Production Subsidies and Agricultural Trade

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Abstract: This paper examines the impact of subsidies and other determinants on agricultural trade by applying the Poisson Pseudo-Maximum Likelihood (PPML) method to the gravity model using panel data of 72 exporting and 256 importing countries for 20 years from 2000 to 2019. The results show that aggregated Producer Support Estimates (PSEs) have no significant effect on agricultural trade. However, decomposing PSEs into commodity and non-commodity supports provides additional insights. Even though the coefficient estimates of commodity-specific supports are insignificant, non-commodity supports modestly increase agricultural trade and are statistically significant. When exploring the impact of commodity-specific subsidies on trade, dynamic analyses show that these subsidies do not have immediate effects, but lead effects are negative and have anticipatory effects. Meanwhile, non-commodity supports show contemporaneous and delayed effects. Furthermore, the analyses reveal that free trade agreements (FTAs) contribute positively to trade, while the World Trade Organization (WTO) does not impact agricultural trade. Market size variables consistently show strong significance.

Keywords: Domestic Subsidies, Gravity Model, International Trade, Agricultural Commodities

JEL: Q17, F13

1 Introduction

Government subsidies to domestic producers can impact trade by increasing production thus expand exports, which can be detrimental to foreign producers who do not receive government support. Additionally, subsidies interfere with market forces and can make trade difficult by leading to overproduction and reducing prices. According to a report by the Organisation for Economic Co-operation and Development (OECD (2021)), the total amount of support provided to farmers in 54 countries in 2019-2021 was around $817 billion, which is 13% higher from 2018-2020 period. Domestic support paid to individual producers/farmers also increased and reached $611 billion per year during 2019-2021 period. Furthermore, in 2019, the percentage of total farm receipts that came from government support was highest in Iceland (52%), Norway (51%), and Switzerland (46%), while it was lowest in Australia (1.2%), Chile (1.6%), and New Zealand (1.7%).

In terms of the breakdown of subsidies, the OECD reports that in 2019, about 76% of total support to agriculture in OECD countries was provided through measures that are considered to have potentially distorting effects on production and trade, such as price support and market price support. This type of support can create trade distortions and make it difficult for farmers in other countries to compete. Domestic subsidies given to producers can be decomposed into commodity-specific and non-commodity-specific supports. Commodity-specific support refers to government support programs targeted to particular agricultural commodities or products. Non-commodity-specific support refers to government support programs that are not targeted to particular agricultural commodities or products. In 2019, the percentage share of commodity and non-commodity specific PSEs were 43.4% and 56.6%, respectively.

Studies have shown that domestic subsidies play a significant role in determining agricultural trade flows using partial equilibrium (Koo and Kennedy, 2006) and general equilibrium simulation models (Bouët et al., 2005; Anderson and Valenzuela, 2007; Yu and Jensen, 2010); however, the gravity agricultural trade literature examining the impact of

subsidies on trade is scant. Tong et al. (2019) estimate the elasticity of U.S. farm exports to farm subsidies using a gravity model of state-level farm exports to 100 major trading destinations from 1999 to 2011. The findings indicate that a 1% decrease in farm subsidies, measured by direct payment, counter-cyclical payments and commodity, disaster, and crop insurance, would result in a 0.40% per annum reduction in U.S. farm exports, amounting to a reduction of approximately $15.3 billion per year if the complete farm subsidy program was abolished. The study provides evidence that amber-box subsidy programs, like counter-cyclical payments and marketing loan gains, have the strongest effect on farm exports, whereas green-box subsidy payments like direct payments have a negligible effect. The study also reveals that subsidy payments affect exports solely in agricultural commodities, not in livestock. Devadoss et al. (2021) use a multi-country gravity model to analyze how various factors impact agricultural trade of 18 agricultural commodities[1] for 161 exporting and 180 importing countries over the years 1996 to 2010. The factors include trade policies, domestic farm policies (measured by Nominal Rate of Assistance), factor endowments, and trade frictions. They find that domestic subsidies have a statistically insignificant effect on trade. Kondaridze and Luckstead (2023) comprehensively study the impact of domestic subsidies, measured by Producer Single Commodity Transfers (PSCT), and other factors on international trade of dairy products by looking at 49 exporting and 235 importing countries from 2000 to 2016. They find that domestic supports positively but moderately impacts the bilateral dairy trade. The results show that a 1 percent increase in PSCT leads to a 0.02 percent increase in trade, which is statistically significant. In dollar values that is, on average, a 1 percent increase in PSCT translates to a modest increase in dairy trade by $0.77 million. The moderate effect could be explained by the nature of domestic subsidies; the farmers invest money into improving product quality and making production more efficient, and domestic subsidies have no direct effect on international trade.

