-0.398	-0.394	-0.397	-0.397	-0.396	-0.383	-0.393	-0.390
						Corn					
GDP_TPP	1.722	1.727	1.727	1.727	1.727	1.727	1.727	1.727	1.725	1.727	1.727
GDP_US	-1.434	-1.439	-1.439	-1.439	-1.439	-1.439	-1.439	-1.439	-1.437	-1.439	-1.438
GMO_index_3	-3.819	-3.831	-3.831	-3.831	-3.831	-3.831	-3.831	-3.831	-3.827	-3.831	-3.830
GMO_index_6	-9.092	-9.123	-9.123	-9.123	-9.123	-9.123	-9.123	-9.123	-9.112	-9.123	-9.119
GMO_index_7	-2.082	-2.089	-2.089	-2.089	-2.089	-2.089	-2.089	-2.089	-2.087	-2.089	-2.088
						Oilseeds					
GDP_TPP	2.063	1.375	2.073	2.047	2.073	2.038	2.072	2.047	2.020	2.006	2.010
GDP_US	-2.015	-1.343	-2.024	-2.000	-2.024	-1.991	-2.024	-1.999	-1.973	-1.959	-1.963
GMO_index_3	0.249	0.166	0.250	0.247	0.250	0.246	0.250	0.247	0.244	0.242	0.243
GMO_index_6	-2.703	-1.802	-2.715	-2.683	-2.715	-2.670	-2.715	-2.682	-2.647	-2.628	-2.634
GMO_index_7	0.374	0.250	0.376	0.371	0.376	0.370	0.376	0.371	0.366	0.364	0.365

Summary and Conclusions

- This paper quantified the effect of GMO risk index and other traditional trade variables on U.S. exports to 11 TTP countries.
- Heckman selection model of gravity model is employed to analyze trade flows.
- The trade variables including GDP of the exporting and importing country and exchange rate are all significant and mostly with expected signs for the three GMO crops.

Summary and Conclusions

- The marginal effect of GDP_TPP is highest for oilseeds (2.01) compared to corn (1.727) and cotton (0.733).
- The marginal effect of GDP_US is positive for cotton and negative for corn and oilseeds.
- The marginal effect of GMO Risk Index is negative for corn and cotton.
- The marginal effect of GMO Risk Index is negative and positive for oilseeds.

Thanks and Questions