Tariff Equivalent of Technical Barriers to Trade with Imperfect Substitution and Trade Costs

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Abstract

The price-wedge method yields a tariff-equivalent estimate of technical barriers to trade (TBT). An extension of this method accounts for imperfect substitution between domestic and imported goods and incorporates recent findings on trade costs. We explore the sensitivity of this revamped TBT estimate to its key determinants (substitution elasticity, preference for home good, and trade cost). We use the augmented approach to investigate the ongoing US-Japan apple trade dispute and find that removing the Japanese TBT would yield limited export gains to the United States. We then draw policy implications of our findings.

Keywords: apple, Japan, SPS, TBT, technical barriers to trade, trade cost, trade dispute, WTO.

JEL Code: F1, F18, Q17, Q18

1. Introduction

Article 20 of the General Agreement on Tariffs and Trade (GATT) permits governments to set their own standards and regulations on trade in order to protect human, animal, or plant life or health, provided they do not discriminate among countries or use this motive as concealed protectionism. In addition, two specific World Trade Organization (WTO) agreements deal with food safety and animal and plant health, and with product standards: the Sanitary and Phytosanitary Measures Agreement (SPSA) and the Technical Barriers to Trade Agreement (TBTA). The SPSA allows countries to set their own standards, but it requires that the standards should not arbitrarily discriminate between countries with similar conditions. The TBTA was generated to minimize unnecessary obstacles in regulations, standards, and testing and certification procedures. In practice, however, some governments use stricter health and safety regulations than necessary to isolate domestic producers from international competition. The stricter regulations may lead to questionable impediments to imports that compete with domestic products, in addition to the existing tariff barriers. When the possibility of a disease or pest transmission is very low or threat to food safety is small, these trade impediments often cause welfare losses for importing countries and mercantilist losses for exporting countries due to reduced exports.

These issues have of course attracted the attention of economists (Anderson, McRae, and Wilson; Bureau, Marette, and Schiavina; Josling, Roberts, and Orden; Roberts and Krissoff). The growing literature on sanitary and phytosanitary (SPS) regulations and other technical barriers to trade (TBT) often uses a price-wedge approach[1] to quantify the impact of a barrier on market equilibrium and trade (see, for example, Calvin and Krissoff; and Campbell and Gossette).

[1] The price wedge measures the difference between the internal price of a good and the reference price of a comparable good, such as a border price. It attributes the price difference to trade barriers and transportation cost. The price wedge can be expressed as a specific tax/tariff, or an ad valorem tax/tariff (Beghin and Bureau).

Although not unique or sophisticated, the method has been legitimized in the economics literature with some prescriptions and qualifiers to account for transportation cost and quality differences (Baldwin; Deardorff and Stern). The use of a price-wedge approach often abstracts from quality differences or simply addresses the difference by choosing "close" substitutes. Transportation costs may be reduced to the CIF-FOB differential and abstract from the internal transportation cost once imports are landed. All price-wedge estimates we are aware of rely on the assumption of homogeneous commodities and a price arbitrage condition. By assuming that domestic and imported goods are perfect substitutes, the gap between their prices reflects trade impediments from various policies and natural protection. Border tariffs and transportation and transaction costs prevent full arbitrage between the two prices (Head and Mayer). Hence, in principle, the price gap can yield an estimate of the tariff equivalent of the TBT once transportation and trade costs and other impediments have been taken into account.

In this paper we derive a revamped tariff-equivalent estimate of a TBT. We extend the price-wedge framework by first relaxing the homogeneous commodity assumption, a straightforward but instrumental step overlooked in the literature on TBT measurement. We account explicitly for commodity heterogeneity and perceived quality of substitutes. Next, we incorporate recent developments and findings on large and costly border effects arising from transportation, linguistic differences, and poor infrastructure and law enforcement (Anderson and van Wincoop; Head and Mayer; Hummels and Skiba). Two major findings of this new literature are particularly relevant to our work. First, trading costs are very large and often greater than policy impediments and cannot be ignored. While CIF/FOB ratios have fallen over time, other transportation and trade costs have remained high and have been underestimated. Second, these costs are structured on a per-unit basis rather than following the so-called iceberg method;[2] they act as a specific tariff rather than an ad valorem tax (Hummels and Skiba). These per-unit costs shift supply in a parallel manner rather than proportionally, which influences the estimate of the TBT. We provide a consistent approach to apportion the internal-border price difference between potential sources of the difference (quality and heterogeneity of goods, border tariff, TBT, transportation and other transaction costs). This approach allows us to elucidate the respective role of each source leading to a credible estimate of the tariff equivalent of the TBT.

