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Tariff Elasticity in Korea's Imports: A Structural Gravity Approach Using Micro-Level Data*

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This paper estimates Korea's tariff elasticity using 2014 transaction-level customs data covering about 7.5 million import records from 230 exporters and 10,557 HS10 products. Using the structural gravity framework of Fontagné et al. (2022), we employ PPML with alternative fixed-effect structures to address endogeneity. Tariff elasticities range from 5 to 10 in absolute value when exporter—product fixed effects are excluded, but fall sharply once these fixed effects are included, largely because limited within-year identifying variation constrains estimation rather than indicating that tariff effects are economically small. Elasticities differ across products: consumer goods are highly elastic, homogeneous goods such as minerals display very large elasticities, and several HS sections show no significant estimates. These results highlight substantial heterogeneity across products and the risks of relying on a single aggregate elasticity. We also show that non-tariff trade costs matter: freight and insurance charges vary more than tariffs and remain strongly elastic under extensive fixed effects. Tariff and transport-cost elasticities are statistically similar when exporter—product fixed effects are excluded but diverge once detailed controls are added. Robustness checks using log-linear OLS and bias-corrected PPML support the qualitative patterns.

Keywords: Tariff Elasticity, Trade Elasticity, Gravity Equation, PPML, Product-level Data

JEL Classification: F10, F12, F15

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I. Introduction

International trade is one of the most important factors shaping economic relations and growth. Among trade policy tools, tariffs remain the most practical instrument for protecting domestic industries and raising government revenue. Changes in tariff policy directly influence cross-border transactions and can generate broad economic effects. Since taking office in 2025, the Trump administration's second term has pursued sweeping tariff hikes—through universal and reciprocal tariffs—on both allies and non-allies. While such measures may shelter specific industries, they also risk disrupting trade and investment flows and creating uncertainty for the U.S. and global economies. Concerns center on potential inflation from tariff pass-through to U.S. consumers and the burden on U.S. multinationals operating abroad. Whether these policies will ultimately harm the U.S. economy and spill over globally remains a key question, underscoring the need to understand and predict the economic effects of tariff actions.

The tariff elasticity of trade, defined as the responsiveness of trade flows to tariff changes, is essential for evaluating such effects. High elasticity implies that tariff changes cause large shifts in imports or exports, whereas low elasticity indicates limited responsiveness. Research on tariff elasticity provides several important insights. It helps assess the impact of tariff changes on domestic industries, consumer prices, and the overall economy (Amiti et al., 2019); it informs optimal tariff design (Broda and Weinstein, 2006); it aids strategic trade negotiations by revealing sensitivity to foreign tariff adjustments (Fajgelbaum et al., 2020); and it serves as a core parameter in simulation models such as computable general equilibrium (CGE) and counterfactual analyses (Green and Scheinkman, 1979); Finally, most international trade models require two key values to measure welfare changes from trade: the change in import penetration and the trade elasticity. While import penetration is relatively easy to observe, trade elasticity must be statistically estimated based on a model (Arkolakis et al., 2012). Estimating trade elasticity using trade costs other than tariffs—such as prices or transportation costs—can lead to issues including simultaneity bias and measurement error. Therefore, using tariffs to estimate trade elasticity is essential for overcoming these problems (Fontagné et al., 2022).

A number of studies provide tariff elasticity estimates using detailed micro-data with granular tariff information (e.g. Broda and Weinstein, 2006; Caliendo and

Parro, 2015; Kee et al., 2009; Imbs and Mejean, 2015; Ossa, 2015; Simonovska and Waugh, 2014; Soderbery, 2018; de Bromhead et al., 2019). However, similar research in Korea remains limited due to data constraints and lack of awareness of its importance. This paper aims to fill this gap by comparing key estimation methodologies and applying them to transaction-level customs data—about 7.5 million import records from 230 exporting countries covering 10,557 HS-10 products.

The contributions of this study are threefold. First, it offers the first detailed product-level tariff elasticity estimates for all products using Korean data, providing a foundational dataset for future research. Second, by using customs data that include actual duties and freight-insurance costs for every transaction, our analysis enables comprehensive comparisons across aggregation levels, tariff-versus transport - cost-based estimates, and alternative methodologies. Third, by directly controlling for country-product-time freight and insurance costs, the paper reduces endogeneity concerns and empirically tests the theoretical prediction that tariff and transport-cost elasticities are identical—an outcome supported in part by the analysis.

Policy-wise, the tariff elasticity estimates can inform optimal tariff calculations, free trade agreement (FTA) evaluations, tariff-revenue projections, and welfare assessments. They also support calibration of simulation models such as CGE, and by providing Korea-product-specific parameters, they enhance the realism of domestic trade-policy analysis. Ultimately, this paper aims to establish a benchmark for future research and offer guidance for Korea's trade-policy direction.

The structure of this paper is as follows: Section II presents the theoretical background of this study by introducing the model of Fontagné et al. (2022) and discussing how it can be applied to the empirical analysis. Sections III and IV presents the econometric specifications and estimation results, respectively. Section V concludes offering implications for future research and Korean trade policy based on the main findings.

II. Theoretical Foundation and Implications

1. Theoretical Framework

In this section, we present the theoretical framework introduced by Fontagné et al. (2022), which provides the basis for the structural gravity equation used in our empirical analysis of tariff elasticity. Their model is grounded in the Armington

(1969) framework and has a key advantage: the estimable empirical equation is derived entirely from the importer's utility-based demand function, without relying on an exporter supply equation based on profit maximization. We first outline the core elements of the Fontagné et al. (2022) model and then derive the structural gravity equation used in our analysis.

To derive the import demand function, consider the following Constant Elasticity of Substitution (CES) utility function and budget constraint:

$$U_{jkt} = \left(\sum_i \left(\frac{q_{ijkt}}{\alpha_{ikt}}\right)^{\rho_k}\right)^{1/\rho_k} \qquad s.t. \quad \sum_i p_{ijkt} q_{ijkt} = E_{jkt} \tag{1}$$

In Equation (1), subscripts *i* and *j* denote the exporting and importing countries, respectively; *k* denotes the product; and *t* refers to time. q_{ijkt} represents country *j*'s demand for product *k* produced in country *i* at time *t*, and p_{ijkt} is its corresponding price. α_{ikt} is a demand shifter capturing product characteristics specific to country *i*'s variety of product *k* at time *t*. E_{jkt} represents country *j*'s total expenditure on product *k* at time *t*. Under the Armington (1969), $\sigma_k > 1$ be the elasticity of substitution across varieties, with defined such that $\rho_k = (\sigma_k - 1)/\sigma_k$. A lower σ_k reflects greater product differentiation and more limited substitutability; a higher σ_k implies more homogeneous products and easier substitution.

Maximizing utility subject to the budget constraint yields the following import demand function:

$$q_{ijkt} = p_{ijkt}^{-\sigma_k} \alpha_{ikt}^{1-\sigma_k} P_{jkt}^{\sigma_k - 1} E_{jkt} \tag{2}$$

where $P_{jkt} = \left(\sum_i \left(\alpha_{ikt} p_{ijkt}\right)^{1-\sigma_k}\right)^{1/(1-\sigma_k)}$, which denotes the consumer price index (average price) for product *k* in country *j* at time *t*. Using Equation (2), total import expenditure can be expressed as:

$$p_{ijkt} q_{ijkt} = \left(\alpha_{ikt} p_{ijkt}\right)^{1-\sigma_k} P_{jkt}^{\sigma_k - 1} E_{jkt} \tag{3}$$

In Equation (3), p_{ijkt} is the duty-inclusive final price at which country *i*'s product *k* is sold in country *j* at time *t*. This price incorporates freight, insurance, other trade costs, and tariffs. Directly estimating Equation (3) requires detailed information on—the unit price in the destination market.