The main research question of this study is, what is the impact of domestic subsidies

[1]This commodities include barley, rice, cocoa beans, rubber, coffee, sorghum, cotton, soybeans, grapes, sugar, maize, tea, oats, tobacco, pepper, tomatoes, potatoes, and wheat.

on aggregate agricultural commodity trade? This study examines the effects of PSEs on aggregate agricultural trade by estimating gravity models with 72 exporting to 256 importing countries from 2000 to 2019 while controlling for key covariates such as market size, trade agreements, and friction variables. The study employs a Poisson Pseudo Maximum Likelihood (PPML) estimator for contemporaneous and dynamic analyses using lagged-policy and lead-policy data approaches. The results show that aggregate PSEs have no significant effects. However, when the PSEs are decomposed into commodity and non-commodity PSEs, positive but moderate effects of non-commodity supports are observed. The insignificant commodity support suggests that the impact of commodity-specific PSE measures needs to be examined for individual commodities instead of at the aggregate level. The results from the dynamic analyses show that commodity-specific subsidies do not have contemporaneous or delayed effects, while lead effects of commodity-specific subsidies negatively affect trade and have anticipatory effects. In terms of non-commodity supports, we observe contemporaneous effects for both lag- and lead-policy analysis, as well as delayed effects. Free trade agreements (FTAs) boost trade, while World Trade Organization (WTO) is insignificant across models. Market size variables are strongly significant throughout every analysis.

Our contributions are three fold. We aim to extend on agricultural trade literature to (i) examine the impact of aggregate PSEs on aggregate agricultural trade, (ii) decompose PSE into commodity and non-commodity subsidies, and (iii) estimate delayed and anticipatory effects of PSEs and other policy variables.

The remainder of the paper is organized as follows: Section 2 presents the econometric specification. Section 3 explains the data used. Section 4 discusses the results. Section 5 concludes.

2 Econometric Specification of Gravity Model

We estimate a structural gravity model to examine the impacts of domestic subsidies, free trade agreements, WTO, and exporter and importer size on aggregate agricultural trade. Because policy variables may have dynamic impacts on trade, we also examine the effects of lags and leads of policies variables, with a particular interest in subsidies.

We use the PPML estimator (Silva and Tenreyro, 2006) to estimate the structural gravity model defined as

$$T_{ijt} = \exp\left\{\beta_1 \ln S_{it} + \beta_2 A_{ijt} + \beta_3 \ln T_{it} + \beta_4 \ln T_{jt} + \eta_{ij} + \eta_i + \eta_j + \eta_t\right\} + \varepsilon_{ijt}, \tag{1}$$

where $i, j = 1, \ldots, N$ are importing and exporting country indices; T_{ijt} is a bilateral trade flow for country pair i, j in year t; $\ln S_i$ is domestic subsidies given to farmers in exporting country i in year t; A_{ijt} is a vector of trade agreements, such as free trade agreements and WTO joint membership between exporter i and importer j in year t; $\ln T_{it}$ is the total value of production $\left(\sum_j T_{ijt}\right)$ for exporter i in year t; and $\ln T_{jt}$ is the total value of consumption $(\sum_i T_{ijt})$ of agricultural products for importer j in year t; η_{ij} is country-pair fixed effects that controls for all time-invariant factors and unobserved heterogeneity that impact bilateral trade relationships; η_i, η_j, and η_t are exporter, importer, and time fixed effects; and ε_{ijt} is a standard mean-zero error term. Because exporter-time and importer-time fixed effects (which control for multilateral resistance terms) are perfectly collinear with the domestic subsides, we proxy these terms using size variables (T_{it} and T_{jt}) and exporter, importer and time fixed effects. These three fixed effects control for all measured and unmeasured country-specific and time varying factors that could affect bilateral trade.

To estimate the gravity model with friction variables, we defined

$$\begin{aligned} T_{ijt} \;=\; & \exp\left\{\beta_1 \ln S_{it} + \beta_2 A_{ijt} + \beta_3 \ln T_{it} + \beta_4 \ln T_{jt}\right\} \times \\ & \exp\left\{\beta_5 \ln D_{ij} + \beta_6 Lang_{ij} + \beta_7 Col + \beta_8 Cont_{ij}\right\} \times \end{aligned} \tag{2}$$

$$\exp\{\eta_i + \eta_j + \eta_t\} + \varepsilon_{ijt},$$

where $\ln D_{ij}$ is the log of distance from exporter i to importer j, $Lang_{ij}$ is common language between exporter i and importer j, Col_{ij} is colonial history between exporter i and importer j, and $Cont_{ij}$ is shared border between exporter i and importer j.

