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IDE DISCUSSION PAPER No. 796

Tariff Rates in Gravity

Kazunobu HAYAKAWA*, Taiyo YOSHIMI

August 2020

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Keywords: Gravity; Tariffs; Regional trade agreements
JEL Classification: F15; F53

* Senior Research Fellow, Economic Geography Studies Group, Development Studies Center, IDE (kazunobu_hayakawa@ide.go.jp)

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INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

Tariff Rates in Gravity§

Kazunobu HAYAKAWA*
Development Studies Center, Institute of Developing Economies, Japan

Taiyo YOSHIMI
Faculty of Economics, Chuo University, Japan

Abstract: In investigations on the role of tariff rates in the gravity equation, applied tariff rates (i.e., the lowest available rates) are often introduced. However, not all exporters use the lowest available rates, especially when some cost is incurred in using those rates. This implies that it is not prudent to introduce only the applied tariffs into the gravity equation. Accordingly, this study discusses how to deal with tariff variables in the gravity estimation. Specifically, it empirically demonstrates that when multiple tariff schemes are available, omitting tariffs in either scheme creates a remarkable bias in the estimates. When we control for other tariffs by explicit variables or fixed effects defined at an appropriate level (e.g., importer-product-year fixed effects), the use of applied tariffs can be justified.

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1. Introduction

Although tariffs are an essential factor in international trade, few studies evaluate the gravity equation with tariff rates for global trade, particularly because gathering data on tariffs and creating a tariff variable is time-consuming and laborious. However, Disdier et al. (2015) acquired data on applied tariff rates (i.e., lowest available tariff rates) from the MAcMap by the Centre d'Informations Internationales (CEPII) and introduced them into their gravity equation. They found a negative coefficient for the applied tariffs, indicating that lower applied tariffs lead to larger trade values. Recently, some tariff databases have become available, including the Tariff Analysis Online facility and the

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§ We would like to thank Naoto Jinji, Fukunari Kimura, Yoshimasa Komoriya, Kenta Yamanouchi, Hitoshi Sato, Kyoji Fukao, and the seminar participants at Keio University, Kangwon National University, the Economic Research Institute for ASEAN and East Asia (ERIA), the Nagoya International Economics Study Group (NIESG), the Japan Society of International Economics, the Japanese Economic Association, the Western Economic Association International (WEAI), and the Institute of Developing Economies (IDE-JETRO). This work was supported by JSPS KAKENHI Grant Numbers 17H02530 and 20H01518. All remaining errors are our own.

* Corresponding author: Kazunobu Hayakawa; Address: Wakaba 3-2-2, Mihama-ku, Chiba-shi, Chiba, 261-8545, Japan. Tel: 81-43-299-9680; Fax: 81-43-299-9724; E-mail: kazunobu_hayakawa@ide-gsm.org.

World Integrated Trade Solution (WITS). Thus, the number of gravity studies with tariff variables is expected to increase.

Limited studies result in a lack of clarity on the kinds of tariffs to be employed and the method for introducing these tariffs into the gravity equation. For example, it is assumed that applied tariffs can be used when all exporting firms use the lowest tariff rates, for example, regional trade agreement (RTA) rates for exports to RTA member countries. However, this assumption contradicts reality. For instance, Keck and Lendle (2012) showed that the share of imports under the RTA regimes out of the total imports is below 100%, even for products eligible for RTA regimes.[1] Because exporters incur some costs to use preference regimes, particularly costs to certify the origin of goods, not all exporters use these available regimes. This implies that introducing only the applied tariffs into the gravity equation is not a rational strategy.

This study examines tariff variables in the gravity equation. A gravity model is developed considering the coexistence of alternative tariff regimes: the most favored nation (MFN) regime and an RTA regime. In particular, the study introduces the tradeoff across MFN and RTA regimes discussed by Demidova and Krishna (2008) and Cherkashin et al. (2015). The gravity model herein makes two predictions for the effect of tariffs on bilateral trade: (1) bilateral trade depends on all available tariffs, including MFN and RTA tariffs, and (2) the trade is always negatively associated with RTA tariffs, while the effect of MFN tariffs on trade depends on several factors and parameters. It can be even positive, indicating that when MFN tariffs are reduced, trade values decrease because some RTA users switch over as MFN users when the tariffs are reduced. These switching exporters decrease their volume of exports because MFN rates are still higher than RTA rates after those reductions.

Next, the gravity equation with tariff variables is estimated for worldwide trade. Specifically, various equations are estimated, which include the equation with only MFN tariffs, only RTA tariffs, and both MFN and RTA tariffs. Comparing the estimates in these tariffs, the direction and magnitude of the bias resulting from omitting either type of tariff are discussed. Consequently, given the positive association between MFN and RTA tariffs, the estimate in MFN tariffs in the equation without RTA tariffs is found to suffer from downward bias, and its positive effect is underestimated. Similarly, excluding MFN tariffs is found to yield upward bias and underestimates the negative coefficient for RTA tariffs. Thus, the use of applied tariffs is justified subject to controlling for MFN tariffs by introducing the fixed effects defined at an appropriate level (e.g., importer-product-year fixed effects). Otherwise, the estimates suffer from omitted-variable bias.

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[1] Specifically, imports in Australia from the United States or Canada are approximately 50%. The share of European Union imports from Mexico is approximately 80%. A similar share can be found in the case of U.S. imports from Australia.

Several researchers have focused on the specification, testing, and validation of gravity equations. Several authors, such as Anderson (1979), Bergstrand (1985), Helpman and Krugman (1985), Bergstrand (1989), Deardorff (1998), Eaton and Kortum (2002), and Anderson and van Wincoop (2003), have examined the theories. Gravity equations have been developed by allowing firm heterogeneity similar to à la Melitz (2003), including Chaney (2008), Helpman et al. (2008), Bergstrand et al. (2015), Anderson et al. (2016), and Heid and Larch (2016). Nevertheless, no studies have focused on including tariffs in the gravity analysis.[2] From a theoretical perspective, the coefficient for tariffs is associated with trade elasticity or the elasticity of substitution, which is crucial in quantifying the welfare impacts of tariff reduction (Costinot and Rodríguez-Clare, 2014). Thus, the possible magnitude and direction of the bias in tariff coefficients are demonstrated. This empirical study helps address tariff variables in the gravity estimation.

The remainder of this study is presented as follows. Section 2 presents the gravity equation. Sections 3 and 4 show the empirical framework and results, respectively. Section 5 concludes the study.

2. Gravity Equation with the Choice of a Tariff Scheme

This section presents the gravity equation considering the exporters' choice among alternative tariff schemes.[3] The theoretical discussion is based on Demidova and Krishna (2008) and Cherkashin et al. (2015), wherein two alternative tariff schemes, MFN and RTA, are available for exporters. The tradeoff mechanism presented in these studies is introduced into the gravity framework developed by Chaney (2008).