Fontagné et al. (2022) highlight the practical difficulty of obtaining accurate unit prices due to limited data on physical quantities, freight and insurance costs, and tariff-inclusive charges. Using proxies entails a significant risk of measurement error. They therefore propose using the Free on Board (FOB) price, denoted p_{ikt}, rather than the final consumer price. Adding freight and insurance to the FOB price yields the Cost Insurance and Freight (CIF) price, and applying tariffs to the CIF price gives the final price, p_{ijkt}. Assuming full pass-through of all variable trade costs,[1] the relationship between FOB and final prices can be expressed as:

$$p_{ijkt} = p_{ikt}\left(1+\tau_{ijkt}\right)\left(1+\delta_{ijkt}\right) \tag{4}$$

where δ_{ijkt} is the ad valorem freight-insurance rate applied to the FOB price, and τ_{ijkt} represents the ad valorem tariff rate imposed by country *j* on product *k* produced in country *i* at time *t*. Accordingly, $p_{ikt}\left(1+\delta_{ijkt}\right)$ represents the CIF price, and the tariff rate is applied to this CIF price. Consequently, substituting Equation (4) into Equation (3) yields the following expression for total import expenditure in terms of FOB prices:

$$p_{ikt}q_{ijkt} = \left(\alpha_{ikt}p_{ikt}\right)^{1-\sigma_k}\left[\left(1+\tau_{ijkt}\right)\left(1+\delta_{ijkt}\right)\right]^{-\sigma_k}P_{jkt}^{\sigma_k-1}E_{jkt} \tag{5}$$

When estimating a structural gravity model, α_{ikt} and p_{ikt} can be absorbed using exporter-product-time fixed effects, and P_{jkt} and E_{jkt} can be captured using importer-product-time fixed effects. Thus, as long as FOB-based bilateral import data are available, empirical estimation does not require information on product characteristics, FOB unit prices, average destination-market prices, or total expenditure. All essential explanatory variables reduce to the characteristics of

[1] This implies that all variable trade costs are fully passed on to the final consumer. Empirically, Cavallo et al. (2021) show that U.S. tariffs on Chinese goods were passed through to import prices at a rate of about 95 percent, meaning that the tax burden was ultimately borne by the United States as the importing country. However, Soderbery (2018) provides evidence that higher levels of product differentiation in the importing country are associated with lower tariff pass-through to final consumer prices.

product k traded between countries i and j at time t, namely the tariff rate (τ_{ijkt}) and the freight-insurance rate (δ_{ijkt}).

2. Application to the Empirical Analysis

From Equation (5), we can derive several features that are relevant for the empirical analysis. First, the tariff elasticity of total imports is given by $-\sigma_k$. Because the coefficient is negative, higher tariffs reduce total import expenditure. Second, a larger absolute value of σ_k implies a stronger response of imports to a one-unit increase in tariffs. In other words, when products are more homogeneous and substitution is easier (higher σ_k), tariff elasticity increases; when products are highly differentiated and substitution is difficult (lower σ_k), tariff elasticity decreases. Thus, in the model of Fontagné et al. (2022), the degree of product differentiation is a key determinant of the magnitude of tariff elasticity.

In practice, Head and Mayer (2014) compare 435 estimates derived from gravity models with fixed effects and report substantial heterogeneity, with an average absolute elasticity of 6.74 and a standard deviation of 9.3. Bajzik et al. (2020) conduct a meta-analysis using 3,524 elasticity estimates from 42 studies and find that the average absolute value of tariff elasticity ranges from 2.5 to 5.1, with a median of 3.8. Accordingly, they conclude that tariff elasticity estimates vary widely depending on the degree of product differentiation. The extent of product differentiation itself varies with data characteristics, country- and product-specific features, and estimation methods. For example, Fontagné et al. (2022) empirically show that standardized products such as minerals exhibit a high elasticity of 19, whereas highly differentiated products such as footwear show a much lower elasticity of 3.6. Similar patterns are also confirmed in Broda and Weinstein (2006), Kee et al. (2009), and de Bromhead et al. (2019).

Against this background, this paper aims not only to estimate the Korea's average import tariff elasticity but also to examine whether tariff elasticity estimates exhibit heterogeneity across products. Specifically, this paper classifies all products into consumer goods, intermediate goods, and capital goods, and further categorizes them into 20 sections at the HS 2-digit level to compare and analyze the tariff elasticity for each group. This type of comparative analysis based on product classification is, to the best of our knowledge, the first of its kind and represents a distinctive contribution of this paper.

Finally, we note from Equation (5) that the elasticity with respect to freight and insurance costs also equals $-\sigma_k$, the same as the tariff elasticity. Therefore, the freight-insurance rate is included as a key explanatory variable in the structural gravity equation proposed by Fontagné et al. (2022). However, due to data limitations in their empirical analysis, they use geographic distance between countries as a proxy for the actual freight-insurance rate and conduct various additional analyses to mitigate the resulting endogeneity concerns. By using the Korean customs data that include actual freight and insurance charges for all trade transactions, this paper minimizes measurement error for these variables and employs freight-insurance rates observable at the exporter-product-time level. This allows us to conduct an empirical analysis that more faithfully reflects the structural gravity equation. Based on the theory, we can also empirically examine whether tariff elasticity and freight-insurance elasticity are indeed identical. These features represent a significant advantage of this paper over existing studies.

III. Econometric Specifications

1. Estimation Equation

For estimation, we use the PPML estimator of Santos Silva and Tenreyro (2006), who show that log-linear gravity models can suffer from bias due to Jensen’s inequality and heteroskedasticity. PPML has since become standard in gravity-model applications (e.g. Baier et al., 2018; Egger et al., 2022; Cheong, 2023). Although PPML can naturally handle zero trade flows, our highly disaggregated data contain too many zeros, and most of all, tariff information is available only when trade occurs. As a result, the tariff variable—and thus our analysis—is restricted to positive-trade observations, meaning the PPML estimates address heteroskedasticity-related bias only.[2] Based on Equation (5) derived from Fontagné

[2] Excluding zero trade flows may introduce selection bias if the extensive margin (i.e., the decision to trade) is systematically related to tariff levels. However, several features of our setting mitigate this concern. Our specification includes highly disaggregated exporter—product fixed effects, so identification is driven by within-pair variation over time and relies on tariff changes for already active trade relationships, thereby limiting selection through entry and exit at the extensive margin. In addition, trade relationships in many product categories are relatively persistent, and zero flows are comparatively infrequent, further reducing the quantitative importance of selection. Nonetheless, if

et al. (2022), we estimate the model using the Poisson-pseudo maximum likelihood (PPML) method as follows:

$$IMPORTS_{ikt} = \exp(\beta_0 + \beta_1\, ln(1 + Tariff_{ikt}) + \beta_2\, ln(1 + TPCR_{ikt}) \\ + Z_i\beta_3 + \varpi_{it} + \eta_{ik} + \mu_{kt}\,) \times \epsilon_{ikt} \tag{6}$$

In Equation (6), the variable $IMPORTS_{ikt}$ corresponds to the variable $p_{ikt}q_{ijkt}$ in Equation (5) and represents the total value of Korea's imports of product *k* from exporting country *i* in period *t*. Following Fontagné et al. (2022), this is measured using the FOB-based import value—that is, the value before tariffs and transport costs are added.

The variable $Tariff_{ikt}$ corresponds to τ_{ijkt} in Equation (5) and denotes the average import tariff that Korea imposes on product *k* from exporting country *i* in the same period. The raw data used in this study include actual transaction-level tariff information at the HS 10-digit level. Based on this, we construct average tariff measures at the HS 6-digit levels, aggregated quarterly for the benchmark analysis. Assuming that tariffs are imposed as ad valorem duties on the CIF price and are fully passed through to consumer prices, the explanatory variable is expressed in log-change form to estimate the trade elasticity—that is, the change in imports resulting from tariff-induced price changes. Recent studies such as Amiti et al. (2019) and Fajgelbaum et al. (2020) provide empirical evidence that, at least in the short run, U.S. tariffs on Chinese exports were fully passed through to U.S. consumer prices. Moreover, even if pass-through is incomplete for certain products, exporter-specific deviations from full pass-through are absorbed by the exporter-product fixed effects included in Equation (6).

The variable $TPCR_{ikt}$ corresponds to δ_{ijkt} in Equation (5) and represents the freight-and-insurance rate, calculated as the ratio of freight and insurance costs to the import value for shipments from country *i* to Korea. Since these data are observed at the transaction level, we aggregate them using import-value weights by period and product to construct suitable measures for analysis. The vector Z_i

higher tariffs disproportionately eliminate marginal trade relationships, omitting zero flows may attenuate the estimated tariff elasticity; accordingly, our estimates should be interpreted as reflecting the intensive-margin response and may represent a lower bound of the overall tariff elasticity.

contains standard control variables commonly included in gravity equations, such as the exporter's GDP, per-capita GDP, geographic distance from Korea, and WTO membership.[3]

To address endogeneity and unobserved heterogeneity in the model, this study incorporates several fixed effects. First, the exporter-time fixed effects (ϖ_{it}) control for global shocks, time-varying shocks specific to Korea as the importing country, macroeconomic conditions in the exporting country (such as GDP and per-capita GDP), bilateral unobserved characteristics between Korea and each trading partner, and worldwide aggregate shocks. Second, the exporter-product fixed effects (η_{ik}) remove all exporter-product-specific unobserved heterogeneity that remains constant over the sample period, thereby isolating the effects of tariffs and freight-insurance rates from other confounding factors. Third, the product-time fixed effects (μ_{kt}) control for the multilateral trade resistance term (MRTs) for each product in Korea at time t, as implied by Anderson and van Wincoop (2003), as well as Korea's total expenditure on product k at time t, both of which appear on the right-hand side of Equation (5).