The gravity model with lagged policy variables is defined as

$$\begin{aligned} T_{ijt} &= \exp\{\beta_1 \ln S_{it} + \beta_2 \ln S_{it-1} + \beta_3 \ln S_{it-2} + \beta_4 \ln S_{it-3} + \beta_5 A_{ijt}\} \times \\ &\quad \exp\{\beta_6 A_{ijt-1} + \beta_7 A_{ijt-2} + \beta_8 A_{ijt-3} + \beta_9 \ln T_{it} + \beta_{10} \ln T_{jt}\} \times \\ &\quad \exp\{\eta_{ij} + \eta_i + \eta_j + \eta_t\} + \varepsilon_{ijt} \end{aligned} \tag{3}$$

where $\ln S_{it}$, $\ln S_{it-1}$, $\ln S_{it-2}$, and $\ln S_{it-3}$ are domestic farm subsidies in exporter i in years t, $t-1$, $t-2$ and $t-3$, respectively. A_{ijt}, A_{ijt-1}, A_{ijt-2}, and A_{ijt-3} are vectors of trade agreements between exporter i and importer j in years t, $t-1$, $t-2$ and $t-3$, respectively.

The gravity model with lead policy variables is defined as

$$\begin{aligned} T_{ijt} &= \exp\{\beta_1 \ln S_{it} + \beta_2 \ln S_{it+1} + \beta_3 \ln S_{it+2} + \beta_4 \ln S_{it+3} + \beta_5 A_{ijt}\} \times \\ &\quad \exp\{\beta_6 A_{ijt+1} + \beta_7 A_{ijt+2} + \beta_8 A_{ijt+3} + \beta_9 \ln T_{it} + \beta_{10} \ln T_{jt}\} \times \\ &\quad \exp\{\eta_{ij} + \eta_i + \eta_j + \eta_t\} + \varepsilon_{ijt} \end{aligned} \tag{4}$$

where $\ln S_{it}$, $\ln S_{it+1}$, $\ln S_{it+2}$, and $\ln S_{it+3}$ are domestic subsidies given to farmers in exporter i in years t, $t+1$, $t+2$ and $t+3$, respectively. A_{ijt}, A_{ijt+1}, A_{ijt+2}, and A_{ijt+3} are vectors of trade agreements between exporter i and importer j in years t, $t+1$, $t+2$ and $t+3$, respectively.

3 Data Description

We use panel data for bilateral trade flows and domestic sales for the 26 agricultural industries[2] for 72 exporting and 256 importing countries[3] spanning the years 2000-2019 obtained from International Trade and Production Database for Estimation (ITPD-E) database developed by the United States International Trade Commission (USITC, U.S. International Trade Commission). For subsidies, we collect PSEs data from two sources: the Organisation for Economic Co-operation and Development (OECD) and the Agricultural policy monitoring and evaluation and Inter-American Development Bank (IDB, (Inter-American Development Bank, 2023)) Agricultural Policy Monitoring for the period 2000-2019. The advantage of using the PSEs is that they are a consistent measure of government support across countries; however, given that the OECD and the IDB do not report PSEs for all the countries, the data is limited to 72 exporters and 256 importers. The trade agreements, such as FTAs and WTO memberships, and friction variables are obtained from the Dynamic Gravity Dataset developed by USITC.

Total PSE subsidies are divided into two categories: (i) commodity supports based on commodity outputs and payments based on non-current Area (A), Animal Numbers (AN), Receipts (R) or Income (I) (production not required) and (ii) non-commodity payments based on current A/An/R/I (production required), payments based on non-current A/An/R/I (production not required), payments based on input use, miscellaneous payments and payments based on non-commodity criteria. It is worth noting that the commodity specific subsidies do not apply to a consistent set of commodities across countries[4], which only allows us to analyze aggregate subsidies.

[2]Wheat, rice (raw), corn, other cereals, cereal products, soybeans, other oilseeds (excluding peanuts), animal feed ingredients and pet foods, raw and refined sugar and sugar crops, other sweeteners, pulses and legumes (dried, preserved), fresh fruit, fresh vegetables, nuts, live cattle, live swine, eggs, other meats, livestock products and live animals, cocoa and cocoa products, cotton, tobacco leaves and cigarettes, spices, other agricultural products, forestry, fishing, and dairy products.

