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Virtual Water Trade: Does Bilateral Tariff Matter?

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Selected Paper prepared for presentation at the 2017 Agricultural & Applied Economics Association Annual Meeting, Chicago, Illinois, July 30-August 1

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Virtual Water Trade: Does Bilateral Tariff Matter?

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Abstract

This paper explores the determinants of blue and green virtual water trade (VWT) across nations and tests whether the policy relevance of virtual water can be enhanced by considering comparative advantages, as well as whether virtual water is an endowment effect. To achieve this goal, we build a panel database on blue and green virtual water trade among paired trading countries from 1998 to 2002.Using an Anderson-van Wincoop (AvW) gravity model with fixed effects and estimating the Poisson Pseudo-Maximum Likelihood (PPML) specifications, we study how the bilateral tariff affect the intensity of blue and green VWT. Results show that there are no big different effects between determinants of blue and green virtual water import; while there are different effects among the determinants of VWT of 19 crops. Tariff has a negative effect on the blue and green virtual water import for more water intensive crops.

Keyword: virtual water, gravity model, tariff, international trade

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Virtual Water trade: Does Bilateral Tariff Matter?

1. Introduction

Economic growth, changing dietary habits, and climate change may exacerbate problems of water scarcity and uneven distribution of water (Debaere 2014). Thus, an evaluation of the movement of water between nations may serve as a useful tool to monitor this scarce resource. Analysis of virtual water trade (VWT) provides a way to evaluate the amount of water in products traded between countries. First proposed by Allan (1997, 1998), virtual water is the volume of water used during the entire production chain, a measure of embedded water in a product (Fracasso 2014). Blue VWT is the trade of irrigation water embedded in trade, and green water is the precipitation on land, stored in soil or vegetation. Following the trade of embedded water may provide a useful way identify and mediate the challenges of water scarcity.

Fracasso (2014) demonstrates that countries with scarce water tend to import water-intensive goods from water abundant countries using a gravity model. Debaere (2012) finds that relatively water abundant countries tend to export more water-intensive products. However, Ansink (2010) uses a 2×2×2 model to prove that comparative advantage in the production of water-intensive goods only holds under certain conditions and that virtual water trade does not necessarily follow the Heckscher–Ohlin-Vanek (HOV) trade model.

To explore whether bilateral tariff reshapes the VWT flows across nations, we augment the gravity model of VWT with water-relevant variables, following Fracasso (2014).We extend this model by including ad valorem equivalents (AVE) of tariffs to consider the effect of trade policy on VWT. To tackle the problem of multilateral resistance terms (MRT), the presence of zero virtual water trade value and the potential heteroscedasticity problem, we estimate PPML model with importer, exporter, year and commodity fixed effects. There are four main differences between this paper and Fracasso (2014), the first is that we provide the theoretical foundation for virtual water trade (VWT) with HOV theory. In addition, virtual water trade is for 19 different crops rather than the aggregate agricultural goods. Moreover, we interpret the empirical result with the water intensity and not in Fracasso's paper. Lastly, the bilateral tariff is more suitable in the gravity model and has been applied into our AvW gravity model instead of unilateral tariff, results demonstrate tariff could decrease the virtual water import significantly and insignificant impact in Fracasso's paper.

This paper is the first to estimate the determinants of bilateral blue and green virtual water trade using PPML model with fixed effects of importer, exporter, year and commodity. The purpose of this paper is to estimate the determinants of the VWT using the AvW gravity model. The specific objectives are to determine: 1) whether bilateral tariffs reshape the VWT flows; 2) whether the policy relevance of virtual water can be enhanced by considering bilateral tariff.

2. Literature Review

Virtual water is always calculated by the environmental engineering methods (Siebert and Döll 2010; Konar 2011; 2013); virtual water is defined as the volume of water used during the entire production chain (Fracasso 2015). VWT does not originate within the economic literature, which was first proposed by Allan (1997, 1998). Most of VWT has been calculated into unilateral value and only a few into bilateral amount (Hoekstra and Hung 2002; Oki etc. 2003; Ashok 2008; Wang etc. 2013; Konar 2011; Hoff 2013).