We systematically explore the robustness of the tariff-equivalent estimate to underlying assumptions on commodity heterogeneity, home-good preference, trading costs, and the chosen reference data. We show the importance of selecting best values of these key determinants (substitution elasticity, home-good preference, and trade cost) on which the policy analysis can be centered. We then analyze the sensitivity of the TBT estimate around these central values of the determinants and associated welfare implications. The analysis shows the value of narrowing the set of possible estimates of the TBT using available data and knowledge on the quality and heterogeneity of the domestic and competing imported goods.

Our paper bridges two methods often used to estimate the trade effects of TBT: the tariff-equivalent–price-wedge approach mentioned previously and the gravity-equation approach.[3] Recent conceptual developments have provided theoretical foundations to the gravity-equation approach and account explicitly for relative prices of traded and domestic substitutes and for trading costs. In addition, they attempt to better measure and decompose "border effects" of trade barriers and transportation costs between trade partners. These new approaches have been

[2] The iceberg method refers to transportation cost being proportional to the value of a good. To ship a unit value of a good it takes (1+x%) unit value of that good to be shipped out. Transportation cost is equal to x% of the unit value of the good and "melts" away.

[3] The gravity equation approach links trade flows between two countries to observable variables such as their relative income, and to variables inhibiting trade such as distance, linguistic barriers, and trade policy barriers (Anderson and van Wincoop).

applied to aggregate trade data but not to individual commodities (Anderson and van Wincoop; Head and Mayer).

Calvin and Krissoff provide a tariff equivalent of phytosanitary barriers in the Japanese apple market regarding the risk of contamination by fire blight that has been the origin of a long WTO dispute between the US and Japan (WTO 2002-2004). The dispute has attracted much attention. Calvin and Krissoff use the law of one price under a homogeneous commodity assumption (arbitrage condition) to calculate the tariff equivalent of SPS barriers affecting apple imports in Japan to avoid damages from fire blight. By assuming that Japan's domestic apples and imported apples are perfect substitutes, the gap between the prices of domestic and imported apples accounts for the border tariff and other trade impediments that prevent full arbitrage. The latter authors also abstract from other border effects (internal transportation and transaction costs), leading to a likely overstatement of the cost of a TBT barrier, other things being equal. They use several reference years to mitigate annual variations in the reference data used to calibrate the tariff equivalent to the TBT. Using recent data and the proposed revamped approach, we provide a new investigation of the Japan-US apple dispute. We compute the tariff equivalent of Japanese TBT regulations affecting apple trade and quantify the impact of removing these policies on welfare and apple trade flows. We also draw policy implications. The apple dispute offers an opportunity to validate our contention that departures from perfect substitution and significant trade costs have a substantial impact on the estimate of SPS/TBT regulation and hence on welfare and policy implications derived from this estimate.

2. Analytical Framework

As in the gravity equation, we use the simple constant elasticity of substitution (CES) model to incorporate the heterogeneity of goods in consumers' preferences and eventually to calculate the tariff equivalent estimate of a TBT (Hummels and Skiba). Define domestic and imported apples, *D* and *I.* We assume the case of a small country facing a parametric exogenous world price of imports. The price P_D of the domestic good is determined by the domestic good market equilibrium, as explained later in the paper. The representative consumer maximizes utility U subject to a budget constraint:

$$\underset{D,I}{Max} \quad U(D,I) = (\alpha D^{\rho} + (1-\alpha) I^{\rho})^{1/\rho} + AOG \;\; s.t. \quad p_D D + p_I I + AOG = M_T \, , \tag{1}$$

where M_T is expenditure on all goods; α, ρ are parameters reflecting preferences; and p_D and p_I are consumer prices of the two goods *D* and *I*. AOG is the aggregate *numéraire* good. Home-good preference implies $\alpha > ½$. The corresponding indirect utility function deriving from consuming apples is

$$V(p_D, p_I, M) = (M_T - AOG^*)(\alpha^{\sigma} p_D^{1-\sigma} + (1-\alpha)^{\sigma} p_I^{1-\sigma})^{\frac{1}{\sigma-1}} \, , \tag{2}$$

and the corresponding expenditure function is

$$e(p_D, p_I, u) = (u - AOG^*)(\alpha^{\sigma} p_D^{1-\sigma} + (1-\alpha)^{\sigma} p_I^{1-\sigma})^{\frac{1}{1-\sigma}} \, . \tag{3}$$