While exporting, firms can choose either MFN (M) or RTA (R) tariff scheme. Let i, j, and p indicate the exporting country, importing country, and product, respectively. In both types of schemes, exporters must pay fixed costs for exports, denoted by f_{ip}. Further, when exporting under the RTA scheme, they also incur additional fixed costs, such as those to certify the origin of goods, which are denoted by f_{ip}^{R}. These fixed costs vary by exporting countries and products. Here, τ_{jp}^{M} and τ_{ijp}^{R} denote the (one plus) MFN and RTA tariff rates, respectively (τ_{jp}^{M}, τ_{ijp}^{R} >1). While the former rates are the same across exporting countries, the latter are specific to the country pair (and product). When exporting under the RTA scheme, exporters should comply with the rules of origin (RoO), which warrants a change in their procurement sources, which in turn leads to a rise in procurement costs. Such procurement adjustment costs are captured by ρ_{ijp} as ad valorem cost for RTA usage ($\rho_{ijp} > 1$), which differ by country pairs and products.[4]

[2] Hayakawa (2013) introduced applied tariffs into the gravity equation but did not differentiate those with MFN tariffs and did not examine the possible bias of omitting MFN tariffs.

[3] The details of the derivation are provided in Appendix A.

[4] The procurement adjustment costs are based on the RoO, which varies by RTAs. Thus, we assume

We assume $\rho_{ijp}\tau_{ijp}^{R} < \tau_{jp}^{M}$. Therefore, exporters face a tradeoff at which they enjoy lower variable cost ($\rho_{ijp}\tau_{ijp}^{R}$) while paying an additional fixed cost (f_{ip}^{R}) when they use an RTA tariff scheme.

We introduce this tradeoff into the gravity framework and examine how MFN and RTA tariff rates affect the product-level bilateral trade. Consequently, the following product-level gravity equation that presents potential determinants of bilateral trade is obtained:

$$X_{ijp} = \mu_p \frac{Y_i Y_j}{Y}\left(\frac{w_i}{\theta_{jp}}\right)^{-\gamma_p} T_{ijp}. \tag{1}$$

X_{ijp} is the bilateral trade of each product, μ_p is the weight on each product in the importing country's utility, Y_i (Y_j) is the exporting (importing) country's total income, Y is the global gross domestic product (GDP), and w_i is the wage in the exporting country. γ_p is the shape parameter of the Pareto distribution of exporting country's productivity. T_{ijp} is the trade cost component defined by

$$T_{ijp} = \left(\tau_{jp}^{M}\right)^{-\gamma_p}\left(f_{ip}\right)^{1-\frac{\gamma_p}{\sigma_p-1}} + \left[\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1} - \left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p-1}\right]^{\frac{\gamma_p}{\sigma_p-1}}\left(f_{ip}^{R}\right)^{1-\frac{\gamma_p}{\sigma_p-1}}. \tag{2}$$

σ_p is the elasticity of substitution among differentiated products. θ_{jp} is the multilateral resistance variable (MRV) discussed in Chaney (2008) and varies by importing countries and products.[5]

This study focuses on the case where some exporters use the MFN scheme and others the RTA scheme to reveal the role of both MFN and RTA tariff rates. This case is called the heterogeneous regime, which is realized when the tariff reduction under the RTA scheme does not overcome additional utilization costs of the scheme. Specifically, the heterogeneous regime is realized when the following condition holds

$$\frac{f_{ip}}{f_{ip}+f_{ip}^{R}} < \left(\frac{\rho_{ijp}\tau_{ijp}^{R}}{\tau_{jp}^{M}}\right)^{\sigma_p-1}. \tag{3}$$

If condition (3) is violated, all exporters use the RTA scheme. This case is called the homogeneous regime in which MFN rates do not affect the product-level bilateral exports because no firms use MFN rates.

In addition to standard gravity factors such as outputs in importing and exporting countries, the gravity equation (1) reveals how tariff rates, fixed costs, and procurement adjustment cost affect the product-level bilateral trade. The gravity equation indicates that RTA tariff rates (τ_{ijp}^{R}), the procurement adjustment cost (ρ_{ijp}), and the fixed costs (f_{ip} and f_{ip}^{R}) have negative effects on exports.[6] The sign of the effect of MFN tariff rates (τ_{jp}^{M}) is not determined. When MFN rates are reduced, some firms that sold only in their

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that those costs are specific to country-pair (and product).

[5] The definition of θ_{jp} is given in (A4) in Appendix A.

[6] Elasticities are provided in Appendix B.

domestic market start exporting, indicating the negative coefficient for MFN rates. However, some RTA users switch to use MFN rates when MFN rates are reduced. If MFN rates are higher than RTA rates, (tariff-inclusive) export prices set by these exporters become higher after they switch. Therefore, demand falls, and export values decrease, implying a positive coefficient. However, given that MFN rates affect product-level bilateral trade, omitting these rates leads to an omitted-variable problem.

3. Empirical Framework

Based on the earlier theoretical discussion, this section provides the empirical framework to examine how gravity estimates are biased if tariff rates are not adequately controlled for. Specifically, the following product-level gravity equations are estimated to identify the direction and magnitude of the bias.

$$\ln X_{ijpt} = \alpha \times \ln(1 + MFN_{jpt}) + \delta_{ijt} + \delta_{ijp} + \delta_{ipt} + \epsilon_{ijpt}. \quad (4)$$

$$\ln X_{ijpt} = \beta \times \ln(1 + RTA_{ijpt}) + \delta_{ijt} + \delta_{ijp} + \delta_{ipt} + \epsilon_{ijpt}. \quad (5)$$

$$\ln X_{ijpt} = \alpha \times \ln(1 + MFN_{jpt}) + \beta \times \ln(1 + RTA_{ijpt}) + \delta_{ijt} + \delta_{ijp} + \delta_{ipt} + \epsilon_{ijpt}. \quad (6)$$

X_{ijpt} is the exports of product p from country i to country j in year t. MFN_{jpt} and RTA_{ijpt} are MFN tariffs and RTA tariffs, respectively. MFN tariffs do not differ across exporting countries. Further, RTA tariffs are equal to MFN tariffs if any tariffs under the RTA regimes are not available. Thus, this variable of RTA tariff rates is called "applied tariff rates."[7] δ_{ijt}, δ_{ijp}, and δ_{ipt} are the country pair-year fixed effects, country pair-product fixed effects, and exporter-product-year fixed effects, respectively. ϵ_{ijpt} is a disturbance term.

Three types of fixed effects control for various elements that affect bilateral trade. The country pair-year fixed effects capture the time-variant country pair characteristics such as exchange rates or other bilateral trade facilitation arrangements. This type of fixed effect also contributes to controlling for country-level market sizes represented by Y_i, Y_j, and Y in equation (1). The country pair-product fixed effects control for the standard gravity elements, including geographical distance, historical ties, or cultural similarity in addition to various parameters such as the elasticity of substitution and the weight in the utility function (μ_p). This type of fixed effect also controls for procurement adjustment costs (ρ_{ijp}) and two types of fixed costs (f_{ip} and f_{ip}^R).[8] Finally, the

[7] From the theoretical perspective, the coefficients for tariff variables should be different across countries and products. However, we do not differentiate those and estimate the average magnitude.