However, because this study is restricted to a single importing country, Korea, it is not possible to fully control for all trade-resistance variables on the right-hand side of Equation (5) solely through fixed effects. While the product-time fixed effects effectively control for the MRTs and Korea's total expenditure on each product at time t, variables that vary at the exporter-product-time level, such as bilateral trade costs and other time-varying bilateral characteristics, share the same dimensionality as the dependent variable and therefore cannot be fully absorbed by fixed effects alone. Even so, by including exporter-time, exporter-product, and product-time fixed effects simultaneously, the analysis minimizes potential unobserved biases arising from these factors to the greatest extent possible. Finally, ϵ_{ikt} denotes the idiosyncratic error term.

It is worth noting that, as Fontagné et al. (2022) point out, the coefficients on tariffs and on freight-insurance rates—β_1 and β_2—should theoretically yield identical

[3] In gravity-model estimations, it is common to include a wide range of control variables, such as FTA indicators and measures of cultural or religious proximity. However, because this study uses for a single year (2014), all variables that vary only at the exporter level in year 2014 are absorbed by the exporter fixed effects. As a result, the estimated tariff elasticities with exporter fixed effects, remain unchanged regardless of whether such controls are included.

unbiased estimates. In practice, however, imperfections in the theoretical and econometric models and measurement errors can cause the two coefficients to differ. Moreover, unequal pass-through rates for tariffs and freight-insurance costs are plausible, and such differences naturally arise when the structure of freight and insurance markets differs from that of product markets.

2. Data

For the empirical analysis, we use 2014 customs data from the Korea Customs Service, which contains about 7.5 million transaction-level records with the HS 10-digit codes and daily time stamps. Although multi-year data would be ideal for this study, we have access only to the 2014 dataset, thus the empirical analysis relies unavoidably on a single year of data. In 2014, Korea imported goods from about 230 exporting countries, covering 10,557 HS-10 products. China accounts for the largest share with about 2.87 million transactions (38%), followed by the United States with about 750,000 transactions (10%).

After restricting the sample to 181 countries with available GDP data and excluding observations reporting zero freight or insurance, the final dataset contains 4,796,705 transaction-level observations.

To estimate tariff elasticities using Equation (6), transaction-level data must be aggregated to the appropriate analysis level. We use the HS 6-digit level data as our benchmark, as this level represents the most disaggregated global standard commonly used in empirical analysis, allowing for comparability with existing studies while still enabling micro-level analysis.

For estimation at the HS 6-digit level, HS 10-digit product information is first aggregated to HS 6-digit. The dependent variable, total import value, is obtained by summing HS 10-digit import values within each HS 6-digit category for the same import date and exporting country. For explanatory variables such as tariff rates and freight-insurance ratios, which may vary across HS 10-digit products within the same HS 6-digit category, we aggregate them using import-value weights.[4]

[4] HS 6-level tariff measures constructed as import-value weighted averages may partly reflect shifts in the composition of HS 10 products within a given HS 6 category, in addition to policy-driven tariff variation. However, several features of our empirical design help mitigate this concern. First, the inclusion of country–product and time fixed effects absorbs a substantial amount of unobserved heterogeneity that may be correlated with systematic differences in product composition across

The dependent variable, FOB-based import value, is constructed by subtracting total freight and insurance costs from the reported dutiable value. The effective tariff rate is reconstructed using the statutory tariff rate and the tariff-reduction rate at the HS 10-digit level, thereby capturing the tariff actually applied in practice. We then aggregate these measures to the HS 6-digit level using import-value weights. The freight-insurance rate, used as an additional explanatory variable, is constructed by dividing the sum of total freight charges and total insurance premiums (both in KRW) by the import value on an FOB basis. This measure is first constructed at the HS 10-digit level and then aggregated to the HS 6-digit level using import-value weights.

In addition, because the customs data are recorded daily, the variables must be aggregated to a chosen time unit. Although we have only a single year of data, we aim to exploit panel-data methods—especially to address endogeneity—which requires some time variation, making monthly or quarterly aggregation a natural option. We use quarterly rather than monthly or annual data because tariff changes affect trade with a lag driven by global supply chains, production cycles, and logistics networks. Monthly data are highly sensitive to short-term volatility and may distort underlying trade patterns, whereas quarterly data help smooth such noise and seasonal fluctuations. Thus, the quarterly frequency provides a more suitable time dimension for panel analysis.

Since tariff rates and freight-insurance ratios may vary across quarters, we also construct these variables as import-value-weighted averages at the exporter-product level.

Exporter GDP, GDP per capita, geographic distance, and WTO membership are obtained from the CEPII database. Product classifications into capital, intermediate, and consumer goods follow the UN BEC (Broad Economic Categories) system and its correspondence with HS 2012 codes.

countries and over time. Second, HS 10-level tariff schedules are typically highly correlated within narrowly defined HS 6 categories, which limits the scope for large compositional bias in practice. Consistent with this, Table 1 shows that the number of HS 6 observations (137,693) exceeds 70% of HS 10 observations (192,758), suggesting that many HS 6 codes correspond closely to a single HS 10 category.

Table 1 presents summary statistics for the key variables used in this study, organized into three panels based on product detail and time aggregation. Panel (a) reports basic statistics for import values, tariff rates, and freight-insurance rates calculated from transaction-level HS 10-digit customs records. The average effective tariff rate, reflecting duty reductions, is about 5.7%, while the average freight-insurance rate is about 14.8%. Panel (b) shows summary statistics for the same HS 10-digit variables aggregated to the quarterly level. Although tariff rates change little with aggregation, freight-insurance rates rise by roughly 10 percentage points, suggesting that products with larger import values tend to have higher freight-insurance rates. All variables—import value, effective tariff rate, and freight-insurance rate—are expressed in natural logarithms, consistent with the specification used in the regression analysis. Panel (c) presents statistics for data aggregated to the HS 6-digit level using import-value weights.

Table 1. Summary Statistics of Key Variables

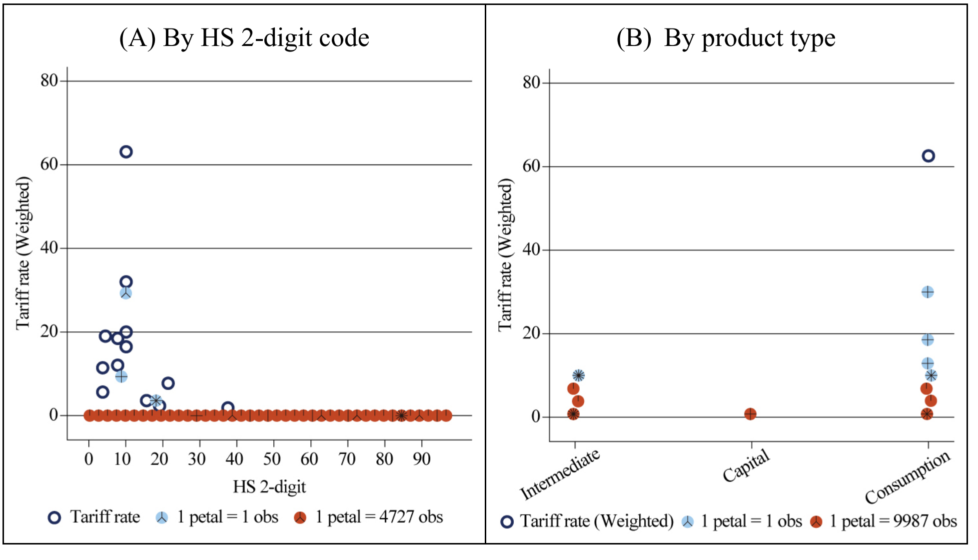
Variable	Observations	Mean	Std. Dev.	Min	Max
(a) Transaction-level, HS 10-digit					
Import value (million KRW)	4,796,705	99.90	1,390	1	292,000
Tariff rate (%)	4,796,705	5.729	9.522	0	6,210
Freight-insurance ratio (%)	4,796,705	14.845	594.296	0	320,009
(b) Quarterly, HS 10-digit					
Import value (million KRW)	192,758	2,370	34,300	1	3,550,000
Tariff rate (%)	192,758	5.550	15.137	0	1,807
Freight-insurance ratio (%)	192,758	24.656	421.492	0	75,408.91
ln(Imports)	192,758	18.42261	2.630979	5.231109	28.89877
ln(1+Tariff)	192,758	0.0505127	0.0698588	0.00E+00	2.948116
ln(1+TPCR)	192,758	0.0907949	0.2752152	1.72E-11	6.626836
(c) Quarterly, HS 6-digit					
Import value (million KRW)	137,693	3,320	58,800	1	9,150,000
Tariff rate (%)	137,693	5.703	15.697	0	1,800
Freight-insurance ratio (%)	137,693	26.281	459.934	0	75,408.91
ln(Imports)	137,693	18.60066	2.719884	5.231109	29.84432
ln(1+Tariff)	137,693	0.0515499	0.0736836	0	2.944439
ln(1+TPCR)	137,693	0.095172	0.2834417	1.78E-11	6.626836

Note: The tariff rate refers to the actual imposed tariff rate after taking into account tariff reductions from the basic tariff rate.