The associated Marshallian demand functions are

$$D(p_D, p_I, M_T) = \left(\frac{\alpha}{p_D}\right)^{\sigma} \frac{M_T - AOG^*}{\alpha^{\sigma} p_D^{1-\sigma} + (1-\alpha)^{\sigma} p_I^{1-\sigma}} \, ,$$

$$(4)$$

$$I(p_D, p_I, M_T) = \left(\frac{1-\alpha}{p_I}\right)^{\sigma} \frac{M_T - AOG^*}{\alpha^{\sigma} p_D^{1-\sigma} + (1-\alpha)^{\sigma} p_I^{1-\sigma}} \, ,$$

with $\sigma = \dfrac{1}{1-\rho}$ being the elasticity of substitution and AOG^* being the optimal consumption amount of the *numéraire*. Parameter α functions as a quality shift (Hummels and Klenow), which lowers the effective price of D and increases its consumption, other things being equal. It has the opposite effects on I, increasing its effective price and decreasing its consumption. Observable price-quantity pairs and some additional information to select α and σ can be used to infer the tariff-equivalent estimate of the TBT and the interface between α and the tariff-equivalent estimate of the TBT.

The TBT first leads to a higher marginal production cost and process cost such as orchard and harvest inspections and buffer requirements (measured as TBT_1). This first part of the TBT leads to a higher price of apples exported to Japan because of a shift in the marginal cost for the apples going to Japan (Calvin, Krissoff, and Foster). In addition, strict inspection requirements, vendor and ordering issues, and additional requirements are added to the imported price once the apples are landed in Japan. Variable TBT_2 represents these costs in the market channel, which have been noted in the case of Japan (Gehrt et al.). Therefore the import price p_I is expressed as

$$p_I = p_{US} + TBT_1 + TBT_2 + IT_R + Tariff + T_R = p_{US} + TBT_T + IT_R + Tariff + T_R, \quad (5)$$

where price p_{US} represents the price/cost of US apples going elsewhere than Japan, IT_R is the insurance and freight and other international trade costs of apples exported to Japan, $Tariff$ is the specific import tariff, T_R is the per-unit transportation and transaction cost from the harbor to the wholesale internal market, and TBT_T is the tariff equivalent of the two components of the TBT ($TBT_T = TBT_1 + TBT_2$), respectively.

From utility maximization, we know that the marginal rate of substitution is equal to the relative price of the substitute goods, or

$$MRS = \frac{MU_D}{MU_I} = \frac{p_D}{p_I} = \frac{p_D}{p_{US} + TBT_T + IT_R + Tariff + T_R}, \quad (6)$$

where MRS is the marginal rate of substitution, and MU_j indicates the marginal utility of good j.

From (6), the tariff equivalent of the TBT, TBT_T, is solved after deriving the MRS from (1) and substituting it back into (6). TBT_T is a function of the relative cost of the two goods, their volumes, the elasticity of substitution, the preference parameter, international trade costs, internal transaction and transportation cost, and border tariff: [4] [5]

$$TBT_T = p_D \frac{1-\alpha}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}} - p_{US} - IT_R - Tariff - T_R \,. \tag{7}$$

Equation (7) nests the conventional technique that assumes perfect substitutes leading to the TBT in order to explain the differential between the domestic price and international price adjusted for transportation. To see this, assume $\alpha = ½$ and let $\sigma \rightarrow \infty$.[6] Then the tariff-equivalent estimate of the TBT is $TBT_T = p_D - p_{US} - (IT_R + T_R) - Tariff$. If the tariff and TBT are removed, the latter expression will lead to the arbitrage condition $p_D = p_{CIF}$, with $p_{CIF} = p_{US} + (IT_R + T_R)$. In real life these two prices would differ because of quality differences and imperfect substitutability. To measure the sensitivity of TBT_T to preference/quality, imperfect substitutability, and transportation cost, we compute the sensitivity elasticities of the TBT estimate with respect to σ, α, and transportation cost in the empirical section.