[8] While this theoretical framework does not incorporate the time dimension, each parameter or variable changes over time. In particular, although fixed costs are assumed time-invariant, these costs might be controlled for by exporter-product-year fixed effects if they change over time. By contrast, procurement adjustment costs are based on the RoO, which does not usually change over time. Furthermore, we control for the change of factor prices, which affects the magnitude of originated value-added, by exporter-product-year fixed effects. Thus, we claim that the effects of procurement

exporter-product-year fixed effects capture the supply-side characteristics such as factor prices and technology in exporting countries (w_i). In these equations, no importer-product-year fixed effects are introduced to explicitly examine the role of MFN rates, which have the variation at the same level as those fixed effects.

As shown earlier, the equation should include both MFN and RTA tariffs. Thus, compared with estimates in equation (6), those in equations (4) and (5) are biased because of omitting either type of tariff. By comparing the results in these two equations, the direction and magnitude of the bias are known when not controlling for both types of tariffs. Furthermore, for more consistent estimates in RTA tariffs, we control for importer-product-year fixed effects (δ_{jpt}) as follows.

$$\ln X_{ijpt} = \beta \times \ln\left(1 + RTA_{ijpt}\right) + \delta_{ijt} + \delta_{ijp} + \delta_{ipt} + \delta_{jpt} + \epsilon_{ijpt}. \qquad (7)$$

A comparison of the estimates between equations (6) and (7) show the direction and magnitude of the bias when not controlling for the remaining time-variant importer-product-level characteristics such as MRV (θ) or product-level demand sizes.

A product is defined at an HS six-digit level. The study years are 1995, 2000, 2005, 2010, and 2015. Although the data are available every year, the data of every five years are used to reduce the computational burden in the estimation. The data sources are as follows. Trade data are obtained from the CEPII.[9] It is called "BACI" database and is an updated version of the data provided in Gaulier and Zignago (2010). The database offers disaggregated data on bilateral trade flows for 222 countries. The tariff variables are constructed by employing the data on tariffs from the WITS database.[10] In particular, a variable of RTA tariffs includes both RTA tariffs and unilateral preference tariffs (e.g., the generalized system of preferences, GSP) or other preference tariffs. When multiple-preference rates are available, the lowest rates are chosen for each tariff-line code. As mentioned earlier, when any preference tariffs are unavailable, the MFN tariffs are chosen. Then, the tariffs up to an HS six-digit-level are averaged by simple average. Table 1 presents the basic statistics for the variables. The models are estimated by the ordinary least square (OLS).[11]

=== Table 1 ===

adjustment costs are controlled for by our set of fixed effects.

[9] http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=37

[10] http://wits.worldbank.org/WITS/

[11] This study excludes zero-valued trade but includes a log of trade. This exclusion is because we estimate for the trade of approximately 5,000 products among more than 200 countries for 5 years. Thus, even if the observations with zero-valued trade are excluded, the number of observations exceeds 20 million. Furthermore, the number of dummy variables for fixed effects is nearly nine million. Thus, applying nonlinear estimation techniques (e.g., pseudo-Poisson maximum likelihood technique) to this model is beyond the scope of computation, and the log-likelihood is less likely to achieve convergence in the standard threshold.

4. Empirical Results

This section presents the estimation results. Following Egger and Tarlea (2015), the standard errors are clustered by country pair-product and year. The OLS results of equations (4), (5), and (6) for all products are, respectively, as shown in columns (I), (II), and (III) in the upper panel of Table 2. In the former two columns, both MFN and RTA tariffs have significantly negative coefficients. In column (III), when both MFN and RTA tariffs are introduced simultaneously, the coefficient for RTA tariffs remains negative while that for MFN tariffs becomes significantly positive. Furthermore, the absolute magnitude of the coefficient for RTA tariffs increases, indicating an underestimation of the negative impact of RTA rates when the impact of MFN rates is ignored. The degree of this underestimation reaches approximately at 14.6% ($\approx 100 \times [|-0.715| - |-0.624|]/|-0.624|$). Specifically, a 1% reduction of RTA tariffs increases trade by 0.7%, while a 1% reduction of MFN tariffs decreases it by 0.1%. Thus, a contrasting effect on trade was found between MFN and RTA tariffs.

=== Table 2 ===

Section 2 theoretically demonstrated that the sign of the effect of MFN tariff rates is unclear. Along with reductions in MFN rates, there is a rise in the number of exporters as more potential exporters enter the market, which increases the total exports. By contrast, some RTA users switch to MFN in response to MFN tariff rate reductions. There is a fall in exports by these switching exporters because MFN rates are still higher than RTA rates after those reductions. These contrasting effects offset each other, thus obscuring the net effect of MFN rates on trade. Our empirical results imply that the latter effect dominates the former and that the resulting net effect is positive; the reduction of MFN tariffs decreases exports. Conversely, consistent with the discussion in Section 2, RTA tariffs are negatively associated with exports.

Further, a comparison of the results in the three columns shows that the relationship between MFN and RTA tariffs is important for interpreting their differences. In this study sample, these two tariffs are positively correlated, partly because RTA tariffs cannot be higher than MFN tariffs. Thus, in the products with low MFN tariffs, RTA tariffs must be similar to or lower than MFN tariffs, which results in a positive relationship between the two tariffs. Besides, from a theoretical perspective, owing to the tariff-complementarity effect (Bagwell and Staiger, 1999), the reduction of tariffs through RTAs induces countries to decrease MFN tariffs. Some empirical studies support this effect (e.g., Estevadeordal et al., 2008; Calvo-Pardo et al., 2011).

Given this positive association between MFN and RTA tariffs, the comparison in the coefficient for MFN tariffs between columns (I) and (III) indicates that the disturbance term in equation (4) is negatively correlated with MFN tariffs.[12] As found in column (III), RTA tariffs are negatively associated with exports and thereby the disturbance term in equation (4). Given that such RTA tariffs are positively correlated with MFN tariffs, the estimate in MFN tariffs in equation (4) suffers from the downward bias, and its positive effect is underestimated. Similarly, the comparison in the coefficient for RTA tariffs between columns (II) and (III) indicates that the disturbance term in equation (5) is positively correlated with RTA tariffs. Again, as shown in column (III), MFN tariffs have a positive association with exports. Thus, omitting MFN tariffs yields the upward bias and underestimates the negative coefficient for RTA tariffs.

Next, equation (7) is estimated, which controls for the remaining time-variant importer-product-level characteristics such as MRV or product-level demand sizes. The result is shown in column (IV). The coefficient for RTA tariffs is again estimated to be significantly negative. Its magnitude does not change significantly compared with that in column (III). The absolute magnitude slightly decreases. For example, larger product-level demand size leads naturally to larger trade. Furthermore, since products with large demand are liberalized in RTAs (Baier and Bergstrand, 2004), the product-level demand size is negatively associated with RTA tariffs. As a result, the remaining time-variant importer-product-level characteristics yield a negative correlation between RTA tariffs and the disturbance term in equation (6) and thereby create a small and downward bias in the estimate in RTA tariffs in equation (6). Nevertheless, MFN tariffs account for a major part of the time-variant importer-product-level characteristics in the effects on trade because the coefficient for RTA tariffs does not differ significantly between columns (III) and (IV).