Most literature supports that virtual water trade could alleviate the problem of uneven water distribution, reduce the potential water conflict and verify the comparative advantage of virtual water. For example, Fracasso (2014) demonstrated that countries with scarce water tend to import the service of water embodied in the water-intensive goods and vice versa. Reimer (2012) demonstrated the comparative advantage using 2 country by 2 goods model. Debaere (2012) finds that relatively water abundant countries tend to export more water-intensive products, and verify water as the comparative advatange, but its effect is less than the traditional production factors affecting the trade flows, such as labor and physical capital. However Ansink (2010) uses $2\times 2 \times 2$ model to prove that comparative advantage in the production of water-intensive goods only holds under certain conditions, and virtual water trade does not necessarily follow the Heckscher–Ohlin-Vanek trade model. Moreover, Fracasso, Sartori and Schiavo (2015) provide the empirical results to support Ansink (2010) using the gravity model, they find that the country with the abundant water does not necessarily export the water-intensive service to other countries. However, there are few papers to provide the economic foundation for the import tariff impact on virtual water trade.

To date, the gravity model is one of most successful empirical models in economics (Anderson 2011), and it has often been used to analyze bilateral trade flows. The gravity model is a useful tool to investigate bilateral virtual water trade (Konar and Caylor 2013; Tamea et al. 2014). Although the gravity model was ad hoc, it was found to have high explanatory power when applied to the real data and the double-log relation makes more economic sense than a linear specification. Given its empirical success, formal theoretical foundations have already been provided by Anderson and van

Wincoop (2003) (a conditional Armington-type specification), Eaton and Kortum (2002) (a Ricardian or supply side specification), and Helpman and Krugman (1985) (a monopolistic competition model). Applying a gravity model to focus on the determinants of virtual water trade is not new. Within this literature, particularly relevant for our analysis, the bilateral trade are studied among the supply-oriented trade flows. For example, Fracasso (2014) use the gravity model to test the hypotheses whether virtual water trade is in line with HOV theory, countries export their relative water intensity based on the water endowments, as well as whether virtual water trade reflects the water endowment in one country. His empirical results show that water endowment and water pressure matters the water content of bilateral trade in agricultural products, and countries with scarce water tend to import the service of water embodied in the water-intensive goods and vice versa. However, they retain the policy implication from their findings, only when water efficiency, dietary regimes, regional disparities within countries, and the like are included into the gravity model. Fracasso, Sartori and Schiavo (2015) also apply the gravity model to investigate the determinants of the virtual water trade, but they find the country with the larger water endowment does not necessarily export virtual water to other counties; higher water irrigation price reduces the virtual water trade. Consideration of the comparative advantage of the water could help us to understand the virtual trade pattern and policy implications, and provide a possible way to make the policy implication in the perspective of virtual water trade.

From a technical perspective, there are three main problems which need to be taken into consideration when we estimate the drivers of VWT. Omitting these Multilateral Resistance Terms (MRTs) can bias the estimates of the gravity model

(Anderson and van Wincoop 2003; Xiong and Beghin 2011). Fixed effect removes the effect of those time-invariant characteristics so we can assess the net effect of the predictors on the outcome variable. Fixed effect can also be used to capture the size effects of incomes (Disdier, Fontagne and Mimouni 2008; Disdier and Marette 2010) and correct the bias from omitting MRTs (Baier and Bergstrand 2007; Nhuong et al. 2013). Second, in presence of zero trade value, Silva and Tenreyro (2006) find that the Jensen's inequality results in the log-linearized model using OLS misleading in presence of the heteroscedasticity, PPML provides the robust results to different patterns of heteroscedasticity based on the Mont Carlo simulation and shows no sign of the misspecification. To deal with the zero trade value, they also use $\ln(1+\mathrm{T_{ij}})$, Tobit ($\ln(a+\mathrm{T_{ij}})$), NLS ($\mathrm{T_{ij}}$), PPML ($\mathrm{T_{ij}} > 0$), and PPML ($\mathrm{T_{ij}}$) covering 136 countries in 1990. They conclude that log-linearity of the gravity equation suffers from severe misspecification because of the presence of heteroscedasticity and the incompatibility with zero trade value; PPML is superior to other methods when they use the AvW gravity model. Third, the selection bias of the treatment effect results from non-natural experimental data.

The aim of the VWT metaphor is to alleviate the uneven water distribution and solve the water scarcity problem by trading the virtual water across nations. Recently scholars have estimated determinates of the virtual water, found the evidence to support VWT coincide with HOV theory, and made the policy implications. At the same time, the idea that VWT is a comparative advantage only holds under some special conditions.