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[4] Other functional forms (rather than the CES) can be used. They lead to slightly different specifications of equation (7). The CES is flexible, with a wide range of possible substitution between *D* and *I*. To illustrate alternatives, a linear- expenditure system (LES) specification leads to $TBT_T = p_D \frac{1-\alpha_D}{1-\alpha_I}\left(\frac{(D-\gamma_D)^{\alpha_D - 1}}{(I-\gamma_I)^{\alpha_I - 1}}\right) - p_{US} - IT_R - Tariff - T_R$, with minimum subsistence parameters γ_j and preference parameters α_j (j = D, I) to be identified with extraneous information.

[5] The ad valorem tariff equivalent is $TBT_T^{\%} = \frac{p_D}{p_{CIF}} \frac{1-\alpha}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}} - \frac{p_{US}}{p_{CIF}} - it_R - t - t_R$, where t is the ad alorem tariff, it_R is the ad alorem tariff equivalent of international transportation, insurance, and transaction cost, and t_R is the internal transportation and transaction cost.

[6] We thank a referee for suggesting this nesting.

For the welfare analysis, we use the usual Equivalent Variation (EV) measure of the consumer's welfare, with $EV = e(\tilde{p}_0, u_1) - m_0$, where $\tilde{p} = (p_D, p_I)$ and subscripts 0 and 1 indicate initial and new prices.

We use a small displacement model to determine the price of domestic apples and eventually infer the impact of removing the TBT barrier on imports and domestic market equilibrium. Let S be the retail supply of domestic apples, which is an increasing function of domestic apple price and exogenous parameter λ:

$$S(p_D, \lambda) = \lambda p_D^{\varepsilon_S}, \tag{8}$$

where ε_S represents the own-price elasticity of the domestic apple supply. Decreases in parameter λ would reflect upward shifts in supply if contamination occurs and induces an increase in the cost of production. Using equations (4) and (8) the equilibrium domestic price p_D^e and quantity are determined by the market equilibrium condition, or

$$D(p_D^e, p_I) = S(p_D^e, \lambda). \tag{9}$$

Equations (4), (7), and (8), and condition (9) constitute the model. With the elimination of the TBT, p_I decreases and p_D will fall if there is no risk of contamination from the increased imports. The demand for domestic products declines with the change in p_I. Then the domestic market adjusts at a lower price such that demand equals supply. Imports expand as the direct effect of the decrease in the import price is larger than the feedback effect of the lower domestic price, by stability. If contamination occurs, the price of domestic apples may not decrease, as the domestic supply shifts upward to reflect the increased cost from contamination. The domestic apple equilibrium quantity is further reduced by the contamination. Imports increase. For simplicity, we assume away feedback effects from apple suppliers into the income of the representative consumer. We turn next to our investigation of the Japan-US apple dispute starting with some key stylized facts on the dispute.

3. The Japan-US Apple Dispute

The high technical barriers to importing apples into Japan have brought repeated complaints from several exporting countries and have led to a 30-year dispute (Elms). The latest episode of this dispute has been taking place within the WTO. *Japan-Measures Affecting the Importation of Apples* (WTO, 2002-2004) relates to the United States' complaint about the Japanese requirements imposed on apples imported from the United States and their inconsistency with WTO principles. The prohibitions and requirements included, for example, the prohibition of imported apples from states other than designated areas in Oregon and Washington; the prohibition of imported apples from any orchard (whether it is free of fire blight or not) if fire blight was detected within a 500-meter buffer zone surrounding such orchard; the requirement that export orchards be inspected three times a year (at blossom, fruitlet, and harvest stages) to check if fire blight is present in order to apply the aforementioned prohibitions; the requirement that at the post-harvest stage apples for export to Japan be separated from fruits for export to other markets; and chlorination of apples for export to Japan.

In 1997, the United States requested that Japan modify its import restrictions on apples based on published scientific evidence that mature, symptomless apples are not carriers of fire blight. In 2000, the United States agreed to carry out joint research proposed by Japan to confirm the results of those earlier studies. The USDA's Agricultural Research Service (ARS) and Japan's Ministry of Agriculture Forestry and Fisheries (MAFF) conducted the joint research. The research results confirmed that mature, symptomless apples are not carriers of fire blight. This finding provided additional scientific support for the US position. Since the results of this research were released in February 2001, the US government has repeatedly pressured Japan to modify its import restrictions. After extensive bilateral discussions with USDA scientists, Japan refused to modify its import restrictions in October 2001.