In the lower panel of Table 1, the study products are restricted only to those where RTA tariffs are lower than MFN tariffs (i.e., RTA-eligible products), while the trade in all products is studied in the upper panel. Specifically, in the upper panel, the study observations include even trade with RTA nonmember countries. The focus on RTA-eligible products has pros and cons. One advantage is that two tariff variables assume distinct values. Thus, their role is separately identified. However, this leads to identifying the effects of RTA tariffs only through the over-time change of RTA tariffs per se. In other words, the identified effect excludes the effect of eliminating tariffs immediately after the start of RTA tariff reduction. It reflects the effects of the *gradual* reduction of RTA tariffs. Thus, the study products tend to be sensitive compared with those where tariffs are immediately eliminated (Maggi and Rodríguez-Clare, 2007).

The sign and statistical significance in tariff variables remain unchanged compared with the result in the upper panel, except for MFN tariffs in column (III). Overall, the coefficients for MFN and RTA tariffs decrease compared with those in the upper panel.

[12] We do not statistically test the differences in the coefficient magnitude across columns because their tests need computation of the variance–covariance matrices of residuals. Their computation is practically infeasible in our models with nearly nine million dummy variables for fixed effects.

In particular, the absolute value in RTA tariffs increases. Thus, the trade in sensitive products changes significantly by a tariff reduction than the average among all products. Moreover, the coefficient for RTA tariffs increases remarkably in column (IV) compared with that in column (III). It also becomes larger than the coefficient obtained in column (II). These results imply that there are some significant importer-product-year elements that create a negative correlation between RTA tariffs and the disturbance terms in equations (5) and (6). Given that the study products are mainly sensitive products in this estimation, protection for domestic producers appears to be a key factor. A higher level of protection leads to a higher level of RTA tariffs and to the smaller value of trade.

Finally, these models are estimated for differentiated and nondifferentiated products separately. The differentiated products are classified based on the "liberal" classification of products by Rauch (1999). Table 3 reports the estimation results. Given that the coefficients for tariffs are related to the elasticity of substitution, the absolute magnitude is slightly larger in nondifferentiated than in differentiated products. Overall, the results in both types of products are similar to those in the upper panel in Table 2. Notably, the coefficient for RTA tariffs in column (IV) further decreases in nondifferentiated products. Thus, in contrast to the earlier results, in the case of nondifferentiated products, some dominant importer-product-year elements exist that create the *positive* correlation between RTA tariffs and the disturbance terms in equations (5) and (6). Given that agricultural goods are categorized into nondifferentiated products, nontariff measures (NTMs), such as sanitary and phytosanitary measures, are significant measures. Instead of reducing tariffs via RTAs, countries may introduce NTMs such as decreasing trade (e.g., Beverelli et al., 2019; Niu et al., 2020).

=== Table 3 ===

5. Concluding Remarks

This study examined tariff variables in the gravity equation and demonstrated that when multiple tariff schemes are available, omitting tariffs in either scheme creates a remarkable bias in the estimates. Specifically, omitting MFN tariff yields upward bias and underestimates the negative coefficient for RTA tariffs. Similarly, the estimate in MFN tariffs in the equation without RTA tariffs suffers from the downward bias, and its positive effect is underestimated. Thus, to obtain consistent estimates, all available tariff variables or control for those rates must be included by introducing appropriate fixed effects. Although this study did not differentiate between RTA and other preference tariffs (e.g., GSP tariffs), such differentiation is also important. Furthermore, most of the studies estimate the gravity equation at a country pair-year level rather than a country pair-product-year level. At this level of analysis, the introduction of only applied tariffs can produce consistent estimates if we control for importer-year fixed effects. Such fixed effects are often introduced to control for importer's MRV. Therefore, the coefficient for applied tariffs obtained in the existing studies can be taken as a consistent estimate.

References

Anderson, James E., "A Theoretical Foundation for the Gravity Equation," *American Economic Review*, 1979, 69(1), 106–116.

Anderson, James E. and Eric van Wincoop, "Gravity with Gravitas: A Solution to the Border Puzzle," *American Economic Review*, 2003, 93(1), 170–192.

Anderson, James E., Eric van Wincoop, Mykyta Vesselovsky, and Yoto V. Yotov, "Gravity with Scale Effects," *Journal of International Economics*, 2016, 100, 174–193.

Baier, Scott L. and Jeffrey H. Bergstrand, 2004, Economic Determinants of Free Trade Agreements, *Journal of International Economics*, 64(1): 29-63.

Bergstrand, Jeffrey H., "The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence," *Review of Economics and Statistics*, 1985, 67(3), 474– 481.

Bergstrand, Jeffrey H., "The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade," *Review of Economics and Statistics*, 1989, 71(1), 143–153.

Bergstrand, Jeffrey H., Mario Larch, and Yoto V. Yotov, "Economic Integration Agreements, Border Effects, and Distance Elasticities in the Gravity Equation," *European Economic Review*, 2015, 78, 307–327.

Beverelli, Cosimo, Mauro Boffa, and Alexander Keck, "Trade Policy Substitution: Theory and Evidence," *Review of World Economics*, 2019, 155, 755–783.

Chaney, Thomas, "Distorted Gravity: The Intensive and Extensive Margins of International Trade," *American Economic Review*, 2008, 98(4), 1707–1721.

Cherkashin, Ivan, Svetlana Demidova, Hiau Looi Kee, and Kala Krishna, "Firm Heterogeneity and Costly Trade: A New Estimation Strategy and Policy Experiments," *Journal of International Economics*, 2015, 96(1), 18–36.

Costinot, Arnaud and Andrés Rodríguez-Clare, "Trade Theory with Numbers: Quantifying the Consequences of Globalization." In *Handbook of International Economics,* Vol. 4, 2014, 197-261, Elsevier.

Deardorff, Alan V., "Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World?," in Jeffrey A. Frankel, ed., *The Regionalization of the World Economy*, Chicago: University of Chicago Press, 1998, chapter 1, pp. 7–32.

Demidova, Svetlana and Kala Krishna, "Firm Heterogeneity and Firm Behavior with Conditional Policies," *Economics Letters*, 2008, 98(2), 122–128.

Disdier, Anne-Célia, Lionel Fontagné, and Mondher Mimouni, "Tariff Liberalization and Trade Integration of Emerging Countries," *Review of International Economics*, 2015, 23(5), 946–971.

Eaton, Jonathan and Samuel Kortum, "Technology, Geography, and Trade," *Econometrica*, 2002, 70(5), 1741–1779.

Egger, Peter and Filip Tarlea, "Multi-way Clustering Estimation of Standard Errors in Gravity Models," *Economics Letters*, 2015, 134(C), 144-147.

Gaulier, Guillaume and Soledad Zignago, "BACI: International Trade Database at the Product-Level. The 1994-2007 Version," CEPII Working Paper, N°2010-23, 2010.

Hayakawa, Kazunobu, "How Serious is the Omission of Bilateral Tariff Rates in Gravity?," *Journal of the Japanese and International Economies*, 2013, 27, 81-94.

Heid, Benedikt and Mario Larch, "Gravity with Unemployment," *Journal of International Economics*, 2016, 101, 70–85.