3. **The Theoretical Foundation of Virtual Water Trade**

We first present a theoretical foundation for virtual water trade (VWT) with HOV theory. Though the maximization of constant elasticity of substitution (CES) utility provides the basis from consumption side for the gravity model, HOV theory can provide the basis from production, thus this section is a good theoretical supplement.

Allan (1997) first referred to the new terms of “virtual water,” but water content is another name of virtual water (Davis and Weinstein, 2003), which has a long history in international trade. Virtual water is the water ‘embodied’ in a product and the amount water input per unit of output times the trade volume of crops, not in real sense, but in virtual sense. It links food, trade and water together. It refers to the water needed for the production of the product. Global trade in goods and services brings along global trade in “virtual water.” VWT is the trade of water embedded in trade, which may be a useful tool to reduce the problem of water scarcity and uneven distribution problems.

Water content in the import of crop products is calculated using the amount water input per unit of output times the trade volume of crops; we use the VWT based on Hoff et al. (2013), who calculated the water content embedded in the imports of crop products. Reimer (2012) provides the economic foundation for virtual water trade without a tariff from production side; we extend him to develop a theoretical model of virtual water trade with and without the tariff. We use $n\times 2\times 3$ model, that is to say, there are many countries, we take the home country and foreign country as example and both of them are small open economy (SOEs), two factors (capital K and water W), and three goods (other grains, paddy rice, and the wheat).

By comparison, the home country is water scarce, and the foreign country is water abundant:

$\frac{W}{K} > \cdots > \frac{W^*}{K^*}$.

The good 1 is water intensive:

$\frac{a_{1W}}{a_{1K}} > \frac{a_{2W}}{a_{2K}} > \frac{a_{3W}}{a_{3K}}$, $(\frac{W}{K})_1 > (\frac{W}{K})_2 > (\frac{W}{K})_3$

where a_{iW} (a_{iK}) denotes the amount of water (capital) input per good i ($i = 1,2,$ and 3), a_{2W} (a_{2K}) denotes the amount of water (capital) input per good 19. We assume perfect competition in product markets and factor markets, identical and homothetic tastes across countries, free trade, and no transportation costs. Home country price and foreign country price are equalized, $p_1 = p_1^*$, $p_2 = p_2^*$, and $p_3 = p_3^*$. Identical technology has also been assumed, and thus a_{1W}, a_{2W} , and a_{3W} are the same among nations.

Under with trade, home country imports water intensive good 1 (M_1), and export capital intensive good 2 (X_2):

$$M_1 = C_1 - y_1$$

$$X_2 = y_2 - C_2$$

The water content of consumption:

$a_{1W}(y_1 + M_1) + a_{2W}(y_2 - X_2) = W + a_{1W}M_1 - a_{2W}X_2$

The home country budget constraint: $p_1c_1 + p_2c_2 = p_1y_1 + p_1y_2$, $p_1M_1 = p_2X_2$, we can get $M_1 = \frac{X_2P_2}{P_1}, X_2 = \frac{M_1P_1}{P_2}$, thus water content of consumption: $W + a_{1W}M_1 - a_{2W}X_2 = W + M_1\left(a_{1W} - a_{2W}\frac{P_1}{P_2}\right)$, or $W + a_{1W}M_1 - a_{2W}X_2 = W + X_2(a_{1W}\frac{P_2}{P_1} - a_{2W})$

Zero profit condition-free entry: $a_{1W}n + a_{1K}r = p_1;\ a_{2W}n + a_{2K}r = p_2$

Thus water content of consumption becomes into $W + X_2\left(\frac{a_{1W}*a_{2K} - a_{2w}*a_{1K}}{a_{1W}w + a_{1K}r}\right) > W$, since $a_{1W} * a_{2K} - a_{2w} * a_{2K}$ is positive, and water content of production stays the same, this home country (water scarce) must be a net importer of water.