[3]See the exporting countries in Table 4 in the appendix.

[4]Different countries get government supports on different commodities depending on the region and the continent.

Table 1 reports summary statistics of the variables used in the analysis. Because PSEs are defined at the aggregate level, we aggregate the 26 agricultural industries into one agricultural sector. Based on 72 exporting, 256 importing countries, and 20 years, there are 368,640 bilateral trade flows in total; however, due to missing data and singleton observations for which the bilateral-pair fixed effects perfectly predict the level of trade , the estimation only utilized 241,183 of the observations. Trade flow range from 0 to $977,155.3 mln, and of the 241,183 observations, 35.7% or 86,148 are zero trade values.

4 Econometric Results

In this section, we provide results from estimating gravity models without and with friction variables and dynamic analysis to capture the short and long-term policy responses.

4.1 Gravity Model

This subsection analyzes the impact of subsidies, along with FTAs, joint WTO membership, size and friction variables on agricultural trade by implementing different gravity models defined in equations 1 and 2.

Table 1: Descriptive Statistics

	Mean	Std. Dev.	Median	Minimum	Maximum	N
Bilateral Trade Flows	181.391	6,946.492	0.1	0.000	977,155.3	241,183
Policy Factors						
Total Subsidies	6,258.701	21,416.17	1,308.1	0.000	221,506	241,183
Commodity Specific Subsidies	2,794.177	17,377.16	465.0	0.000	165,690	241,183
Non-Commodity Specific Subsidies	3,464.506	7,675.773	848.0	0.000	62,676	241,183
FTA	0.220	0.415	0.0	0.000	1.000	241,183
WTO joint	0.689	0.463	1.0	0.000	1.000	241,183
Size Factors						
Export Production	40,154.5	104,319.800	10,277	5.100	997,275.5	241,183
Import Consumption	11,262.1	59,583.530	262.7	0.000	1,053,706.7	241,183

Notes: Unit measure for trade, subsidies, exporters' production and importers' consumption is USD, Million.

Table 2: Gravity Analysis of the Determinants of AG Commodity Trade - Exporters

	(1)	(2)	(3)	(4)
Policy Variables				
Log(PSE)	0.006	0.005		
	(0.01)	(0.012)		
Log(PSE Commodity)			-0.01	-0.013
			(0.009)	(0.012)
Log(PSE Non Commodity)			0.022**	0.022**
			(0.008)	(0.009)
FTA	0.135**	-0.255**	0.129**	-0.278***
	(0.049)	(0.092)	(0.05)	(0.092)
WTO Joint	0.033	0.274**	0.031	0.259**
	(0.025)	(0.095)	(0.025)	(0.092)
Size Variables				
Log(Exporter Prod)	0.355***	0.427***	0.367***	0.437***
	(0.043)	(0.036)	(0.044)	(0.038)
Log(Importer Cons)	0.682***	0.646***	0.687***	0.661***
	(0.048)	(0.041)	(0.048)	(0.041)
Friction Variables				
Log(Distance)		-2.039***		-2.024***
		(0.052)		(0.052)
Common Language		1.075***		1.069***
		(0.126)		(0.127)
Colonial History		-0.528**		-0.514**
		(0.219)		(0.22)
Contiguity (Common Borders)		-0.711***		-0.681***
		(0.147)		(0.148)
N of observations	200,149	223,077	197,684	220,153
Adjusted Pseudo R^2	0.996	0.968	0.996	0.968

Notes: Robust standard errors, clustered by country-pair, are reported. All the regressions include exporter, importer, and time fixed effects, while columns 1 and 3 include country-pair fixed effects as well. *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$

Table 2 reports the estimated coefficients of four estimated gravity models. Columns (1) and (2) report models with aggregate PSEs, and columns (3) and (4) detail models with aggregate PSEs decomposed into commodity and non-commodity specific subsidies. The models reported in columns (1) and (3) include country-pair fixed effects, and columns (2) and (4) contain friction variables, which serve as a sensitivity analysis for the variable of interest (aggregated, commodity, and non-commodity specific PSEs). Countries provide

domestic subsidies to support domestic production. This support, on the other hand, can increase trade as more production can lead to excess supply and a boost in international competitiveness.