In March 2002, the United States requested WTO consultations concerning Japan's import restrictions on US apples. Consultations in April 2002 failed to settle the dispute. In May 2002, the United States requested that the WTO establish a panel to consider the Japanese restrictions. In June 2002, a panel was established by the Dispute Settlement Body (DSB) of the WTO to consider this issue. Before the panel, the United States claimed that Japan was acting inconsistently with some articles of the SPSA, certain articles of the Agreement on Agriculture, and the so-called GATT 1994. In July 2003, the panel found that Japan's phytosanitary measures were maintained without sufficient scientific evidence and inconsistent with Japan's obligation, did not qualify as a provisional measure, and were not based on a risk assessment. In September 2003, Japan appealed the WTO panel ruling. In addition to Japan's appeal, the United States cross-appealed the panel report. At the same time, third participants, such as Australia, Brazil, the European Union, and New Zealand, filed their submissions. After more investigations, in November 2003, the DSB upheld the findings of July 2003. Therefore, the Appellate Body recommended that the DSB request that Japan bring its inconsistent measures into conformity with SPSA.

Half a year later, in July 2004, the United States held that Japan failed to comply with the recommendations and rulings of the DSB by the end of the reasonable period of time. Therefore, the United States requested that the DSB establish a panel and simultaneously requested authorization on suspension of concessions and other obligations in one or more of the following: tariff concessions and related obligations under the GATT 1994 on a list of products;

and concessions and other obligations under the SPS Agreement and the Agreement on Agriculture. Because Japan objected to the United States' suspension request, this matter has been referred to arbitration. Because of the need to consult scientific experts, the arbitration panel completed its report in June 2005, which is being circulated now.

Between 1971 and 1992, Japan imported only 4,500 boxes of apples, all from South Korea and North Korea. In June of 1993, Japan permitted some import of New Zealand apples. After that, the United States and Australia also exported apples to Japan but not continuously over time. New Zealand, EU, and Korean apples have fire blight or a related form. Australia and Chile have been free of fire blight. Although Japan opened its door to foreign apples meeting the SPS and TBT standards regarding fire blight, the importing quantity has been quite low compared with the domestic production. As shown in Table 1, the import shares never exceeded 0.35% between 2000 and 2002, the last period prior the constitution of the dispute panel. The low import share is partly due to the high tariff and TBT barrier increasing the cost of exporting to Japan.

Table 1. Japanese Apple Production and Imports

Year	P_{US} (yen/kg)	Domestic Production (MT)	Domestic Wholesale		Import		Import Share
			Quantity (MT)	Price (yen/kg)	Quantity (MT)	CIF Price (yen/kg)	
2000	149	799600	691600	238	594	156	0.09%
2001	129	930700	674600	246	2339	126	0.35%
2002	139	925800	768700	182	120	237	0.02%

Source of data: Japan Customs, USDA.
Note: MT denotes metric tons.

In addition to the high technical barrier referred to in the dispute, the higher quality of the domestic product cannot be neglected. Fruits in general and apples in particular are an important part of the Japanese diet (Huang). Japanese consumers exhibit a strong home-good preference relative to imported apples. This fact has been repeatedly established (American University;

Kajikawa; Shim, Gehrt and Lotz; USDA). According to Japanese consumers, domestic apples have a higher quality because of their sweeter flavor and bigger size. For instance, after Japan opened its apple market to imports in 1995, US apples entered Japan at much lower prices than Japanese domestic products. However, after an initial success, the sales of US apples declined because Japanese consumers complained that US apples were too sour and did not cater to Japanese tastes (American University). Japanese consumers prefer apples with brix (a measure of sugar level) in a certain range and a specific brix-to-acid ratio. But imported apples do not meet these requirements. In addition, imports are smaller in size and less juicy (Kajikawa). For Japanese consumers who believe that apples must have an appropriate brix and acid level, firmness, juice, size, and flavor, imported apples cannot be a perfect substitute for domestic products.