Figure 1 illustrates the distribution of average import tariff rates based on tariff variables aggregated at the HS 6-digit level. Panel (A) shows the distribution across HS 2-digit categories. As seen in Figure 1(A), Korea's import tariff rates are generally very low—mostly converging toward zero—at the HS 2-digit level. However, products in the HS 01-20 categories, which include live animals and agricultural and fishery goods, exhibit relatively higher tariff rates compared to other product groups. Indeed, out of roughly 7.5 million total transactions, 2,784,623 were subject to a zero import tariff, indicating that a substantial share of imports enters duty-free.

Panel (B) presents the distribution of tariffs by product type—intermediate goods, capital goods, and consumption goods. According to Figure 1(B), tariff rates are lowest for capital goods, while intermediate goods face slightly higher rates. For both categories, the maximum tariff rate generally remains below 10 percent. In contrast, consumption goods are more frequently subject to relatively high tariffs, with about 15 percent of all consumption goods facing rates of 10 percent or more. This pattern aligns with Shapiro (2021), who argues that consumption goods tend to face relatively high levels of protectionist tariffs.

Figure 1. Distribution of Tariffs (Data: HS 6-digit)



IV. Empirical Results

1. *Benchmark Estimation Results*

In this section, we present the estimated trade elasticity with respect to tariffs using HS 6-digit quarterly data following Equation (6). Table 2 reports the results, with each column differing in the set of fixed effects included. As the scope of fixed effects expands, it allows for more precise controls and better mitigation of endogeneity; however, this comes at the cost of reduced data variation and weakened identification. Therefore, the choice of fixed effects must be made carefully, in line with the data structure and research objectives, and the results should be interpreted with caution. Given the limitations of using single-year data, this study presents results across multiple fixed-effect specifications to account for the characteristics of the dataset.

Column (1) of Table 2 presents results using standard gravity controls with quarter and product fixed effects. Despite potential endogeneity, most gravity coefficients show expected signs. From columns (2)–(4), where exporter fixed effects are included, most standard gravity controls are absorbed. Tariff elasticity estimates in these columns cluster around –9, slightly high but broadly consistent with previous studies.

Columns (5)–(7) introduce exporter-product fixed effects at HS 2-, 4-, and 6-digit levels. As these fixed effects become more granular, estimated tariff elasticities drop substantially in absolute value. Under the most restrictive specification (exporter-HS 6-digit), tariff elasticity is close to zero and statistically insignificant.

Notably, until exporter-product fixed effects are introduced (i.e., up to column (4)), tariff and transportation-cost (measured as freight and insurance ratio) elasticities are statistically indistinguishable from each other.[5] This finding is consistent with structural gravity theory as shown in Equation (5) and an important empirical contribution, as previous studies have not explicitly documented this. By directly controlling for transportation costs rather than proxy variables such as distance,

[5] See Appendix Table A1 for the test results on the statistical equivalence of the transportation-cost elasticity estimates in columns (1) through (4).

the analysis minimizes endogeneity highlighted by Fontagné et al. (2022) and confirms that tariff and transportation-cost elasticities are similar for our data.

Table 2. Tariff Elasticity: HS 6-digit level, PPML (Quarterly)

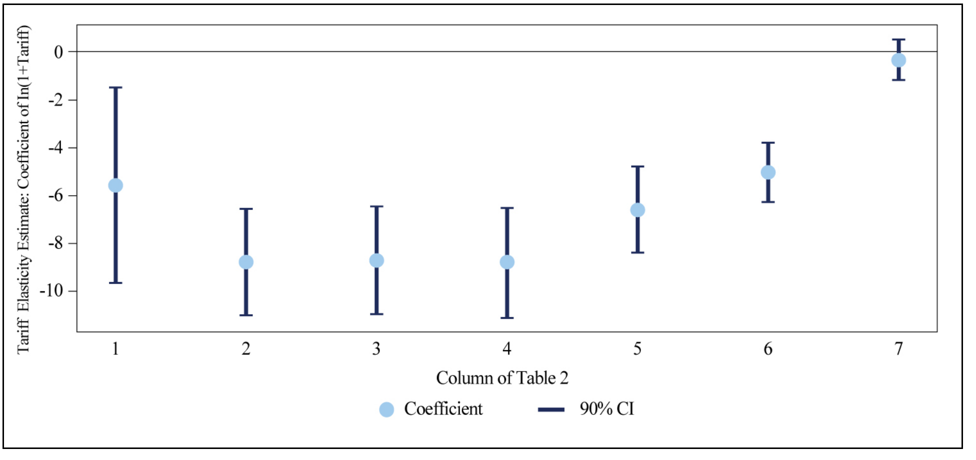
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Imports	Imports	Imports	Imports	Imports	Imports	Imports
ln(1+Tariff)	-5.572^{***}	-8.761^{***}	-8.694^{***}	-8.800^{***}	-6.595^{***}	-5.029^{***}	-0.365
	(2.069)	(1.131)	(1.140)	(1.166)	(0.921)	(0.629)	(0.438)
ln(1+TPCR)	-9.168^{***}	-10.73^{***}	-10.88^{***}	-10.97^{***}	-15.54^{***}	-19.86^{***}	-11.81^{***}
	(2.028)	(2.748)	(2.842)	(2.999)	(2.151)	(1.381)	(1.851)
lnGDPi	0.345^{***}						
	(0.0457)						
lnGDPPCi	0.173^{***}						
	(0.0623)						
lnDistance	-0.614^{***}						
	(0.0605)						
WTO	0.917^{**}						
	(0.447)						
Constant	17.37^{***}	25.11^{***}	25.12^{***}	25.16^{***}	25.45^{***}	25.68^{***}	25.43^{***}
	(1.462)	(0.0820)	(0.0830)	(0.0861)	(0.0609)	(0.0393)	(0.0430)
Observations	118,824	118,824	118,824	118,824	118,824	118,824	118,824
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HS6 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FEs	No	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-Qrt FEs	No	No	Yes	Yes	Yes	Yes	Yes
Qrt-HS6 FEs	No	No	No	Yes	Yes	Yes	Yes
Cntry-HS2 FEs	No	No	No	No	Yes	Yes	Yes
Cntry-HS4 FEs	No	No	No	No	No	Yes	Yes
Cntry-HS6 FEs	No	No	No	No	No	No	Yes
Pseudo R2	0.711	0.797	0.801	0.811	0.895	0.957	0.988

Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

However, once exporter-product fixed effects are added (column (5) onward), the transportation costs elasticity becomes significantly larger in absolute value than the tariff elasticity. Even under the strictest fixed effects, that is, column (7), the transportation-cost elasticity remains large (–11.81) and significant at the 1% level. This likely reflects greater within-exporter–product variation in transportation-costs compared to tariff rates. Indeed, among 137,693 observations, only 16,197 show no transportation costs variation at the exporter—HS 6-digit level, and only 26% show differences smaller than 0.1 percentage points—much higher variation than for tariffs.

Figure 2 illustrates the coefficient estimates of $ln(1 + Tariff)$ with 90% confidence intervals across different fixed-effect specifications corresponding to columns (1)–(7) of Table 2.

Figure 2. Tariff Elasticity: HS 6-digit level, PPML (Quarterly)



2. Heterogeneity Across Products

1) By product characteristics

Tariff elasticity can differ depending on product characteristics. In particular, intermediate goods, capital goods, and consumption goods exhibit different demand structures, substitutability, and policy responses. As a result, their trade flows are expected to respond differently to changes in prices and trade policies (Caliendo and Parro, 2015; Giri et al., 2021).

Intermediate goods are inputs used in production. When they consist of customized components tied to specific production processes, their trade elasticity may be relatively low. At the same time, because intermediate inputs directly affect firms' cost structures and profitability, firms have strong incentives to respond to price changes and seek cheaper suppliers. For standardized intermediate goods such as raw minerals—where product homogeneity is high—substitutability across suppliers is greater, implying potentially high trade elasticity.

Capital goods, by contrast, often involve customized design, technical compatibility, and installation requirements tailored to specific production processes. These features tend to generate long-term relationships between suppliers and buyers. Such relationship specificity raises switching costs and reduces the likelihood of shifting suppliers in response to price changes. Capital goods are also durable, with demand arising intermittently and irregularly, implying limited short-run responses to relative price changes (Bas et al., 2024). These factors may contribute to the relatively low trade elasticity observed for capital goods.