The results for the aggregate PSE fail to confirm the hypothesis because, while the coefficient estimates on PSEs are positive in columns (1) and (2), they are not statistically significant. The insignificant coefficient estimates could potentially suggest that aggregated trade flows do not fully capturing the effects of PSEs. Therefore, we also provide the estimates of decomposed PSEs into commodity and non-commodity specific PSEs in columns (3) and (4).[5] The results indicate that the commodity specific supports are statistically insignificant. This result may occur because the set of products that receive commodity-specific PSEs is a sub-set of all agricultural commodities that varies by country. This changing subset of commodities by country introduces substantial noise in terms of the impact of these subsidies on aggregate trade. Therefore, this result suggest that the impact of commodity specific PSE measures needs to be examined for individual commodity instead of aggregate agricultural trade. However, non-commodity specific PSEs are positive and significant in both models in column (3), with country-pair fixed effects, and column (4), with friction variables, confirming the hypothesis that subsidies increase exports. The results in column (3) reveal that a 1 percent increase in non-commodity specific PSE increases trade moderately, by 0.022 percent. Non-commodity-specific PSE boost production (in the case of variable input subsidies) or overall productivity and efficiency of the agricultural section (in the case of supports for on-farm services or fixed capital formation), which can in turn result in higher exports.

Next, we turn to the impact of other policy, size, and friction variables on aggregate trade. Based on the results in columns (1) and (3), FTA boosts trade by about 14 percent ($= 100 \times (\exp(0.13) - 1)$); however, the coefficient estimates for joint WTO membership are significant at about 20% significance level. We expect a positive relationship between

[5]The further decomposition of the PSEs can be found in Table 5, Appendix A.

size factors and bilateral trade as larger producing countries typically export more and larger consuming countries import more. The results confirm this hypothesis as a 1 percent increase in the value of exporters' production increases trade by 0.35 percent, and a 1 percent increase in the value of importers' consumption expands trade by 0.68 percent. Thus, the size of the importer appears to have a larger impact on trade than the size of the exporter.

In column (2), we added the friction variables and removed the country-pair fixed effects relative to the model reported in column (1). With country-pair fixed effects removed, the estimated coefficient on FTA becomes negative and significant, while WTO membership remains positive and becomes significant. However, caution must be taken in interpreting the coefficient estimates for policy variables in 2 because the unobserved heterogeneity between trade partners (the primary concern for endogeneity in policy variables) is not controlled for when the model does not include country-pair fixed effects. Consequently, the remaining analyses based on columns (2) and (4) will focus only on size factors and friction variables.

The results show that the size factors remains positive and significant, with small changes in the magnitude of the coefficient estimates. For all friction variables, the coefficient estimates are statistically significant. The negative relationship between distance and bilateral trade and the positive relationship between common languages and bilateral trade are consistent with *a priori* expectations. Specifically, the farther the countries are geographically located from each other, the less the countries trade, as a 1 percent increase in distance decreases the bilateral trade flows by roughly 2.1 percent. This distance coefficient estimate is larger compared to Helpman et al. (2008), Chor (2010), Tong et al. (2019), and Devadoss et al. (2021) who obtain estimates of -1.5, -1.22, -1.2, and -1.16 for aggregate, manufacturing, agricultural, and farm product trade, respectively. Furthermore, if the importing and exporting countries share a common language, then fewer trade frictions exist and trade expands. The results show that countries that share a common language trade agricultural products, on average, 193.2 percent more than countries that do not. The coefficient estimates of colonial history and contiguous border are negative and decrease trade

by 69.6 percent and 103.5 percent, respectively. The negative relationship between colonial history and bilateral trade flows highlights the effects of colonialism on trade patterns and the challenges faced by former colonies in establishing mutually beneficial trade relationships with their former colonizers. A possible explanation for the negative relationship between contiguity and bilateral trade can be that territorial border conflicts that suppress trade between neighbors.[6]

4.2 Gravity Model with Lags and Leads of Policies

Next, we examine the long-run responses of the determinants of agricultural trade and provide robustness analysis on the impact of other factors in relation to the results in Table 2. For this analysis, we focus the analysis on commodity and non-commodity PSEs, FTAs, WTO, and size variables.[7] Table 6 presents six gravity models that include lagged- and lead-policy variables given by equation (3) and (4). The models in columns (1)-(3) examine the immediate and 1, 2, and 3 years delayed effects for the policy variables. The models in columns (4)-(6) assess the immediate and 1, 2, and 3 years anticipation effects for the policy variables. Market size variables do not vary significantly from year to year and will only be estimated for contemporaneous effects.

[6]For example, China, Russia, and Turkey are involved in ongoing border conflicts with their neighboring countries. The latter two can be supported by the most recent wars in eastern Europe.