Import tariff on good 1

In n countries cases (countries all over the world), we assume the home country and foreign country are SOEs, both countries are price takers and tariff cannot affect the p_1 and p_1^*. If the home country raises a tariff on the import of good 1 (water intensive product), this will lead to an increase of good 1's price 1 from p_1 to (1+t) p_1. Water consumption of home country becomes:

$$W + a_{1W}M_1 - a_{2W}X_2 = W + a_{1W}M_1 - a_{2W}\frac{M_1 P_1(1+\mathrm{t})}{P_2} = W + M_1\left(a_{1W} - a_{2W}\frac{P_1(1+\mathrm{t})}{P_2}\right) = W + M_1[\frac{(a_{1W}a_{2K}-a_{2W}a_{1K})r}{a_{2W}w+a_{2K}r} - \frac{(a_{1W}a_{2W}w+a_{2W}a_{1K}r)t}{a_{2W}w+a_{2K}r}] \gtrless W.$$

Since $a_{1W}a_{2K} - a_{2W}a_{1K}$ is positive, thus $M_1[\frac{(a_{1W}a_{2K}-a_{2W}a_{1K})r}{a_{2W}w+a_{2K}r} - \frac{(a_{1W}a_{2W}w+a_{2W}a_{1K}r)t}{a_{2W}w+a_{2K}r}]$ has the unsure sign. When home country imposes import tariff on water intensive good 1, we are not sure whether the home country is net water importer. The tariff might be prohibitive, and then there would be no trade. That is to say, even water is a potential source of comparative advantage under trade without the import tariff might reshape water embodied in import. However, the home country would never export water in $2\times 2 \times 2$ mode.

4. **Data and Data Source**

The data are a panel dataset of VWT from 1998 to 2002, with 2,234,265 observations 68.23% of which is zero virtual water trade flows. We focus on contributors to bilateral imports of virtual water trade of 19 crops among 248 countries. Our blue and green virtual water trade data comes from Hoff et al. (2013) for comtrade sector. The data set includes nineteen products (Potatoes, Pulses, dry, Citrus, Grapes, Wheat, Rye, Barley, Maize, Rice, Sorghum, Soybean, Rapeseed, Sunflower, Cocoa, Cassava, Dates, Coffee, Millet, and Groundnuts), which are categorized into seven GTAP types (Veg & Fruit, Other Grain, Wheat, Paddy Rice, Oil Seeds, Other Food, and Other Crop). Data for distance, common border, colonial relationship, regional trade agreements, and common language are from the CEPII database. Data of bilateral ad valorem equivalent of tariff (AVE) of grain (HS-11) are from the Market Access Map (MAcMap), which are computed at the detailed level and measures applied protection at a bilateral level. We merger these four datasets by the country code, ISO country name, year and commodities into one dataset. EU and NAFATA come from Eurostat and the Office of the U.S. Trade Representative. Table 1 below presents the definitions and descriptive statistics for the dependent variable and independent variables, which will be used in the following estimations.

Table 1 goes about here

The water intensity (water input over output) and water abundance data are calculated based on Debaere (2014), since $\frac{W}{Y} = \frac{W}{K} * \frac{K}{Y}$ and all of products are crops and water intensive products, and $\frac{K}{Y}$ are similar and fixed for each product, and then the water intensities of seven categories of crops are ranked by $(\frac{W}{Y})_j$. From Table 2, we can see the rank of products according to the water intensity and water abundance.

Table 2 goes about here

5. **Model Specifications**

In this section, we estimate the determinants of blue and green virtual water trade, and the gravity model is one of the most successful empirical models in estimation of factors affecting international trade (Anderson 2011). However, there are three main problems- the multilateral resistance terms, the presence of the zero trade value and the heteroscedasticity, which have to be concerned using gravity model (Anderson and van Wincoop 2003, Tran etc. 2011, among others). To address the MRTs, potential issue heteroscedasticity and the presence of zero trade value, the PPML model with fixed effects will been applied. The inclusion of GDPs has been questioned without micro-foundation (Tran etc. 2011; Disdier and Marette 2010). Thus, we will follow Anderson and van Wincoop (AvW) (2003) gravity model with fixed effects (exporter, importer, time, and product fixed effect) and without GDPs using PPML methods.

The basic specification of gravity model

$$\ln\left(VWT_{ij}\right) = \alpha_0 + \alpha_i + \alpha_j + \alpha_t + \alpha_c + \sum_1^8 \beta_1 x_{ij} + \varepsilon_{ijt},$$

where *i* denotes exporting country and *j* importing country. In particular, X_{ij} are paired control variables of traditional gravity model: Distance_{ij}, $\text{Regional Trade Agreement}_{ij}$, Contiguity_{ij} , $\text{Common Currency}_{ij}$, Colony_{ij}, $\text{Common Language}_{ij}$. $\alpha_i, \alpha_j, \alpha_t,$ and α_c are exporter, importer, time, and product fixed effects.