Helpman, Elhanan and Paul Krugman, *Market Structure and Foreign Trade. Increasing Returns, Imperfect Competition, and the International Economy*, Cambridge, MA: MIT Press, 1985.

Helpman, Elhanan, Marc Melitz, and Yona Rubinstein, "Estimating Trade Flows: Trading Partners and Trading Volumes," *Quarterly Journal of Economics*, 2008, 123 (2), 441–487.

Keck, Alexander and Andreas Lendle, "New Evidence on Preference Utilization," September 2012. World Trade Organization, Staff Working Paper ERSD-2012-12.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 2003, 71(6), 1695–1725.

Niu, Zhaohui, Chris Milner, Saileshsingh Gunessee, and Chang Liu, Are Nontariff Measures and Tariffs Substitutes? Some Panel Data Evidence, *Review of International Economics*, 2020, 28(2), 408-428.

Rauch, James E., "Networks Versus Markets in International Trade," *Journal of International Economics*, 1999, 48(1), 7–35.

Table 1. Basic Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln Value	21,285,150	4.035	2.398	0	17.735
ln (1+MFN)	21,285,150	0.073	0.087	0	3.434
ln (1+RTA)	21,285,150	0.055	0.088	0	3.434

Source: Authors' computation.

Table 2. Gravity Results

		(I)	(II)	(III)	(IV)
FE: *ijt, ijp, ipt*		X	X	X	
FE: *ijt, ijp, ipt, jpt*					X
(i) All					
	ln (1+MFN)	-0.518***		0.112**	
		[0.064]		[0.026]	
	ln (1+RTA)		-0.624***	-0.715***	-0.709***
			[0.072]	[0.074]	[0.124]
	Adj R-squared	0.7179	0.718	0.718	0.7214
	Number of obs.	21,285,150	21,285,150	21,285,150	21,285,150
(ii) RTA < MFN					
	ln (1+MFN)	-0.624***		0.084	
		[0.085]		[0.055]	
	ln (1+RTA)		-0.774***	-0.838***	-0.747***
			[0.087]	[0.080]	[0.126]
	Adj R-squared	0.7239	0.724	0.724	0.722
	Number of obs.	11,822,900	11,822,900	11,822,900	11,822,900

Notes: The dependent variable is a log of exports defined at country pair-product-year. This model is estimated by the OLS. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Standard error is clustered by country pair-product and year. "*ijt*," "*ijp*," "*ipt*," and "*jpt*" refer to country pair-year fixed effects, country pair-product fixed effects, exporter-product-year fixed effects, and importer-product-year fixed effects, respectively. In panel (ii), the study products are restricted only to those where RTA tariffs are lower than MFN tariffs (i.e., RTA-eligible products).

Table 3. Differentiated Products versus Nondifferentiated Products

		(I)	(II)	(III)	(IV)
FE: *ijt, ijp, ipt*		X	X	X	
FE: *ijt, ijp, ipt, jpt*					X
(i) Differentiated products					
	ln (1+MFN)	-0.498***		0.129**	
		[0.071]		[0.042]	
	ln (1+RTA)		-0.604***	-0.709***	-0.709***
			[0.080]	[0.084]	[0.116]
	Adj R-squared	0.7229	0.723	0.723	0.727
	Number of obs.	14,626,027	14,626,027	14,626,027	14,626,027
(ii) Non-differentiated products					
	ln (1+MFN)	-0.543***		0.086	
		[0.049]		[0.042]	
	ln (1+RTA)		-0.652***	-0.721***	-0.727***
			[0.058]	[0.074]	[0.148]
	Adj R-squared	0.7032	0.7032	0.7032	0.7028
	Number of obs.	6,647,403	6,647,403	6,647,403	6,647,403

Notes: In this table, the models are estimated for differentiated and nondifferentiated products separately. The classification of differentiated products is based on the "liberal" classification of products by Rauch (1999). The dependent variable is a log of exports defined at country pair-product-year. This model is estimated by the OLS. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Standard error is clustered by country pair-product and year. "*ijt*," "*ijp*," "*ipt*," and "*jpt*" refer to country pair-year fixed effects, country pair-product fixed effects, exporter-product-year fixed effects, and importer-product-year fixed effects, respectively.

Appendix A. Derivation of the Gravity Equation

A.1. Representative Household's Utility

The basic structure of the present model follows Chaney (2008). There are $P+1$ types of products. P is the number of differentiated products. Product $p=0$ is a homogeneous product, and others ($p=1\cdots P$) are differentiated. The utility function of the representative household in importing country j is given by

$$U_j = \left(q_{j0}\right)^{\mu_0} \prod_{p=1}^{P} \left(\int_{\omega\in\Omega_p} \left[q_{jp}(\omega)\right]^{\frac{\sigma_p-1}{\sigma_p}} d\omega \right)^{\frac{\sigma_p}{\sigma_p-1}\mu_p}, \sigma_p > 1,$$

where $q_{jp}(\omega)$ is the consumption of the product p produced by firm ω, σ_p is the elasticity of substitution among differentiated products, and μ_p is the utility weight on product p ($\mu_0 + \sum_{p=1}^{P} \mu_p = 1$).

A.2. Trade Costs and Production

Regarding the structure of trade costs, this study follows Demidova and Krishna (2008). Let φ be productivity of each firm, τ_{ijp} the (one plus) tariff rate between exporting country i to importing country j and w_i is the wage. The wage is identical across products given the labor mobility in each country. τ_{ijp} is equal to τ_{jp}^{M} (τ_{ijp}^{R}) when the exporter utilizes an MFN (RTA) tariff scheme. Marginal cost is given by

$$c_{ijp} = \frac{w_i \tau_{ijp}}{\varphi}.$$

When exporting under RTA schemes, exporters must comply with the rules of origin, for which they must change their procurement sources, which leads to a rise in procurement costs. Such procurement adjustment costs are captured by ρ_{ijp} as ad valorem cost for RTA utilization ($\rho_{ijp} > 1$). τ_{jp}^{M} and τ_{ijp}^{R} are the ad valorem MFN tariff ($\tau_{jp}^{M} > 1$) and RTA tariff ($\tau_{ijp}^{R} > 1$), respectively. We assume $\rho_{ijp}\tau_{ijp}^{R} < \tau_{jp}^{M}$ so that not all exports are always undertaken under the RTA scheme. Therefore, the free on board price of the differentiated product can be derived as

$$v_{ijp}(\varphi) = \frac{\sigma_p}{\sigma_p - 1} \frac{w_i \tau_{ijp}}{\varphi}.$$

We assume that productivity follows the Pareto distribution with the following cumulative distribution function:

$$G_p(\varphi) = 1 - \varphi^{-\gamma_p}.$$

γ_p is the shape parameter of the distribution and it is assumed that $\gamma_p > \sigma_p - 1$ to preclude the case where the trade value is dispersed. It is assumed that exporters must bear two types of fixed costs depending on the choice of tariff schemes. One is the usual fixed costs for exporting (f_{ip}) in the labor unit. Exporters must bear this fixed cost regardless of the choice of tariff schemes. The other is the fixed cost for RTA use (f_{ip}^{R}). This cost includes documentation preparation to obtain the certificates of origin, and only exporters who use an RTA tariff scheme must bear this cost.[13]