Consumption goods, which are sold directly to final consumers, generally face many close substitutes and exhibit relatively high price sensitivity with respect to tariffs or trade costs. However, brand loyalty, quality differentiation, and cultural preferences may still limit consumer responses to price changes.

Theoretically, heterogeneity in trade elasticity across product types is an important consideration in trade-model design. Standard models based on CES demand, such as Armington frameworks, often assume identical elasticities across goods. Recent studies, however, emphasize the need for more refined empirical analysis that incorporates heterogeneous elasticities across industries or product categories (Feenstra et al., 2018; Imbs and Mejean, 2015). Shapiro (2021) also highlights that environment-policy-induced trade distortions vary by product type, particularly between consumption and intermediate goods.

To analyze this heterogeneity, we classify products into intermediate, capital, and consumption goods using the UN BEC code mapped to HS 2012 6-digit codes. Table 3 presents the results. Columns (1)–(3) are for intermediate goods, columns (4)–(6) for capital goods, and columns (7)–(9) for consumption goods. Within each product group, the three columns correspond to exporter–HS 2, exporter–HS 4, and exporter–HS 6-digit fixed effects, respectively. For comparability, only specifications that include exporter–product fixed effects are reported.

Comparing columns (1), (4), and (7), which include exporter–HS 2-digit fixed effects, consumption goods show the highest tariff elasticity, followed by capital goods and then intermediate goods. When finer exporter–product heterogeneity is controlled for using exporter–HS 4-digit fixed effects in columns (2), (5), and (8), consumption goods continue to exhibit the highest elasticity, intermediate goods follow, and tariff elasticity for capital goods becomes very small and statistically insignificant. These results align with economic intuition and patterns documented in previous empirical studies.

Finally, columns (3), (6), and (9), which include exporter–HS 6-digit fixed effects, show a substantial reduction in tariff elasticity across all product types, consistent with the limited within-HS-6-digit quarterly tariff variation in single-year data. For capital goods, the estimated elasticity often becomes positive and generally loses statistical significance. Nevertheless, consumption goods continue to exhibit statistically significant elasticity at the 10% level. Indeed, the share of HS 6-digit capital-goods lines with quarter-to-quarter tariff variation below 0.1 percentage points is about 20%, the lowest among all product types, whereas consumption goods exhibit the highest share at about 39%.

Table 3. Tariff Elasticity by Product Type: HS 6-digit level, PPML (Quarterly)

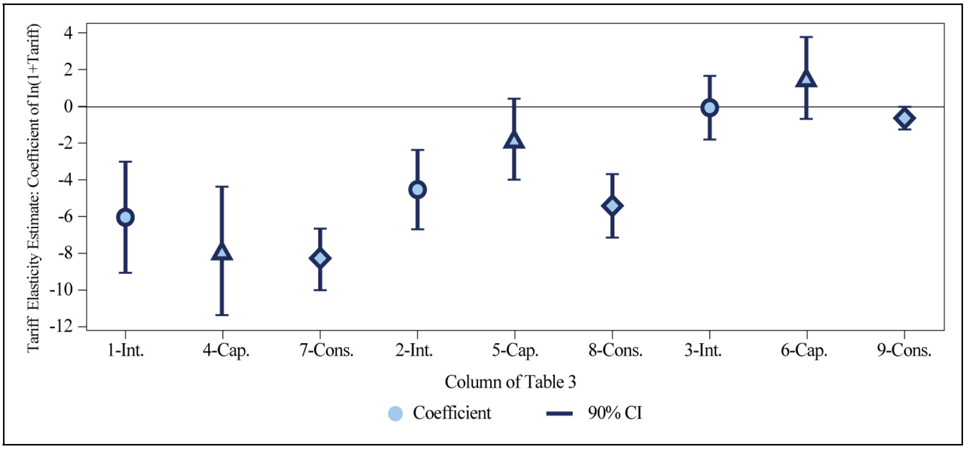
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Intermediate			Capital			Consumption		
	Imports	Imports	Imports	Imports	Imports	Imports	Imports	Imports	Imports
ln(1+Tariff)	–6.071***	–4.536***	–0.0599	–7.882***	–1.784	1.566	–8.361***	–5.400***	–0.632*
	(1.862)	(1.318)	(1.088)	(2.130)	(1.346)	(1.359)	(1.030)	(1.042)	(0.377)
ln(1+TPCR)	–12.49***	–15.19***	–10.84***	–29.86***	–18.89***	–4.711	–25.29***	–26.14***	–18.73***
	(2.615)	(1.408)	(1.777)	(6.111)	(7.177)	(4.955)	(1.618)	(2.019)	(0.986)
Constant	26.12***	26.31***	26.12***	24.43***	24.38***	24.24***	24.59***	24.55***	24.25***
	(0.0910)	(0.0544)	(0.0537)	(0.117)	(0.0990)	(0.0668)	(0.0746)	(0.0757)	(0.0282)
Observations	54,196	54,196	54,196	16,203	16,203	16,203	29,927	29,927	29,927
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HS6 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-Qrt FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Qrt-HS6 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-HS2 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-HS4 FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Cntry-HS6 FEs	No	No	Yes	No	No	Yes	No	No	Yes
Pseudo R^2	0.928	0.975	0.992	0.794	0.918	0.974	0.879	0.933	0.983

Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Meanwhile, elasticity with respect to transportation costs remains consistently much larger in absolute value than tariff elasticity, regardless of product type.

Figure 3 illustrates the coefficient estimates of $ln\ (1+Tariff)$ with 90% confidence intervals across the fixed-effect specifications in columns (1)–(9) of Table 3. For ease of comparison, the figure groups the results by the fixed-effect specification, and within each group the columns compare the estimates across product types.

Figure 3. Tariff Elasticity by Product Type: HS 6-digit level, PPML (Quarterly)



Note: Int, Cap and Cons denote intermediate, capital and consumption goods, respectively.

2) By product level

To analyze the heterogeneity of trade elasticities more systematically, we further estimate trade elasticities at the HS Section level, an aggregation unit suitable for capturing structural differences across product groups. HS Sections not only distinguish between consumption goods, intermediate goods, and capital goods, but also classify products in a way that consistently reflects physical characteristics, positions within production processes, substitutability, relationship specificity, and other structural features—for example, agricultural goods, minerals, machinery, and chemical products.

Table 4 lists the 20 HS Sections classified at the HS 2-digit level and provides brief descriptions of the product groups included in each section.

This classification is advantageous because it indirectly controls for many factors that may influence tariff elasticity, enabling more detailed and empirically robust comparisons than those based solely on functional categories (consumption, capital, intermediate goods). For instance, even within intermediate goods, HS Section 5 (mineral products) consists largely of homogeneous raw materials with high substitutability, implying relatively high tariff elasticity. In contrast, HS Section 6 (products of the chemical industry) includes high-value-added intermediate goods with stronger relationship specificity, suggesting lower elasticity. Therefore, analysis at the HS Section level can provide important insights into the structural heterogeneity of tariff elasticities and their policy implications.

Table 4. HS Sections

Section	HS 2-digit	Product Scope
1	01–05	Live animals and animal products
2	06–14	Vegetable products
3	15	Animal or vegetable fats and oils
4	16–24	Prepared foodstuffs, beverages, and tobacco
5	25–27	Mineral products
6	28–38	Products of the chemical industry
7	39–40	Plastics and articles thereof
8	41–43	Raw hides, skins, leather, and articles thereof
9	44–46	Wood, cork, and articles thereof
10	47–49	Pulp of wood or other fibrous material; paper products
11	50–63	Textiles and textile articles
12	64–67	Footwear, headgear, umbrellas, etc.
13	68–70	Stone, plaster, ceramic, and glass products
14	71	Natural or cultured pearls; precious stones and metals
15	72–83	Base metals and articles thereof
16	84–85	Machinery and electrical equipment
17	86–89	Vehicles, aircraft, and transport equipment
18	90–92	Optical, photographic, precision, and medical instruments
19	93	Arms and ammunition
20	94–96	Miscellaneous manufactured articles

Table 5 reports the estimation results by section. For brevity, it presents only the tariff elasticity estimates from the two models that include exporter–HS 4-digit and exporter–HS 6-digit fixed effects, corresponding to columns (6) and (7) of Table 3, while the full set of results is provided in Appendix Tables A3 and A4.