The specification of PPML Model

$$E(VWT_{ij}|x_{ijt} = \exp[\alpha_0 + \alpha_i + \alpha_j + \alpha_t + \alpha_c + \beta_1 \ln(1 + tariff) + \sum_1^8 \gamma_1 x_{ijt}],$$

VWT_{ij} represents virtual water embodied in the grain products exported by country i to country j. We test the hypothesis that whether tariff has a negative effect on WVT of crops whether virtual water trade is consistent with HOV theory, this is to say, whether tariff has a negative effect on WVT of crops. The coefficients we are interested in is $\boldsymbol{\beta_1}$, under the hypotheses that $\boldsymbol{\beta_1}$is significantly negative, implying that virtual water trade coincide with HOV theory and tariff could reshape virtual water trade. Policy makes might solve water scarcity and uneven distribution issue by enforcing different tariff on different crops. If they are statistically insignificant, tariff has no effect on the virtual water trade.

6. **Empirical Results**

To explore the determinants of virtual water trade across nations and test whether virtual water is the comparative water or not, we include the traditional trade factors into the gravity model with fixed effects. We focus on the bilateral blue VWT, not unilateral trade (net virtual water import or net virtual water export), and also conclude other key factors affecting the trade flows, such as the distance, regional trade agreement, common language, colonial relationship, area, currency and border between any paired countries. PPML model with fixed effects are estimated respectively to address the MRTs problem, the presence of zero virtual water trade value and the potential heteroscedasticity problem.

RESET test using powers of the fitted values of trade, the null hypothesis is that model has no omitted variables. Following Silva and Tenreyro (2006), PPML estimates are adequate based on the p-values (bigger than 0.1) of the heteroskedasticity-robust RESET test. Standard errors are robust to clustering by country pair at the sector level (panel id).

Table 3 and Table 4 report the results of PPML models for blue and green VWT across 19 crops and specific crops (other grains, paddy rice, and wheat) with and without bilateral import tariff. Our interested coefficient (β_1) of $\ln(1 + t\text{ariff})$ [3] is estimated as the price elasticity of importing countries' demand for virtual water, estimated "on average" for all years and countries. The tariff has statistically negative effects on blue and green

[3] We assume tariff is the water price change. From algebra, $E(VWT_{ijpt}|x_{ijt}) = \exp[\alpha_0 + \alpha_i + \alpha_j + \alpha_t + \alpha_c + \beta_1 \ln(1 + \text{tariff}) + \sum_1^8 \gamma_1 x_{ijt}]$ is equivalent to $\ln(VWT_{ijpt}|x_{ijt})$= $\alpha_0 + \alpha_i + \alpha_j + \alpha_t + \alpha_c + \beta_1 \ln(1 + tariff) + \sum_1^8 \gamma_1 x_{ijt}$, where $\Delta P = \text{tariff}$, and P is water price.

virtual water trade. One percent tariff raise decreases VWT of all nineteen crops by 0.416% and 3.154%. The tariff has negative effects on green and blue virtual water trade for less water intensive crops; the effect ranges from -0.416 % to -3.621%. In sum, our results show little difference in the determinants of blue virtual water import and green virtual water imports. However, we find differential effects among the determinants of VWT across 19 crops. The tariff has a negative effect on the blue and green virtual water imports for more water intensive crops, since Other Grains, wheat and paddy rive are more intensive crops than Vegetable & fruit, other crops and other food in our 19-crop sample.

The different effects of bilateral import tariff on blue or green virtual water trade can be explained by differences in elasticities for different categories of crops; thus, VWT may respond to price effects from tariffs in a different way, as suggested by the water elasticities estimated in Chen (2016). This means tariff reductions may increase the trade flow of virtual water and make the water redistribution more efficient. Trade policies such as tariffs may shift the trade of water embedded in products. Results suggest tariffs might be a useful policy instrument for managing the flow of virtual water across countries, thus addressing issues associated with water scarcity.

The estimates demonstrate that a historical conical tie or common language increase virtual trade among any two countries. Distance is the key determinant of virtual water import, and the absolute value of its coefficient is different from previous literature and range from 1.014 to 1.607, such as Grant and Boy (2011) with -1.12 and Anders and Caswell (2009) between -0.719 and -0.10. Dummy variables of countries that share the same border and have colonial ties always trade more, and vice versa. The impact of

Contiguous variable on blue virtual water export flow is much higher than other scholars' estimates. The countries with common border contribute to an increase of 63.07 %[4] virtual water import flow, while a 0.28% decreases of fishery import as estimated by (Wilson 2013). Historical colony increases by 188.35%. All signs of variables are as expected.