[7]The dynamic analysis on aggregated PSEs can be found in Table (6), Appendix (A)

Table 3: Gravity Analysis of the Determinants of AG Commodity and Non-Commodity PSEs

	Lag			Lead		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(PSE Com)	-0.001	0.001	0.002	-0.003	-0.005	-0.007
	(0.005)	(0.005)	(0.005)	(0.009)	(0.01)	(0.012)
Log(PSE Com) (1)	-0.006	-0.006	-0.006*	-0.007*	0.006	0.006
	(0.005)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)
Log(PSE Com) (2)		-0.002	-0.003		-0.018***	-0.008*
		(0.005)	(0.004)		(0.006)	(0.004)
Log(PSE Com) (3)			0.002			-0.015**
			(0.004)			(0.007)
Log(PSE NonCom)	0.022***	0.02***	0.019***	0.024***	0.026***	0.028**
	(0.006)	(0.006)	(0.006)	(0.009)	(0.01)	(0.012)
Log(PSE NonCom) (1)	-0.014**	-0.009	-0.007	0.001	-0.008	-0.006
	(0.007)	(0.005)	(0.005)	(0.008)	(0.007)	(0.008)
Log(PSE NonCom) (2)		-0.013**	-0.009*		0.014*	0.006
		(0.006)	(0.005)		(0.007)	(0.006)
Log(PSE NonCom) (3)			-0.015***			0.011
			(0.005)			(0.007)
FTA	0.062	0.053	0.053	-0.025	-0.028	-0.04
	(0.05)	(0.054)	(0.058)	(0.044)	(0.044)	(0.044)
FTA (1)	0.000	-0.048*	-0.053*	0.176***	0.038	0.042
	(0.044)	(0.026)	(0.028)	(0.054)	(0.038)	(0.039)
FTA (2)		0.045	-0.006		0.155***	0.079**
		(0.053)	(0.034)		(0.051)	(0.036)
FTA (3)			0.069			0.098**
			(0.052)			(0.045)
WTO Joint	0.035	0.035	0.039*	-0.014	-0.016	-0.017
	(0.023)	(0.022)	(0.024)	(0.036)	(0.033)	(0.031)
WTO Joint (1)	-0.008	0.003	-0.007	0.048**	-0.001	0.001
	(0.039)	(0.026)	(0.026)	(0.024)	(0.024)	(0.026)
WTO Joint (2)		-0.017	-0.003		0.053	0.004
		(0.037)	(0.021)		(0.038)	(0.021)
WTO Joint (3)			-0.005			0.054*
			(0.031)			(0.031)
Log(Exporter Prod)	0.295***	0.304***	0.319***	0.297***	0.302***	0.299***
	(0.051)	(0.052)	(0.053)	(0.048)	(0.049)	(0.052)
Log(Importer Cons)	0.716***	0.709***	0.694***	0.71***	0.715***	0.719***
	(0.046)	(0.048)	(0.049)	(0.046)	(0.046)	(0.05)
N of observations	188,163	172,827	158,669	190,156	175,310	161,559
Adjusted Pseudo R^2	0.996	0.996	0.996	0.996	0.996	0.996

Notes: Robust standard errors, clustered by country-pair, are reported. All the regressions include country-pair, exporter, importer, and time fixed effects. *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$

The results reported in Table 3 confirm that the coefficient estimates of commodity specific subsidies are insignificant for the contemporaneous effect (which is consistent with the column (3) in Table (2)) and mostly insignificant for the lagged effects in all three models in columns (1)-(3). Therefore, we conclude that commodity specific subsidies do not have contemporaneous or delayed effects. Furthermore, the coefficient estimates for non-commodity specific PSEs in columns (1)-(3) are consistent with the prior findings. The contemporaneous non-commodity PSEs modestly expand agricultural product trade as the coefficient estimates range from 0.019 to 0.028. While, the results show negative delayed effects for the one, two, and three-year lagged effects in columns (1)-(3), only the one-year lag effect in column (1), the two-year lag effect in column (2) and the two- and three-year lag effects in column (3) are statistically significant and range from 0.009 to 0.015. This results also indicates that the model (3) in Table (2), with a coefficient estimate of 0.022, appear to overestimate the overall impact of subsidies on trade and mask a delayed response of subsidies on trade. These positive contemporaneous effects could be due to the nature of domestic support policies, which can provide financial assistance to farmers or stimulate agricultural investment.

The results in columns (1)-(3) show that FTAs and joint WTO membership have no significant contemporaneous affect on agricultural trade. These results suggest that the immediate and delayed effects do not occur with FTA and WTO memberships, except for one year lag in models (2) and (3) for FTAs, and it takes years for the countries to adjust all the FTA and WTO regulations. Finally, the coefficient estimates for size factors, are largely consistent with the results from Table (2), column (3).