Japanese farmers produce apples with great care and the production of apples is labor intensive. Leaves near each apple are usually plucked away when the fruit is still on the tree, which ensures that the apple receives enough and balanced sunlight to ensure full ripening. Several weeks before harvesting, bags are used to protect individual apples in order to prevent any kind of surface marring. This labor-intensive production leads to a higher quality and at the same time comes at a higher cost. Because of the quality difference and trade barriers, Japanese producers are able to pass the higher costs to consumers in the form of a higher price. Hence, the trade barriers do not explain the entire price wedge. A price differential reflecting the quality premium would remain under free trade. In addition, as a fresh fruit, the internal transportation cost for apples is high and cannot be ignored.

4. Quantifying the Apple Dispute

We apply the framework developed in section 2 to imported apples in Japan. We use all imported apples to estimate I and the average import unit cost measured as the CIF price, shown in Table 1, and to compute the tariff equivalent of the Japanese TBT regulations. [7] Then we estimate the impact of eliminating the TBT. The transportation and transaction cost, including both international and internal cost, IT_R+T_R, is approximately 78.33 yen/kg (Calvin, Krissoff, and Foster). The tariff rate is listed in Table 2 in specific form (17% of P_{CIF}). We analyze long-run and short-run impacts. As in Calvin and Krissoff, the long-run supply elasticity of domestic apples is assumed to be 1, whereas the short-run supply elasticity is assumed to be 0.1. We use Washington State size-88 waxed extra fancy Fuji apples as similar apples exported to Japan and take their price as the p_{US} (USDA).[8] We choose size-88 apples since Japanese consumers prefer apples of a bigger size. We follow the estimate of the Queensland (Australia) Department of Primary Industries and Fisheries (Queensland Government) and assume that with the transmission of pests and disease the production of apples would decrease by a fixed proportion of 20% with the TBT in place. We use 2SLS to estimate the parameter values for σ and α with monthly data for the period 2000-2004 (see Appendix 1). The estimated result for σ is 7.12 with a standard deviation of 2.09; the estimated result for α is 0.64 with a standard deviation of 0.05.[9]

4.1. TBT Estimate and Sensitivity Analysis

The last two columns of Table 2 show the actual tariff (in yen/kg) and (specific) tariff equivalent of the TBT across different reference years when σ and α are assigned to be 7.12 and 0.64 respectively.

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7. In an alternative specification, we treat imports from different countries as imperfect substitutes using a double-nested CES model and calculate the TBT estimate. Results are quite similar to what we present in this paper. For example, when we assume α=0.64, the elasticity of substitution among imports as 10, and σ=7.12, $TBT_T^{\%}$ is 65%, which is quite close to the 60% level obtained by aggregating all imports into one good.

[8] We follow Calvin and Krissoff, except we choose bigger apples (see their footnotes 4 and 5).

[9] Shim, Gehrt, and Lotz. (2002) provide an implicit value of α =0.55 based on a survey of Japanese housewives on their preferences of US and Japanese apples. The latter estimate is smaller than our econometric estimate but within its confidence interval. As we use total apple imports to derive our econometric estimate of α, this difference in data (all imports versus US apple imports) may contribute to the difference in the estimates of α.

Table 2. TBT_T **Across Different Years (**σ=7.12, α=0.64)[10]

Year	Tariff (yen/kg)	TBT_T (yen/kg)
2000	26.52	93.86
2001	21.47	71.02
2002	40.29	92.87

Source: WTO schedules and Japan Customs.

To test the sensitivity of TBT_T to the elasticity of substitution σ and domestic preference/quality parameter α, we assign the central values of their estimates and consider their confidence intervals (central values plus/minus one and then two standard deviations). The TBT estimates are shown in Table 3.

Table 4 gives the elasticity of TBT_T with respect to σ (i.e., ε_σ), holding α constant. Measures of ε_σ show that TBT_T is sensitive to σ, especially when the value of σ is low (poor substitutes). For example, when σ=2.94, ε_σ is less than -1.35, a value which indicates TBT_T would differ a lot even if the change in σ was to be small. Thus, σ plays an important role in the calculation of TBT_T. When σ gets larger, the sensitivity decreases in absolute value. When σ=11.3, the sensitivity is about a fourth of what it is for σ=2.94.

Table 4 also gives the elasticity of TBT_T with respect to α (holding σ constant); TBT_T is highly sensitive to α for the smaller values of α, but this sensitivity decreases as α increases. It is about four times smaller for α=0.74 compared with α=0.54. Good information on α appears to be critical in estimating TBT_T. This fact has implications for gravity equation analyses, which often impose α=0.5. This restriction may strongly bias the estimates of impediments to trade, as the sensitivity of TBT_T with respect to α is at its highest at α=0.5.