The incorporation of the bilateral tariff does not change the marginal effects of the control variables much, implying the robustness of estimates. One percentage point decrease of the AVE reduced VWT by 0.416% and 3.154% for blue and green virtual water import, which is much greater then Disdier, Fontagné, and Mimouni (2008) with a decrease of 0.02 on agricultural trade. This means tariff reduction could increase the trade flow of virtual water and make the water redistribution more efficient. Trade policies such as tariffs may shift the trade of water embedded in products. These results point to the policy relevance of virtual water trade analysis.

In summary, there are no big different effects between determinants of blue virtual water import and green virtual water import; there are different effects among the determinants of VWT of 19 crops. In addition, the tariff has a negative effect on the blue and green virtual water import for more water intensive crops, but positive or no effect on less water intensive crops.

Table 3 and 4 go about here

7. **Conclusion**

To explore the determinants of virtual water trade across nations and test whether bilateral import tariff reshape virtual water trade or not, we include the traditional trade

[4] $e^{(-1.014)}$-1=0.6307

factors and bilateral import tariff in to the gravity model with fixed effects. Previous literature always uses the truncated OLS and PPML specifications of gravity model to estimate the factors affecting the VWT (Fracasso 2014; Fracasso, Sartori and Schiavo 2015). In addition, unilateral trade, such as net virtual water import or net virtual water export, rather than bilateral trade, have been considered in Debaere (2012) and Hoekstra Hung (2005) paper, which might hinder other key characteristics of paired country affecting the trade flows, such as the distance, regional trade agreement, common language and border between any paired countries. To tackle the problem of MRTs, the presence of zero virtual water trade value and the potential heteroscedasticity problem, PPML model fixed effects have been estimated. Virtual water metaphor is to address the problems of water scarcity and uneven distribution of water across the globe. If only the endowment effect of VWT is considered, the estimates of VWT are always biased, thus we will take the comparative advantage into consideration. This paper is the first to estimate the determinants of bilateral virtual water trade with the bilateral tariff, rather than unilateral trade, using PPML with fixed effects of exporters, importers, year and commodity.

The results of PPML model show that traditional trade factors affect the blue virtual water exports, a historical conical tie or common language increase virtual trade any two countries; the distance decreases the VWT. Our interested variable also demonstrates the expected statistically negative signs, and the tariff has a negative effect on the blue virtual water trade.

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Append

Table 1. Definitions of Variable and Sample Statistics

Dependent Variables		Mean	Std. Dev.
Blue Virtual Water Import	Blue virtual water embodied in the grain products imported by country i from country j	8.694	467.568
Green Virtual Water Import	Green virtual water embodied in the grain products imported by country i from country j	9.297	44.593
Independent Variables			
$\text{Ln}(1+\text{tariff}_{ijt})$	Bilateral ad valorem equivalent of tariff (AVE)	0.108	0.146
lnDIST_{ij}	Weighted distance between exporter and importer km	8.697	0.764
Contiguity_{ij}	1 for common border between importer and exporter;0 otherwise	0.020	0.140
$\text{Common Language}_{ij}$	1 for common official of primary language; 0 otherwise	0.129	0.335
$\text{Colony post 1945}_{ij}$	1 for pair ever in colonial relationship post 1945; 0 otherwise	0.008	0.087
$\text{Common Colony}_{ij}$	1 for pair ever in colonial relationship; 0 otherwise	0.013	0.114
$\text{current Colony}_{ij}$	1 for pair current in colonial relationship;0 otherwise	0.0002	0.015
$\ln[\text{Area}_i * \text{Area}_j]$	1 for pair ever in colonial relationship; 0 otherwise	3.002	3.174
$\text{Common Currency}_{ij}$	1 for Common Currency; 0 otherwise	0.010	0.0991
$\text{Regional Trade Agreement}_{ij}$	1 for regional trade agreement in force; 0 otherwise	0.059	0.236

EU	1 for both countries from EU; 0 otherwise	0.008	0.088
NFATA	1 for both countries from NAFATA; 0 otherwise	0.020	0.141
No. of Obs	2,234,265		