A.3. Demand for Differentiated Products

Following Chaney (2008), it is assumed that the number of firms in each country n is positively associated with national labor income ($w_n L_n$) to obtain a tractable gravity framework. Moreover, it is assumed that each worker has w_n shares of the global fund. This global fund gathers all the profits of firms in the world (π) and distributes it to workers. Therefore, the total income of workers in country j (Y_j) is given by the sum of labor income ($w_j L_j$) and dividend ($w_j L_j \pi$). Therefore,

$$Y_j = w_j L_j + w_j L_j \pi.$$

Given the demand function derived by the representative household's cost minimization, the value of export by an exporter with productivity φ, which produces the product p of country i, is written as

$$x_{ijp}(\varphi) = v_{ijp}(\varphi) q_{ijp}(\varphi) = \mu_p Y_j \left[\frac{v_{ijp}(\varphi)}{V_{jp}}\right]^{1-\sigma_p}. \tag{A1}$$

Assuming $\mathcal{M}_{ijp}(\mathcal{R}_{ijp})$ is the set of producers who export under an MFN (RTA) scheme, V_{jp} and π are, respectively, given by

$$V_{jp} = \left(\sum_{k=1}^{N} w_k L_k \left[\int_{\mathcal{M}_{kjp}} \left(\frac{\sigma_p}{\sigma_p - 1} \frac{w_k \tau_{jp}^{M}}{\varphi}\right)^{1-\sigma_p} dG_p(\varphi) \right.\right.$$
$$\left.\left. + \int_{\mathcal{R}_{kjp}} \left(\frac{\sigma_p}{\sigma_p - 1} \frac{w_k \rho_{kjp} \tau_{kjp}^{R}}{\varphi}\right)^{1-\sigma_p} dG_p(\varphi)\right]\right)^{\frac{1}{1-\sigma_p}},$$

$$\pi = \frac{\sum_{p=1}^{H} \sum_{k=1}^{N} \sum_{l=1}^{N} w_k L_k \left[\int_{\mathcal{M}_{kjp}} \pi_{klp}^{M}(\varphi) dG_p(\varphi) + \int_{\mathcal{R}_{kjp}} \pi_{klp}^{R}(\varphi) dG_p(\varphi)\right]}{\sum_{n=1}^{N} w_n L_n},$$

where

$$\pi_{ijp}(\varphi) = \left[v_{ijp}(\varphi) - c_{ijp}(\varphi)\right] q_{ijp}(\varphi) - f_{ip}.$$

[13] Following Helpman et al. (2004) and Helpman et al. (2008), it is assumed that exporters pay fixed costs for exports to each destination without considering the case where exporters deal with export processes for multiple destinations at the same time, thus saving on the total fixed cost. That is, economies of scale are not considered for f_{ip}. Further, in terms of the fixed cost for RTA usage, a similar situation is assumed, that is, exporters pay the fixed cost for RTA usage for each transaction. Given that the model is static, mitigation of these fixed costs through exporters' experiences is not considered. Investigating these possibilities would provide additional theoretical material, but no such cases are examined to keep the model tractable and help obtain an explicit gravity equation.

The upper-right subscripts M and R represent MFN and RTA schemes, respectively.

A.4. Homogeneous and Heterogeneous Regimes

Export profits under MFN and RTA schemes are, respectively, given by

$$\pi_{ijp}^{M}(\varphi) = \frac{\mu_p}{\sigma_p} Y_j \left(\frac{\sigma_p}{\sigma_p - 1} \frac{w_i \tau_{jp}^{M}}{\varphi} \frac{1}{V_{jp}}\right)^{1-\sigma_p} - f_{ip} \text{ and}$$

$$\pi_{ijp}^{R}(\varphi) = \frac{\mu_p}{\sigma_p} Y_j \left(\frac{\sigma_p}{\sigma_p - 1} \frac{w_i \rho_{ijp} \tau_{ijp}^{R}}{\varphi} \frac{1}{V_{jp}}\right)^{1-\sigma_p} - f_{ip} - f_{ip}^{R}.$$

Therefore, export profits under respective schemes become positive when $\varphi > \overline{\varphi}_{ijp}^{M}$ and $\varphi > \overline{\varphi}_{ijp}^{R}$, where

$$\overline{\varphi}_{ijp}^{M} = \lambda_{1p} \left(\frac{f_{ip}}{Y_j}\right)^{\frac{1}{\sigma_p - 1}} \frac{w_i \tau_{jp}^{M}}{V_{jp}},$$

$$\overline{\varphi}_{ijp}^{R} = \lambda_{1p} \left(\frac{f_{ip} + f_{ip}^{R}}{Y_j}\right)^{\frac{1}{\sigma_p - 1}} \frac{w_i \rho_{ijp} \tau_{ijp}^{R}}{V_{jp}},$$

and

$$\lambda_{1p} = \left(\frac{\sigma_p}{\mu_p}\right)^{\frac{1}{\sigma_p - 1}} \frac{\sigma_p}{\sigma_p - 1}.$$

Further, the profit under an RTA scheme becomes larger than that under an MFN scheme when $\varphi > \overline{\varphi}_{ijp}^{R>M}$, where

$$\overline{\varphi}_{ijp}^{R>M} = \lambda_{1p} \frac{w_i}{V_{jp}} \left[\frac{1}{Y_j} \frac{f_{ip}^{R}}{\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p - 1} - \left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p - 1}}\right]^{\frac{1}{\sigma_p - 1}}.$$

It is assumed that fixed trade costs (f_{ip} and f_{ip}^{R}) are high enough so that these thresholds are higher than the lower-bound productivity ($\overline{\varphi}_{ijp}^{M}$, $\overline{\varphi}_{ijp}^{R}$, $\overline{\varphi}_{ijp}^{R>M} > 1$). As shown in figures A1 and A2, some exporters use an MFN scheme and others use an RTA scheme when the following condition holds:

$$\overline{\varphi}_{ijp}^{M} < \overline{\varphi}_{ijp}^{R} \Rightarrow \frac{f_{ip}}{f_{ip} + f_{ip}^{R}} < \left(\frac{\rho_{ijp} \tau_{ijp}^{R}}{\tau_{jp}^{M}} \right)^{\sigma_p - 1}. \tag{A2}$$

This corresponds to equation (2). In other words, some exporters do not use an RTA scheme when the fixed cost for RTA use (f_{ip}^{R}) is large, RTA tariff rate (τ_{ijp}^{R}) is not low enough, or the elasticity of substitution (σ_p) is low. This case is called the heterogeneous regime following Demidova and Krishna (2008). If condition (A2) does not hold, all the exporters use an RTA scheme. This case is called the homogeneous regime.