According to the results with exporter–HS 4-digit fixed effects, Sections 5 (mineral products), 12 (footwear, headgear, umbrellas, feather products, etc.), 9 (wood, cork, and articles thereof), and 8 (raw hides, leather, and articles thereof) exhibit very high tariff elasticities, with absolute values exceeding 10. In contrast, Sections 14 (natural or cultured pearls, precious stones and metals), 13 (stone, plaster, ceramic, and glass products), and 7 (plastics and articles thereof) show positive but statistically insignificant tariff elasticities, suggesting that products in these sections are relatively unresponsive to tariff changes.

Table 5. Tariff Elasticity by HS Sections: PPML

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
FEs		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
Cntry-HS4	ln(1+Tariff)	–0.348	–1.229***	–0.263	–1.769**	–24.79***	–2.920	2.813
		(0.381)	(0.338)	(0.219)	(0.737)	(8.785)	(1.853)	(2.530)
Cntry-HS6	ln(1+Tariff)	–0.817***	–1.064***	–11.25*	–3.917***	–14.43*	–1.282	1.965
		(0.282)	(0.320)	(5.912)	(1.333)	(8.555)	(1.807)	(2.088)
	Observations	1,694	1,977	475	4,778	1,312	12,895	7,285
		(8)	(9)	(10)	(11)	(12)	(13)	(14)
FEs		Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
Cntry-HS4	ln(1+Tariff)	–11.90***	–12.93**	–15.79	–5.278***	–15.60***	3.824	6.484
		(3.535)	(5.489)	(9.879)	(1.057)	(2.302)	(2.385)	(5.457)
Cntry-HS6	ln(1+Tariff)	–1.819	–5.789	–10.80**	–1.144	–2.279	2.140	1.691
		(1.820)	(3.962)	(5.084)	(0.724)	(2.244)	(3.083)	(6.197)
	Observations	2,169	1,405	3,055	18,199	1,673	3,684	598
		(15)	(16)	(17)	(18)	(19)	(20)	
FEs		Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	
Cntry-HS4	ln(1+Tariff)	2.452	–4.922***	1.100	–10.08***	–8.610	–7.572***	
		(1.753)	(1.156)	(4.143)	(1.886)	(12.58)	(2.723)	
Cntry-HS6	ln(1+Tariff)	1.142	3.904***	2.661	–4.461***	–52.14***	1.260	
		(2.957)	(1.102)	(2.663)	(1.731)	(16.69)	(1.910)	
	Observations	12,472	28,582	2,821	7,513	132	4,733	

Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The estimation results including exporter–HS 6-digit fixed effects show some differences compared with those using exporter–HS 4-digit fixed effects. While Section 5 (mineral products) continues to exhibit high tariff elasticity, Sections 12 (footwear, headgear, umbrellas, feather products, etc.), 9 (wood, cork, and articles thereof), and 8 (raw hides, leather, and articles thereof) lose statistical significance. Conversely, Section 10 (pulp of wood or other fibrous materials), which showed high but statistically insignificant elasticity under the exporter–HS 4-digit specification, becomes both statistically significant and remains highly elastic under the exporter–HS 6-digit fixed-effects specification.

Meanwhile, Section 19 (arms and ammunition) shows extremely high tariff elasticity even compared with the exporter–HS 4-digit specification, and the estimate is statistically significant. However, because this section contains only 132 observations while employing highly granular fixed effects, it is highly likely that very little meaningful variation was available for identification.

Figure 4. Tariff Elasticity by HS Sections: PPML, Exporter-HS 4 Fixed Effects

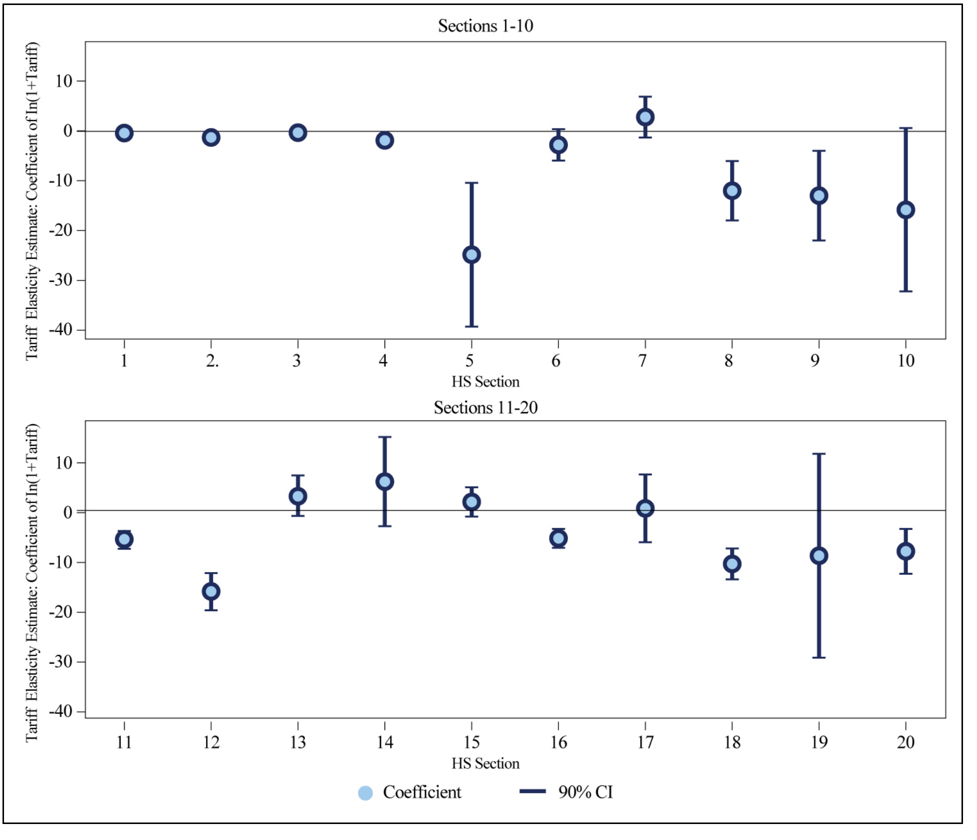


Figure 4 illustrates the coefficient estimates of $ln(1 + Tariff)$ with 90% confidence intervals, based on the exporter–HS 4 fixed-effects specification for 20 HS Sections reported Table 5.

3. Robustness Tests

In this section, we conduct two methodological robustness checks. First, to assess whether our results rely on a particular model specification, we perform a robustness test using a log-linear OLS estimator. Second, following the method proposed by Weidner and Zylkin (2021), we examine whether the inclusion of multi-way fixed effects in a panel structure with a fixed time dimension introduces incidental-parameter bias in the PPML estimator, potentially leading to systematic distortions in the estimated coefficients.

The log-linear equation used in this study to estimate tariff elasticity is as follows.

$$ln(IMPORTS_{ikt}) = \beta_0 + \beta_1\, ln(1 + Tariff_{ikt}) + \beta_2\, ln(1 + TPCR_{ikt}) + Z_i\beta_3 \\ + \varpi_{it} + \eta_{ik} + \mu_{kt} + \epsilon_{ikt} \tag{7}$$

Table 6 presents the results that corresponds to the PPML estimates reported in Table 2. As in the earlier tables, each column differs in the set of fixed effects included. According to Table 6, the tariff elasticity is negative and statistically significant in all cases, consistent with the range of estimates reported in previous empirical studies.

As with the PPML results, the absolute value of the tariff elasticity decreases as exporter-product fixed effects are added, and the decline becomes larger as the product classification becomes more granular, yielding the lowest estimates when exporter–HS 6-digit fixed effects are included. Compared with Table 2, the OLS-based estimates are generally smaller in magnitude than the PPML estimates before exporter-product fixed effects are introduced, but the overall patterns are qualitatively similar. The rate of decline is also smaller, and—as shown in column (7)—even with the full set of fixed effects, the OLS estimates remain larger in magnitude than the PPML estimates and statistically significant.

Furthermore, consistent with the PPML results, the point estimates of trade elasticity decrease slightly across specifications, and tariff elasticity and the transportation-cost elasticity remain similar in magnitude, aligning with the theoretical predictions of the structural gravity model.