Table 2. Direct and Indirect Water Intensity Rank with average bilateral tariff

Water Intensity Rank[5] (W/y)	Crop Name	Average Tariff
	All Crops	0.145
1	Osd: Oil Seeds	0.087
	(Soybean, Rapeseed, Sunflower, Groundnuts)	
2	Gro: Other Grains	0.111
	(Pulses, Rye, Barley, Maize, Sorghum, Millet	
2	Wht: Wheat	0.093
	(Wheat)	
2	Pdr: Paddy Rice	0.276
	(Rice)	
5	V_f: Veg & Fruit	0.186
	(Potatoes, Citrus, Grapes, Cassava, Dates)	
6	Ocr: Other Crops	0.108
	(Coffee)	
7	Ofd: Other Food	0.155
	(Cocoa)	

[5] Direct and indirect water

Table 3. Result of blue virtual water import for all crops and specific crops with and without Tariff

VARIABLES	(1) tariff	(2) no tariff	(3) tariff	(4) no tariff	(5) tariff	(6) no tariff	(7) tariff	(8) no tariff
	19 crops	19 crops	Other grains	Other grains	Paddy rice	Paddy rice	Wheat	Wheat
$\ln(1+ tariff_{ijt})$	-0.416**		1.261**		-3.708***		-3.621***	
	(0.198)		(0.558)		(1.205)		(0.951)	
$\ln DIST_{ij}$	-1.014***	-0.989***	-1.846***	-1.799***	-1.206***	-1.205***	-1.685***	-1.607***
	(0.122)	(0.116)	(0.269)	(0.256)	(0.178)	(0.179)	(0.292)	(0.277)
Contiguity $_{ij}$	0.489**	0.503**	0.666	0.668	0.850**	0.829**	0.305	0.335
	(0.249)	(0.246)	(0.451)	(0.434)	(0.361)	(0.337)	(0.363)	(0.353)
Common Language$_{ij}$	-0.106	-0.102	0.0858	0.145	0.0730	0.0245	0.255	0.217
	(0.199)	(0.195)	(0.524)	(0.527)	(0.250)	(0.244)	(0.283)	(0.279)
Colony post 1945$_{ij}$	1.059***	1.073***	1.139	1.046	0.546	0.911**	1.237*	1.147
	(0.405)	(0.403)	(0.724)	(0.702)	(0.495)	(0.435)	(0.741)	(0.765)
Common Colony$_{ij}$	0.134	0.143	0.167	0.157	0.902*	0.656*	-1.131**	-1.078**
	(0.254)	(0.250)	(0.420)	(0.419)	(0.483)	(0.398)	(0.508)	(0.523)
Current Colony$_{ij}$	-0.859	-0.854	-2.657**	-2.588**	-0.761	-0.834	-1.737	-1.317
	(0.880)	(0.875)	(1.041)	(1.012)	(0.927)	(1.123)	(1.221)	(1.188)
$\ln[Area_i * Area_j]$	-3.518*	-3.494*	1.346	0.718	-4.186*	-4.092*	-3.967*	-4.191*
	(1.931)	(1.925)	(2.585)	(2.572)	(2.175)	(2.221)	(2.406)	(2.223)
Common Currency$_{ij}$	-0.244	-0.231	-0.701***	-0.693***	-0.290*	-0.154	0.494*	0.538*
	(0.160)	(0.158)	(0.203)	(0.201)	(0.170)	(0.170)	(0.293)	(0.290)
Regional Trade Agreement$_{ij}$	0.619***	0.642***	0.0120	0.174	-0.169	0.00316	0.467	0.623*
	(0.217)	(0.216)	(0.375)	(0.375)	(0.368)	(0.388)	(0.354)	(0.342)
EU_{ij}	1.893***	1.942***	3.780***	3.501***	0.682	1.892***	2.712***	2.767***
	(0.377)	(0.365)	(0.724)	(0.687)	(0.484)	(0.403)	(0.613)	(0.624)
$NAFATA_{ij}$	15.10***	15.02***	12.46*	14.20**	22.03***	21.68***	22.73***	22.63***
	(4.922)	(4.907)	(6.508)	(6.483)	(5.608)	(5.717)	(6.132)	(5.681)
RESET test P-values	0.415	0.652	0.013	0.016	0.014	0.012	0.135	0.261
Constant	27.06**	26.68**	-5.723	-2.359	32.32**	31.63**	35.76**	36.89***
	(11.89)	(11.86)	(15.33)	(15.33)	(13.53)	(13.84)	(14.44)	(13.43)
Observations	2,234,265	2,932,650	590,610	758,880	77,960	101,920	69,635	81,445
R-squared	0.192	0.190	0.393	0.384	0.411	0.396	0.328	0.319
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

***, **and * significant at 1%, 5%, and 10%, respectively; numbers in parentheses are robust standard errors clusters in importer, exporter, and products.