For the lead analysis, in Table 3 in columns (4)-(6), the results show that commodity specific subsidies negatively affect trade and have anticipatory effects across all three models. However, only one-year lead effect in column (4), two-year lead effect in column (5) and two and three year lead effects in column (6) are statistically significant and range from -0.007 to -0.018. The negative and significant coefficient estimates for commodity-specific support

could be due to the allocation of resources in anticipation of the support. When support is directed towards specific commodities, it can divert resources away from other sectors or commodities that may have comparative advantages. This reallocation of resources can result in a decline in production or trade for the commodities receiving less support, thus leading to negative coefficients. The coefficient estimates for non-commodity specific PSEs in columns (4)-(6) have only the contemporaneous effect ranging from 0.024 to 0.028, except for two-year lead in column (5). The positive contemporaneous effects observed in the analysis can be attributed to the nature of domestic support policies. These policies offer financial aid to farmers, promote agricultural investments, and drive improvements in productivity, efficiency, and technological advancements.

The results in columns (4)-(6) show that FTAs have a positive and significant anticipatory effects on trade. These results could suggest that exporters start expanding production and exports during the negotiation phase. However, joint WTO membership stays insignificant across models, suggesting that agricultural industries respond differently to the negotiation phase of joining the WTO versus an FTA. And finally, the coefficient estimates for size factors, are largely consistent with the results from Table (2), column (3) and Table (3) columns (1)-(3). Thus, both of the dynamic models show that delayed and anticipation effects are important for fully understanding the impact of policies on aggregate trade.

5 Conclusion

This study uses the Poisson Pseudo-Maximum Likelihood (PPML) method to examine factors influencing agricultural product trade, using panel data on 72 exporting and 256 importing countries over 20 years from 2000 to 2019. Overall, aggregated domestic subsidies do not appear to significantly affect agricultural trade. However, when Producer Support Estimates (PSEs) are broken down into commodity and non-commodity supports, non-commodity supports are found to have a negative but modest impact on agricultural trade. Meanwhile, dy-

namic analyses reveal that commodity-specific subsidies have no immediate or delayed effects; however, they show negative anticipatory effects across all three models. Non-commodity supports show both contemporaneous and delayed effects across both lag and lead-policy analysis. In addition, free trade agreements (FTAs) are found to have a positive impact on trade, while the World Trade Organization (WTO) does not appear to have significant influence across the analyzed models. Throughout the study, market size variables are shown to have consistently strong significance.

Models with friction variables were also analyzed. When the model used to estimate the impacts of policy variables on trade does not include country-pair fixed effects, caution should be exercised in interpreting the coefficient estimates. This is because unobserved heterogeneity between trade partners, which is a primary concern in terms of policy variable endogeneity, is not controlled for. Therefore, the final results in those models were mostly focused on friction variables. The results show strong negative relationships between bilateral trade of agricultural commodities and distance, colonial history, and contiguity, while common languages have a positive impact on trade.

Future work will proceed in two steps: (i) counterfactual analysis using PPML, and (ii) comparing counterfactual analysis to machine learning techniques.

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A Appendix: Additional Tables

Table 4: List of Exporting Countries

	OECD			Non-OECD
1.	Australia	30.	Netherlands	1. Argentina
2.	Austria	31.	New Zealand	2. The Bahamas
3.	Belgium	32.	Norway	3. Barbados
4.	Bulgaria	33.	Poland	4. Belize
5.	Canada	34.	Portugal	5. Bolivia
6.	Chile	35.	Romania	6. Brazil
7.	Colombia	36.	Slovakia	7. China
8.	Costa Rica	37.	Slovenia	8. Dominican Republic
9.	Croatia	38.	Spain	9. Ecuador
10.	Cyprus	39.	Sweden	10. El Salvador
11.	Czech Republic	40.	Switzerland	11. Guatemala
12.	Denmark	41.	Turkey	12. Guyana
13.	Estonia	42.	United Kingdom	13. Haiti
14.	Finland	43.	United States	14. Honduras
15.	France			15. India
16.	Germany			16. Indonesia
17.	Greece			17. Jamaica
18.	Hungary			18. Kazakhstan
19.	Iceland			19. Nicaragua
20.	Ireland			20. Panama
21.	Israel			21. Paraguay
22.	Italy			22. Peru
23.	Japan			23. Philippines
24.	Korea			24. Russia
25.	Latvia			25. South Africa
26.	Lithuania			26. Suriname
27.	Luxembourg			27. Trinidad and Tobago
28.	Malta			28. Ukraine
29.	Mexico			29. Vietnam