[10] The ad valorem estimated values of $TBT_T^{\%}$ for the three years are 60%, 56%, and 39%, respectively.

Table 3. TBT_T **Under Different Values of** σ **and** α

α	σ	TBT_T (yen/kg)
0.54	2.94	1970.68
	5.03	558.07
	7.12	279.48
	9.21	169.38
	11.3	111.70
0.59	2.94	1558.44
	5.03	406.07
	7.12	178.81
	9.21	88.99
	11.30	41.93
0.64	2.94	1210.61
	5.03	277.83
	7.12	93.86
	9.21	21.16
	11.3	---
0.69	2.94	913.19
	5.03	168.16
	7.12	21.23
	9.21	---
	11.30	---
0.74	2.94	655.96
	5.03	73.32
	7.12	---
	9.21	---
	11.30	---

Notes: Bold font denotes central values of α and σ. The shaded area denotes the central case **(**σ =7.12, α =0.64); --- denotes TBT_T negative, which is of no economic importance. (Analysis is for year 2000.)

Table 4. Elasticity of TBT_T **with Respect to** σ **and** α

σ	ε_σ (α =0.64)	α	ε_α (σ =7.12)
2.94	-1.351	0.54	-2.376
4.33	-0.917	0.57	-1.885
5.72	-0.694	0.60	-1.508
7.12	-0.558	0.64	-1.130
8.52	-0.466	0.67	-0.913
9.92	-0.400	0.70	-0.737
11.3	-0.351	0.74	-0.551

Notes: The shaded area denotes the results for central value of parameters. (Analysis is for year 2000.)

Estimates of the elasticity of TBT_T with respect to transportation cost $T_R + IT_R$ show that TBT_T is sensitive to $T_R + IT_R$ when the latter gets large but goes to zero as $T_R + IT_R$ decreases (estimates available from the authors, and provided here as Appendix Table A4). Around the central value (78.33 yen/kg) used in our computation, the elasticity of TBT_T to $T_R + IT_R$ is approximately -0.18 and hence plays some role in the calculation of the TBT_T, although less crucial than the that of the taste parameters. The elasticity of TBT_T with respect to the domestic and imported quantities shows TBT_T is less sensitive to the domestic and imported quantities than it is to their prices (see Appendix Table A4). The moderate elasticities remain nearly constant as quantity levels (*D* and *I*) change. In contrast, the elasticity of TBT_T with respect to the domestic price is always greater than one and gets larger as the domestic price increases (see Appendix Table A4). The elasticity of TBT_T with respect to *Tariff* indicates that the sensitivity of TBT_T goes up as the value of the tariff increases, although all of the estimated values are less than 0.45 (in absolute value) for *Tariff,* ranging from 18.7 to 46.8 yen/kg (see Appendix Table A4).

4.2 Welfare Analysis of the TBT (and Tariff) Removal

The import increases induced by policy reforms are shown in Table 5 for different values of σ and α. By eliminating the TBT (alone and along with the border tariff elimination), apple imports would increase substantially, between 5.24 and 218.11 thousand metric tons (tmt), depending on home-good preference parameter α and the assumed elasticity of substitution. These magnitudes are in a range of values comparable to those of Calvin and Krissoff. These larger imports remain moderate relative to domestic apple consumption. Japan imports apples from Australia, New Zealand, South Korea, and the United States. The US share of apple imports by Japan has varied widely over time. In 2000, the value share of US apples to total apple imports was 24%. Based on the 2000 share, when σ =7.12 and α =0.64, by elimination of both the TBT and the tariff, the expansion of US imports by Japan would amount to only US$4.01 million and would not exceed US$75.73 million, if one assumes σ =2.94 and α =0.54.[11] The losses to US exporters and producers would be smaller than the value of imports, first because they would be valued at lower FOB prices and farmgate prices, respectively, and because producer surplus losses are always smaller than the gross value of forgone production opportunities. The US$75.73 million figure is about half of the lost exports claimed by the United States at the WTO (US$143.4 million).