Table 4. Result of green virtual water import for all crops and specific crops with and without Tariff

VARIABLES	(1) tariff	(2) no tariff	(3) tariff	(4) no tariff	(5) tariff	(6) no tariff	(7) tariff	(8) no tariff
	wheat	wheat	paddy rice	paddy rice	19 crops	19 crops	Other grains	Other grains
$\text{Ln}(1+\text{tariff}_{ijt})$	-3.154***		-2.590**		-0.0218		0.520	
	(0.845)		(1.314)		(0.263)		(0.530)	
			-	-				
lnDIST_{ij}	-1.513***	-1.493***	1.168***	1.204***	-0.960***	-0.954***	-1.593***	-1.591***
	(0.161)	(0.156)	(0.221)	(0.204)	(0.102)	(0.0994)	(0.159)	(0.159)
Contiguity_{ij}	0.350	0.384	1.297***	1.187**	0.281	0.294	0.772***	0.760***
	(0.287)	(0.288)	(0.502)	(0.470)	(0.188)	(0.188)	(0.242)	(0.244)
$\text{Common Language}_{ij}$	0.238	0.249	-0.0526	-0.0406	-0.0381	-0.0457	-0.0512	-0.0484
	(0.201)	(0.195)	(0.289)	(0.280)	(0.162)	(0.160)	(0.256)	(0.257)
$\text{Colony post 1945}_{ij}$	1.476**	1.468**	0.137	0.678*	1.701***	1.708***	0.459	0.477
	(0.697)	(0.699)	(0.487)	(0.391)	(0.361)	(0.360)	(0.563)	(0.560)
$\text{Common Colony}_{ij}$	-0.768	-0.797	0.838**	0.681*	-0.446	-0.442	-0.326	-0.322
	(0.548)	(0.553)	(0.419)	(0.352)	(0.286)	(0.285)	(0.427)	(0.428)
$\text{Current Colony}_{ij}$	-4.952***	-1.148	0.439	-1.859	-0.408	-0.410	-0.927	-0.916
	(1.263)	(1.350)	(1.122)	(1.239)	(1.052)	(0.999)	(1.154)	(1.146)
			-	-				
$\ln[\text{Area}_i * \text{Area}_j]$	-5.386	-5.485*	5.884***	5.855***	-2.991	-2.977	-0.424	-0.604
	(3.361)	(3.330)	(1.335)	(1.359)	(1.845)	(1.844)	(2.098)	(2.094)
$\text{Common Currency}_{ij}$	-0.130	-0.122	-0.0798	0.0314	0.102	0.102	0.0598	0.0725
	(0.385)	(0.388)	(0.249)	(0.260)	(0.170)	(0.169)	(0.196)	(0.196)
$\text{Regional Trade Agreement}_{ij}$	0.538**	0.692***	0.152	0.223	0.320	0.316	0.270	0.304
	(0.270)	(0.252)	(0.378)	(0.385)	(0.195)	(0.193)	(0.217)	(0.215)
EU_{ij}	0.120	0.0905	0.194	1.096**	-0.380	-0.381	-0.318	-0.370
	(0.373)	(0.376)	(0.574)	(0.455)	(0.287)	(0.284)	(0.365)	(0.365)
NAFATA_{ij}	31.09***	30.95***	24.67***	24.63***	15.22***	15.18***	9.353*	9.876*
	(8.615)	(8.526)	(3.495)	(3.555)	(4.699)	(4.696)	(5.379)	(5.359)
RESET test P value	0.07	0.039	0.483	0.514	0.000	0.000	0.036	0.048
Constant	34.81*	35.50*	39.16***	39.13***	22.27*	22.17*	12.98	14.06
	(20.58)	(20.39)	(8.096)	(8.302)	(11.43)	(11.42)	(13.04)	(13.01)
Observations	27,560	32,260	89,900	117,520	2,436,087	3,196,902	758,820	976,440
R-squared	0.709	0.705	0.522	0.511	0.251	0.250	0.404	0.408
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

***, **and * significant at 1%, 5%, and 10%, respectively; numbers in parentheses are robust standard errors clusters in importer, exporter, and products.