=== Figures A1 and A2 ===

A.5. Multilateral Resistance Variable

Combining equations and rearranging, the price index can be solved as

$$V_{jp} = \lambda_{2p} Y_j^{\frac{1}{\gamma_p} - \frac{1}{\sigma_p - 1}} \theta_{jp}, \tag{A3}$$

where

$$\lambda_{2p} = \left[\frac{\gamma_p - (\sigma_p - 1)}{\gamma_p} \left(\frac{\sigma_p}{\mu_p} \right)^{\frac{\gamma_p}{\sigma_p - 1} - 1} \left(\frac{\sigma_p}{\sigma_p - 1} \right)^{\gamma_p} \frac{1 + \pi}{Y} \right]^{\frac{1}{\gamma_p}} \text{ and}$$

$$\theta_{jp} = \left[\sum_{k=1}^{N} \frac{Y_k}{Y} w_k^{-\gamma_p} \left\{ \left(\tau_{jp}^{M} \right)^{-\gamma_h} \left(f_{kp} \right)^{1 - \frac{\gamma_p}{\sigma_p - 1}} - \left[\frac{1}{\left(\frac{1}{\rho_{kjp} \tau_{kjp}^{R}} \right)^{\sigma_p - 1} - \left(\frac{1}{\tau_{jp}^{M}} \right)^{\sigma_p - 1}} \right]^{-\frac{\gamma_p}{\sigma_p - 1}} \left(f_{kp}^{R} \right)^{1 - \frac{\gamma_p}{\sigma_p - 1}} \right\} \right]^{-\frac{1}{\gamma_p}}. \tag{A4}$$

The heterogeneous regime reveals the role of both MFN and RTA tariff rates. In the case of the homogeneous regime, the MFN rate does not affect the bilateral exports. θ_{jp} is called the multilateral resistance variable (MRV) in Chaney (2008).

A.6. Export Value

Using (A3), the export value (A1) can be rewritten as

$$x_{ijp}(\varphi)=\begin{cases}\lambda_{3p}\left(\frac{Y_j}{Y}\right)^{\frac{\sigma_p-1}{\gamma_p}}\left(\frac{\theta_{jp}}{w_i\rho_{ijp}\tau_{ijp}^R}\right)^{\sigma_p-1}\varphi^{\sigma_p-1} & \text{if } \varphi>\overline{\varphi}_{ijp}^{R>M}\\ \lambda_{3p}\left(\frac{Y_j}{Y}\right)^{\frac{\sigma_p-1}{\gamma_p}}\left(\frac{\theta_{jp}}{w_i\tau_{jp}^M}\right)^{\sigma_p-1}\varphi^{\sigma_p-1} & \text{if } \overline{\varphi}_{ijp}^{R>M}>\varphi>\overline{\varphi}_{ijp}^{M}\\ 0 & \text{otherwise}\end{cases} \tag{A5}$$

where

$$\lambda_{3p}=\mu_p\left[\frac{\lambda_{2p}(\sigma_p-1)}{\sigma_p}\right]^{\sigma_p-1}Y^{\frac{\sigma_p-1}{\gamma_p}}=\sigma_p\lambda_{4p}^{1-\sigma}\quad\text{and}$$

$$\lambda_{4p}=\left[\frac{\gamma_p}{\gamma_p-(\sigma_p-1)}\frac{\sigma_p}{\mu_p}\frac{1}{1+\pi}\right]^{\frac{1}{\gamma_p}}.$$

Using these equations, threshold productivity values are obtained as follows:

$$\overline{\varphi}_{ijp}^{M}=\lambda_{4p}\left(\frac{Y}{Y_j}\right)^{\frac{1}{\gamma_p}}\frac{w_i\tau_{jp}^M}{\theta_{jp}}\left(f_{ip}\right)^{\frac{1}{\sigma_p-1}},$$

$$\overline{\varphi}_{ijp}^{R}=\lambda_{4p}\left(\frac{Y}{Y_j}\right)^{\frac{1}{\gamma_p}}\frac{w_i\rho_{ijp}\tau_{ijp}^R}{\theta_{jp}}\left(f_{ip}+f_{ip}^R\right)^{\frac{1}{\sigma_p-1}},\ \text{and}$$

$$\overline{\varphi}_{ijp}^{R>M}=\lambda_{4p}\left(\frac{Y}{Y_j}\right)^{\frac{1}{\gamma_p}}\frac{w_i}{\theta_{jp}}\left[\frac{1}{\left(\frac{1}{\rho_{ijp}\tau_{ijp}^R}\right)^{\sigma_p-1}-\left(\frac{1}{\tau_{jp}^M}\right)^{\sigma_p-1}}\right]^{\frac{1}{\sigma_p-1}}\left(f_{ip}^R\right)^{\frac{1}{\sigma_p-1}}.$$

Then, using (A5), the gravity equation explaining product-level bilateral exports is derived as

$$\begin{aligned}X_{ijp}&=w_iL_i\left[\int_{\overline{\varphi}_{ijp}^{R>M}}^{\infty}x_{ijp}(\varphi)dG_p(\varphi)+\int_{\overline{\varphi}_{ijp}^{M}}^{\overline{\varphi}_{ijp}^{R>M}}x_{ijp}(\varphi)dG_p(\varphi)\right]\\&=\mu_p\frac{Y_iY_j}{Y}\left(\frac{w_i}{\theta_{jp}}\right)^{-\gamma_p}T_{ijp},\end{aligned}$$

with the trade cost component

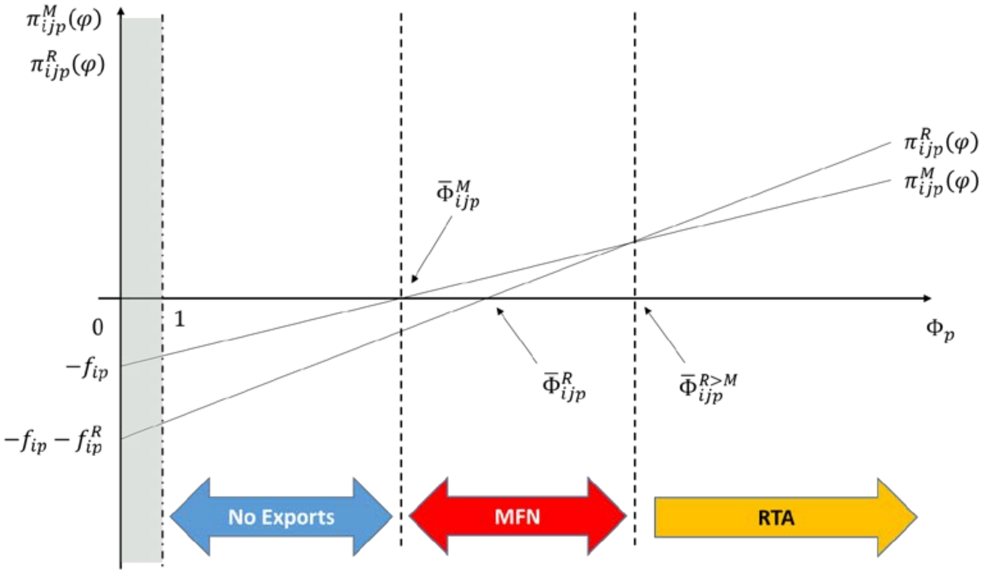
$$T_{ijp}=\left(\tau_{jp}^M\right)^{-\gamma_p}\left(f_{ip}\right)^{1-\frac{\gamma_p}{\sigma_p-1}}+\left[\left(\frac{1}{\rho_{ijp}\tau_{ijp}^R}\right)^{\sigma_p-1}-\left(\frac{1}{\tau_{jp}^M}\right)^{\sigma_p-1}\right]^{\frac{\gamma_p}{\sigma_p-1}}\left(f_{ip}^R\right)^{1-\frac{\gamma_p}{\sigma_p-1}}.$$