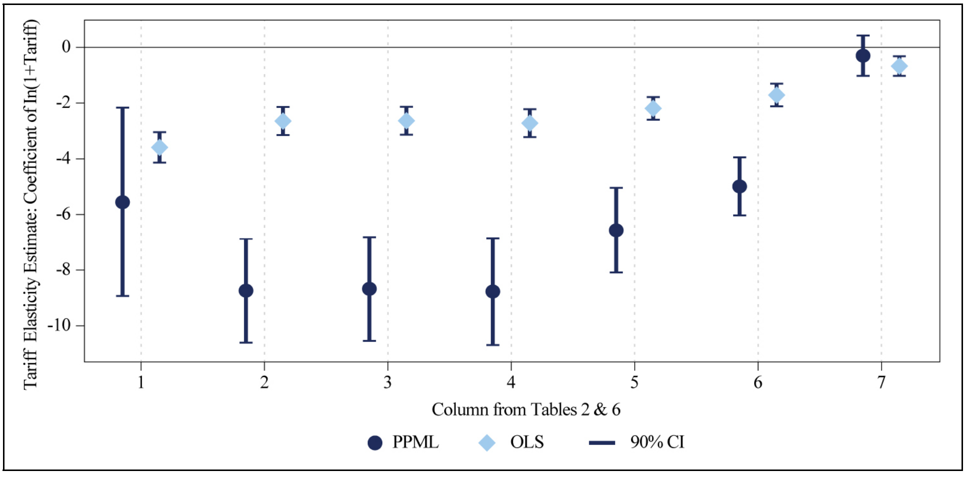
Table 6. Tariff Elasticity: HS 6-digit level, OLS (Quarterly)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	lnImports	lnImports	lnImports	lnImports	lnImports	lnImports	lnImports
ln(1+Tariff)	–3.628***	–2.701***	–2.687***	–2.772***	–2.245***	–1.769***	–0.722***
	(0.334)	(0.300)	(0.300)	(0.323)	(0.246)	(0.225)	(0.205)
ln(1+TPCR)	–4.582***	–4.448***	–4.454***	–4.494***	–4.387***	–4.112***	–3.496***
	(0.0916)	(0.0890)	(0.0886)	(0.0902)	(0.0843)	(0.0775)	(0.0675)
$\ln GDP_i$	0.428***						
	(0.00751)						
$\ln GDPPC_i$	–0.0339***						
	(0.0109)						
lnDistance	–0.520***						
	(0.0148)						
WTO	–0.182						
	(0.193)						
Constant	12.48***	19.42***	19.42***	19.43***	19.39***	19.35***	19.25***
	(0.299)	(0.0182)	(0.0182)	(0.0193)	(0.0155)	(0.0137)	(0.0113)
Observations	118,824	118,824	118,824	118,824	118,824	118,824	118,824
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HS6 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FEs	No	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-Qrt FEs	No	No	Yes	Yes	Yes	Yes	Yes
Qrt-HS6 FEs	No	No	No	Yes	Yes	Yes	Yes
Cntry-HS2 FEs	No	No	No	No	Yes	Yes	Yes
Cntry-HS4 FEs	No	No	No	No	No	Yes	Yes
Cntry-HS6 FEs	No	No	No	No	No	No	Yes
Adjusted R^2	0.427	0.464	0.464	0.439	0.549	0.697	0.832

Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Figure 5 depicts the coefficient estimates of $ln(1 + Tariff)$ with 90% confidence intervals from PPML (Table 2) and OLS (Table 6). For ease of comparison, the results from the same column in the two tables are presented side by side, where blue circles represent PPML estimates and yellow diamonds represents OLS estimates.

Figure 5. Tariff Elasticity: PPML vs. OLS



Weidner and Zylkin (2021) argue that, similar to the classic incidental-parameter problem documented in earlier literature, a large number of fixed effects combined with limited time-series variation can prevent precise estimation of the fixed effects themselves, which in turn may systematically bias the coefficients of interest. They further note that even cluster-robust standard errors may be biased under such conditions. This implies that PPML models with multi-way fixed effects may not possess accurate finite-sample properties, potentially leading to confidence intervals that are either too narrow or too wide.

Because this study uses single-year trade data, the quarterly dataset contains only four time periods, yet requires multi-dimensional fixed effects such as country, time, and products. As a result, it is important to recognize the possibility of bias in PPML estimators and potential distortions in standard errors, and to interpret the results with caution. To address this concern, it is useful to provide an additional robustness check using the incidental-parameter bias correction method proposed by Weidner and Zylkin (2021).

However, unfortunately when applying the asymptotic bias-corrected PPML method to our dataset, the estimation fails to converge when the transportation-cost variable is included. Therefore, the robustness check estimations are performed without this variable.

The results are reported in Table 7. For brevity and clarity, only the results that include exporter-product fixed effects are reported, and since the goal is to compare the degree and direction of bias in point estimates and cluster-robust standard errors, only these two values are presented.

Table 7. Tariff Elasticity: PPML vs. Asymptotic Bias-corrected PPML

	(1)	(2)	(3)	(4)	(5)	(6)
	PPML			Asymptotic Bias-corrected PPML		
FEs	Ctny–HS2 FEs	Ctny–HS4 FEs	Ctny–HS6 FEs	Ctny–HS2 FEs	Ctny–HS4 FEs	Ctny–HS6 FEs
	Imports	Imports	Imports	Imports	Imports	Imports
ln(1+Tariff)	–6.813***	–5.240***	–0.555	–5.651***	–4.357***	–0.573
	(0.909)	(0.673)	(0.470)	(0.649)	(0.728)	(0.550)

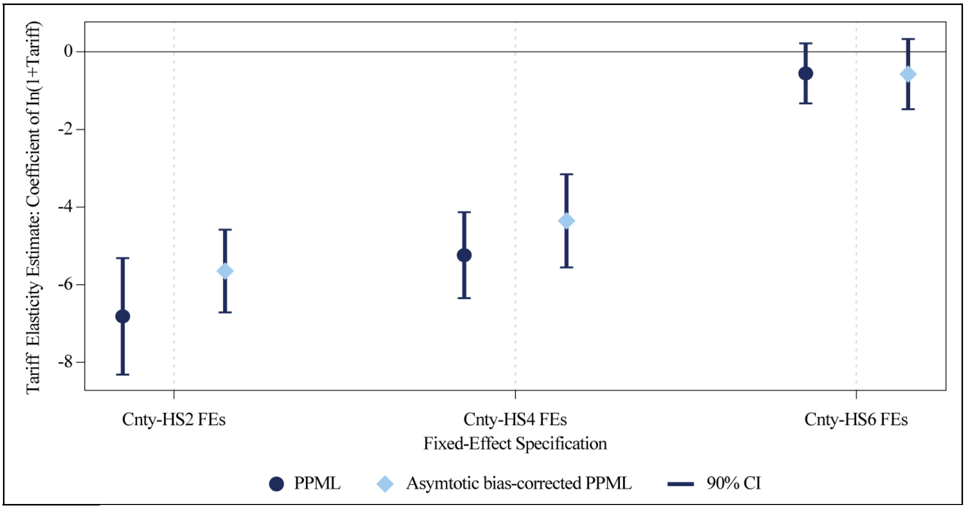
Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Columns (1)–(3) report the results from the conventional PPML estimator for all HS products, while columns (4)–(6) present the corresponding asymptotically bias-corrected PPML estimates. The columns differ according to the level of exporter-product fixed effects included (HS 2-digit, HS 4-digit, and HS 6-digit).

When applying the asymptotic bias-corrected PPML estimator, the coefficient estimates differ somewhat from those obtained using the conventional PPML method; however, the differences between the two are not statistically significant. Moreover, even after accounting for potential bias in the standard errors, the two methods yield consistent conclusions regarding statistical significance. This indicates that both qualitatively and quantitatively, the asymptotic bias-corrected estimates do not differ meaningfully from the conventional PPML results.

Figure 6 illustrates the results reported in Table 7. For ease of comparison, the estimates from the two methods (PPML and asymptotic Bias-corrected PPML) with the same fixed effects are presented side by side, where blue circles represent PPML estimates and yellow diamonds represents asymptotic Bias-corrected PPML estimates.

Figure 6. Tariff Elasticity: PPML vs. Asymptotic Bias-corrected PPML



V. Conclusion

In this paper, we estimate tariff elasticity using 2014 Korean transaction-level customs data, which contain roughly 7.5 million import records from about 230 exporting countries and cover 10,557 HS 10-digit products. Although tariff elasticity is a key parameter for assessing the welfare effects of trade policies, surprisingly few studies provide estimates for Korea using granular data and appropriate empirical specifications. This paper fills this gap. For the estimation, we adopt a structural gravity framework following Fontagné et al. (2022) and employ PPML methods with various fixed-effect specifications to address endogeneity concerns highlighted in the literature.

Our main findings are as follows. First, under the theoretical model of Fontagné et al. (2022), tariff elasticity follows directly from the elasticity of substitution across products: higher substitutability implies greater sensitivity of trade flows to tariff changes. Consistent with this prediction, using Korea's 2014 import data and PPML estimation, we find that tariff elasticity lies between 5 and 10 in absolute value when exporter-product fixed effects are not included, in line with prior studies. Once exporter-product fixed effects are used, however, the estimates fall because tariff variation within a single year becomes limited.

Tariff elasticity also differs across levels of product characteristics and product groups: consumer goods exhibit the highest elasticity, highly homogeneous categories such as mineral products show very large responses, and some sections display no significant reaction at all. This confirms the heterogeneity emphasized by Ossa (2015), who warned that relying on a single average elasticity may lead to an underestimation of welfare gains from trade. Our results highlight the necessity of using detailed product-level or industry-level data to design accurate and effective trade policies.