Source: OECD

Table 5: Gravity Analysis of the Determinants of AG Commodity Trade - Exporters

	(1)	(2)
Log(CO)	-0.014	-0.014
	(0.013)	(0.023)
Log(PC)	0.002	-0.002
	(0.003)	(0.003)
Log(PHNR)	-0.002	-0.001
	(0.003)	(0.003)
Log(PHR)	0.001	0.001
	(0.002)	(0.001)
Log(PI)	0.029***	0.032**
	(0.009)	(0.014)
Log(PM)	0.007***	0
	(0.003)	(0.004)
Log(PN)	0.001	0
	(0.002)	(0.002)
FTA	0.129**	-0.266*
	(0.052)	(0.143)
WTO Joint	0.011	0.232***
	(0.027)	(0.075)
Log(Exporter Prod)	0.381***	0.492***
	(0.049)	(0.043)
Log(Importer Cons)	0.696***	0.614***
	(0.056)	(0.058)
Friction Variables		
Log(Distance)		-2.038***
		(0.098)
Common Language		1.091***
		(0.185)
Colonial History		-0.578*
		(0.325)
Contiguity (Common Borders)		-0.742***
		(0.178)
N of observations	188,168	164,876
Adjusted Pseudo R^2	0.969	0.996

Notes: Robust standard errors, clustered by country-pair, are reported. Both regressions include exporter, importer, and time fixed effects, while column 1 includes country-pair fixed effects as well. *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$

Table 6: Gravity Analysis of the Determinants of Aggregated PSEs

	Lag			Lead		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(PSE)	0.02***	0.019***	0.02***	0.022***	0.019***	0.02***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
Log(PSE) (1)	-0.016	-0.022***	-0.015***	-0.002	-0.012	-0.005
	(0.011)	(0.008)	(0.005)	(0.011)	(0.01)	(0.007)
Log(PSE) (2)	-0.01		-0.011**	-0.01		-0.01**
	(0.009)		(0.004)	(0.006)		90.004)
Log(PSE) (3)	-0.012		-0.012***	-0.011*		-0.01***
	(0.009)		(0.004)	(0.006)		(0.003)
FTA	0.067	0.067	0.056	-0.377**	-0.02	-0.039
	(0.179)	(0.05)	(0.057)	(0.149)	(0.044)	(0.046)
FTA (1)	0.015	-0.004	-0.054*	0.005	0.178***	0.045
	(0.072)	(0.044)	(0.028)	(0.032)	(0.054)	(0.041)
FTA (2)	-0.051		-0.009	0.023		0.076**
	(0.057)		(0.034)	(0.059)		(0.035)
FTA (3)	-0.342**		0.067	0.086		0.104**
	(0.145)		(0.053)	(0.159)		(0.043)
WTO Joint	0.189***	0.028	0.035	0.012	0.000	-0.003
	(0.058)	(0.022)	(0.024)	(0.033)	(0.031)	(0.028)
WTO Joint (1)	0.165	0	0.005	0.007	0.042*	-0.016
	(0.122)	(0.039)	(0.027)	(0.017)	(0.023)	(0.026)
WTO Joint (2)	0.013		-0.001	0.023		0.02
	(0.016)		(0.02)	(0.04)		(0.018)
WTO Joint (3)	0		-0.017	0.384***		0.047
	(0.03)		(0.029)	(0.14)		(0.037)
Log(Exp Prod)	0.387***	0.289***	0.318***	0.373***	0.286***	0.287***
	(0.048)	(0.05)	(0.053)	(0.058)	(0.048)	(0.052)
Log(Imp Cons)	0.668***	0.715***	0.698***	0.675***	0.707***	0.713***
	(0.049)	(0.045)	(0.049)	(0.057)	(0.045)	(0.048)
Log(Distance)	-2.018***			-2.01***		
	(0.094)			(0.098)		
Com Language	1.123***			1.079***		
	(0.193)			(0.186)		
Contiguity	-0.519			-0.522		
	(0.327)			(0.32)		
Colony	-0.644***			-0.63***		
	(0.172)			(0.175)		
N of ob	175,960	190,836	161,645	178,893	192,509	164,255
Adj Pseudo R^2	0.97	0.996	0.997	0.969	0.996	0.997

Notes: Robust standard errors, clustered by country-pair, are reported. The regressions in columns (2), (3), (5) and (6) include country-pair, exporter, importer, and time fixed effects. Regressions in columns (1) and (3) excludes country-pair FEs. *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$