These equations correspond to equations (1) and (2), respectively. The global total profit and the global GDP are derived as follows:

$$\pi=\frac{A}{1-A}\quad\text{where}\quad A=\sum_{p=1}^{P}\frac{\sigma_p-1}{\gamma_p}\frac{\mu_p}{\sigma_p}\quad\text{and}$$

$$Y=\sum_{i=1}^{N}\sum_{j=1}^{N}\frac{Y_iY_j}{Y}\left(\frac{w_i}{\theta_{jp}}\right)^{-\gamma_p}T_{ijp}\left(T_{ip}\right)^{1-\frac{\gamma_p}{\sigma_p-1}}.$$

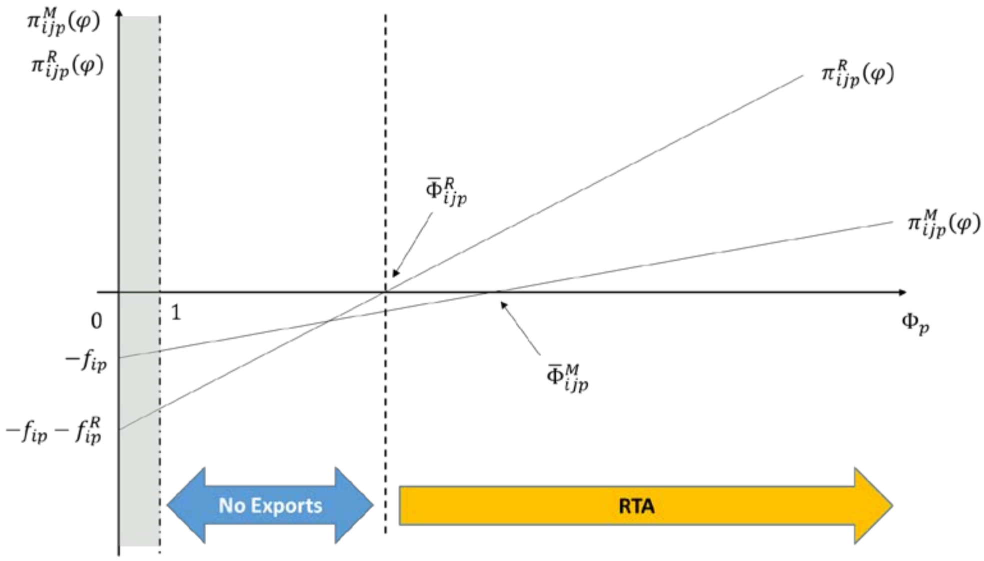
Figure A1. Productivity and the Choice of Tariff Schemes in the Heterogeneous Regime



Source: Authors' compilation.

Note: In the figure, we define Φ_p as $\Phi_p \equiv \varphi^{\sigma_p - 1}$.

Figure A2. Productivity and the Choice of Tariff Schemes in the Homogeneous Regime



Source: Authors' compilation.

Note: In the figure, we define Φ_p as $\Phi_p \equiv \varphi^{\sigma_p - 1}$.

Appendix B. Elasticities

To obtain partial derivatives, following Chaney (2008), it is assumed that the MRV is not affected by bilateral trade costs: $\partial\theta_{jp}/\partial\tau_{jp}^{M} = \partial\theta_{jp}/\partial\tau_{ijp}^{R} = \partial\theta_{jp}/\partial\rho_{ijp} = \partial\theta_{jp}/\partial f_{ip} = \partial\theta_{jp}/\partial f_{ip}^{R} = 0$. This assumption is accepted when the exporter's country is small enough to be compared to the rest of the world. Therefore, based on equations (1) and (2), the following elasticities are obtained:

$$\frac{\partial X_{ijp}}{\partial \tau_{jp}^{M}}\frac{\tau_{jp}^{M}}{X_{ijp}} = \frac{1}{T_{ijp}}\left\{-\gamma_p\left(\tau_{jp}^{M}\right)^{-\gamma_p}\left(f_{ip}\right)^{1-\frac{\gamma_p}{\sigma_p-1}} + \frac{\gamma_p}{\sigma_p-1}\left[\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1} - \left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p-1}\right]^{\frac{\gamma_p}{\sigma_p-1}-1}(\sigma_p - 1)\left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p-1}\left(f_{ip}^{R}\right)^{1-\frac{\gamma_p}{\sigma_p-1}}\right\},$$

$$\frac{\partial X_{ijp}}{\partial \tau_{ijp}^{R}}\frac{\tau_{ijp}^{R}}{X_{ijp}} = -\frac{1}{T_{ijp}}\frac{\gamma_p}{\sigma_p-1}\left[\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1} - \left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p-1}\right]^{\frac{\gamma_p}{\sigma_p-1}-1}(\sigma_p - 1)\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1}\left(f_{ip}^{R}\right)^{1-\frac{\gamma_p}{\sigma_p-1}} < 0$$

$$\frac{\partial X_{ijp}}{\partial \rho_{ijp}}\frac{\rho_{ijp}}{X_{ijp}} = -\frac{1}{T_{ijp}}\frac{\gamma_p}{\sigma_p-1}\left[\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1} - \left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p-1}\right]^{\frac{\gamma_p}{\sigma_p-1}-1}(\sigma_p - 1)\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1}\left(f_{ip}^{R}\right)^{1-\frac{\gamma_p}{\sigma_p-1}} < 0$$

$$\frac{\partial X_{ijp}}{\partial f_{ip}}\frac{f_{ip}}{X_{ijp}} = -\frac{1}{T_{ijp}}\left(\frac{\gamma_p}{\sigma_p-1} - 1\right)\left(\tau_{jp}^{M}\right)^{-\gamma_p}\left(f_{ip}\right)^{1-\frac{\gamma_p}{\sigma_p-1}} < 0$$

$$\frac{\partial X_{ijp}}{\partial f_{ip}^{R}}\frac{f_{ip}^{R}}{X_{ijp}} = -\frac{1}{T_{ijp}}\left(\frac{\gamma_p}{\sigma_p-1} - 1\right)\left[\left(\frac{1}{\rho_{ijp}\tau_{ijp}^{R}}\right)^{\sigma_p-1} - \left(\frac{1}{\tau_{jp}^{M}}\right)^{\sigma_p-1}\right]^{\frac{\gamma_p}{\sigma_p-1}}\left(f_{ip}^{R}\right)^{1-\frac{\gamma_p}{\sigma_p-1}} < 0$$

These elasticities indicate that RTA tariff rates (τ_{ijp}^{R}), the procurement adjustment cost (ρ_{ijp}), and fixed costs for exporting (f_{ip}) and RTA usage (f_{ip}^{R}) have negative effects on exports while the sign of the effect of MFN tariff rates (τ_{jp}^{M}) is not determined.