Third, this paper shows that fixed-effect specifications significantly influence estimated tariff elasticities. Because tariff variation is limited within a single year, exporter-product fixed effects tend to absorb much of this variation, reducing estimated elasticities. This underscores the importance of choosing fixed effects carefully, depending on data structure and research objectives.

Fourth, we document the importance of non-tariff trade costs such as freight-insurance rates. Unlike tariffs, these costs vary substantially across quarters and remain highly elastic even when fixed effects are included, indicating that transportation and insurance costs play a major role in shaping trade flows. Policymakers should therefore consider a broader range of trade costs, not tariffs alone. Finally, the robustness of our results across PPML, bias-corrected PPML, and log-linear models confirms that the structural gravity framework is a reliable and valid approach for estimating tariff elasticity. Robustness checks using log-linear OLS and bias-corrected PPML deliver consistent conclusions.

This paper also contributes to the literature emphasizing the importance of non-tariff trade costs, such as freight-insurance rates, by providing initial empirical evidence that tariff elasticity and transportation-cost elasticity (measured as the freight-and-insurance ratio) can be statistically indistinguishable from each other when exporter-product fixed effects are excluded—consistent with the predictions of the structural gravity model. However, because freight-insurance rates exhibit far greater variation than tariff rates, the magnitudes of the two elasticities diverge and become statistically different once more sophisticated fixed effects are included. These findings are valuable in that they are obtained by directly controlling for transportation costs, rather than relying on proxy variables such as distance, as in previous studies.

However, our study also has an important limitation in that it relies on a single year of data, where tariff variation is inherently limited. Under this constraint, including exporter–product fixed effects tend to absorb much of the available variation, which can lead to downward-biased elasticity estimates or a loss of statistical significance. Therefore, the policy implications we draw should be interpreted with caution, as the observed patterns may partly reflect data limitations rather than structural features of the Korean economy. When exporter–product fixed effects are excluded, tariff elasticity estimates increase with product disaggregation, and the estimated freight-insurance elasticity is of a similar magnitude—consistent with the theoretical model and prior work. Future research using multi-year panel data, where tariff changes occur more frequently, will be essential for producing more robust and policy-relevant elasticity estimates across different fixed-effect specifications.

Tariff elasticity estimates can be applied in a wide range of research areas, including optimal tariff estimation (Broda and Weinstein, 2006), deadweight-loss calculations (Fajgelbaum et al. 2020; Amiti et al., 2019), welfare analysis (Caliendo and Parro, 2015), tariff-revenue projections (Yale Budget Lab, 2024), and evaluations of FTAs and trade policies (Bae et al., 2012; Kim et al., 2014; Kim, 2024). We hope that the present study provides a foundation for future domestic research on tariff elasticity and encourages further empirical applications in these areas.

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Appendix

Table A1. Statistical Equivalence of the Tariff and Transportation-cost Elasticity

	(1)	(2)	(3)	(4)
χ^2	1.65	0.47	0.55	0.49
Prob $>\chi^2$	0.1983	0.4929	0.4603	0.4854

Note: Each column corresponds to the respective column in Table 2.

Table A2. Tariff Elasticity by HS Sections: PPML, Exporter–HS 4 Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
ln(1+Tariff)	–0.348	–1.229***	–0.263	–1.769**	–24.79***	–2.920	2.813
	(0.381)	(0.338)	(0.219)	(0.737)	(8.785)	(1.853)	(2.530)
ln(1+TPCR)	–5.220***	–13.28***	–4.024**	–6.366***	–8.052***	–20.24***	–22.70***
	(1.112)	(4.799)	(1.954)	(1.225)	(2.489)	(1.222)	(5.701)
Constant	23.70***	24.27***	23.13***	22.52***	29.02***	23.49***	23.97***
	(0.0898)	(0.308)	(0.0845)	(0.0805)	(0.178)	(0.0741)	(0.182)
Observations	1,694	1,977	475	4,778	1,312	12,895	7,285
Pseudo R2	0.966	0.972	0.989	0.937	0.993	0.943	0.938
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
ln(1+Tariff)	–11.90***	–12.93**	–15.79	–5.278***	–15.60***	3.824	6.484
	(3.535)	(5.489)	(9.879)	(1.057)	(2.302)	(2.385)	(5.457)
ln(1+TPCR)	–46.00***	–1.636	–15.04***	–35.63***	–40.63***	–20.41***	–42.99**
	(5.749)	(1.224)	(1.544)	(2.595)	(6.398)	(2.239)	(19.50)
Constant	25.58***	22.48***	22.37***	24.39***	26.30***	22.86***	24.38***
	(0.234)	(0.264)	(0.0478)	(0.0820)	(0.148)	(0.143)	(0.200)
Observations	2,169	1,405	3,055	18,199	1,673	3,684	598
Pseudo R2	0.920	0.908	0.921	0.915	0.968	0.936	0.974
	(15)	(16)	(17)	(18)	(19)	(20)	
	Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	
ln(1+Tariff)	2.452	–4.922***	1.100	–10.08***	–8.610	–7.572***	
	(1.753)	(1.156)	(4.143)	(1.886)	(12.58)	(2.723)	
ln(1+TPCR)	–19.26***	–21.87***	–23.02***	–45.18***	–34.35***	–16.40***	
	(1.634)	(3.727)	(3.316)	(8.255)	(12.12)	(1.623)	
Constant	24.33***	24.59***	24.36***	24.41***	24.48***	23.67***	
	(0.0674)	(0.0646)	(0.163)	(0.108)	(0.137)	(0.107)	
Observations	12,472	28,582	2,821	7,513	132	4,733	
Pseudo R2	0.952	0.910	0.927	0.896	0.992	0.922	

Table A2. Continued

	(15)	(16)	(17)	(18)	(19)	(20)	
	Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	
Cntry-Qrt FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-HS4 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Qrt-HS4 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table A3. Tariff Elasticity by HS Sections: PPML, Exporter–HS 6 Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
ln(1+Tariff)	–0.817***	–1.064***	–11.25*	–3.917***	–14.43*	–1.282	1.965
	(0.282)	(0.320)	(5.912)	(1.333)	(8.555)	(1.807)	(2.088)
ln(1+TPCR)	–7.332***	–3.355***	–2.894**	–4.287***	–5.399	–16.27***	–7.815
	(1.316)	(1.104)	(1.467)	(0.467)	(3.486)	(1.091)	(7.361)
Constant	23.94***	23.68***	23.40***	22.71***	28.73***	23.44***	23.88***
	(0.0818)	(0.0751)	(0.166)	(0.113)	(0.190)	(0.0793)	(0.210)
Observations	1,694	1,977	475	4,778	1,312	12,895	7,285
Pseudo R2	0.991	0.991	0.993	0.982	0.997	0.986	0.988
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
ln(1+Tariff)	–1.819	–5.789	–10.80**	–1.144	–2.279	2.140	1.691
	(1.820)	(3.962)	(5.084)	(0.724)	(2.244)	(3.083)	(6.197)
ln(1+TPCR)	–30.76***	–5.802***	–14.07***	–20.13***	–26.61***	–13.76***	–26.99***
	(4.047)	(1.052)	(1.372)	(2.403)	(3.633)	(1.757)	(8.989)
Constant	24.96***	22.46***	22.43***	24.05***	25.48***	22.90***	24.45***
	(0.114)	(0.187)	(0.0345)	(0.0587)	(0.122)	(0.179)	(0.208)
Observations	2,168	1,405	3,055	18,198	1,673	3,684	598
Pseudo R2	0.990	0.975	0.973	0.980	0.993	0.978	0.988

Table A3. Continued

	(15)	(16)	(17)	(18)	(19)	(20)	
	Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	
ln(1+Tariff)	1.142	3.904***	2.661	–4.461***	–52.14***	1.260	
	(2.957)	(1.102)	(2.663)	(1.731)	(16.69)	(1.910)	
ln(1+TPCR)	–13.16***	–9.561**	–14.40***	–25.89***	–23.71***	–16.88***	
	(1.711)	(4.763)	(2.198)	(6.565)	(6.602)	(1.396)	
Constant	24.33***	24.29***	24.30***	24.16***	24.38***	23.45***	
	(0.101)	(0.0677)	(0.119)	(0.0925)	(0.0762)	(0.0852)	
Observations	12,472	28,582	2,817	7,513	132	4,733	
Pseudo R2	0.983	0.977	0.988	0.978	0.996	0.986	
Cntry-Qrt FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cntry-HS6 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Qrt-HS6 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Values in parentheses indicate exporter–HS 6-digit cluster-robust standard errors. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.