Table 5. Increase in Imports (tmt) with the Elimination of TBT (and Tariff) ($\varepsilon_s = 1$)

α	σ	**Increase in Imports by Elimination of TBT**	**Increase in Imports by Elimination of TBT and Tariff**
0.54	2.94	174.46	218.11
	7.12	71.15	118.26
	11.30	29.95	70.77
0.64	2.94	75.40	98.79
	7.12	5.24	11.56
	11.30	---	---
0.74	2.94	22.28	30.20
	7.12	---	---
	11.30	---	---

Notes: --- denotes TBT_T is negative, which is of no economic importance. The shaded area denotes the central case. (Analysis is for year 2000.)

Changes in welfare with elimination of the TBT and the tariff vary under different assumptions on the transmission of disease. Transmission of disease implies an upward shift of the domestic supply of apples because the variable cost of producing apples has increased. Table 6 shows the welfare implications of eliminating the TBT and the tariff for 2000, when assigning different values to α and σ, assuming transportation plus transaction costs of 78.33 yen/kg,

[11] The incremental US$4.01 million of US imports come from the 2000 US value share of all apple imports by Japan, or 22,249,000/92,630,000=24%, applied to the expansion in import value (11.56 TMT *155.91 yen/kg), expressed in US$ with an exchange rate of 107.765 yen/$.

$\varepsilon_s = 1$ (long-run response), and under the condition of no disease transmission. Table 6 shows that the EV and the producer's surplus change dramatically with the changes to σ and α. However, when there is no disease transmission, EV net of tariff revenue loss is greater than the loss of the producer's surplus for both elimination of the TBT and elimination of the TBT and the tariff no matter what values σ and α take.

Table 6. Welfare Analysis with Elimination of the TBT (and Tariff)
($\varepsilon_s = 1$, Without Disease Transmission)

α	σ	Welfare Impact of TBT_T Removal				Welfare Impact of TBT_T +*Tariff* Removal		
		Tariff Revenue Change (1)	EV (2)	Producer Surplus Loss (3)	Net Welfare (1)+(2)-(3)	EV (4)	Producers Surplus Loss (5)	Net Welfare (4)-(5)
0.54	2.94	7760	62839	22593	48006	73958	25276	48681
	7.12	3180	13239	9050	7370	20914	13554	7361
	11.3	1354	4466	3603	2216	10532	8073	2458
0.64	2.94	3369	22067	9705	15731	26636	11385	15251
	7.12	259	767	597	429	1549	1156	392
	11.3	---	---	---	---	---	---	---
0.74	2.94	1014	5444	2523	3935	7017	3334	3683
	7.12	---	---	---	---	---	---	---
	11.3	---	---	---	---	---	---	---

Notes: Welfare is measured in million yen (2000 prices). --- denotes TBT_T not being defined.
The shaded area indicates the central case.

Table 7 shows the welfare implications *with* disease transmission, holding other conditions the same as in the previous analysis. When σ=7.12 and α =0.54, the net welfare is positive. So it is optimal to eliminate either the TBT or both the TBT and tariff in this case. But when the value of α is equal to or larger than 0.64, EV plus the change in tariff revenues do not exceed the loss of producer's surplus and net welfare consequences of the reform are negative no matter what value σ takes on. So the elimination of the TBT may not improve welfare. The same logic applies to the case when both the TBT and the tariff are eliminated.

Table 8 gives the short-run welfare implications of policy reforms for the case without disease transmission when supply of domestic apples is assumed to be very inelastic ($\varepsilon_s = 0.1$).

Supply expansion of perennials takes time, although at the margin apples can be moved from one use to another (from processing to fresh market) on short notice. Supply contraction is more responsive since apples can be removed from the market and stored. In any case, it is interesting to consider the implications of the less-price-responsive supply of domestic apples. As expected, the decrease in domestic price caused by the domestic demand shift is more pronounced with this

Table 7. Welfare Analysis with Elimination of TBT (and Tariff) ($\varepsilon_s = 1$, With Disease Transmission)

α	σ	Welfare Impact of TBTT Removal				Welfare Impact of TBTT +Tariff Removal		
		Tariff Revenue Change (1)	EV (2)	Producer Surplus Loss (3)	Net Welfare (1)+(2)-(3)	EV (4)	Producers Surplus Loss (5)	Net Welfare (4)-(5)
0.54	2.94	8739	49311	25323	32727	60850	28165	32685
	7.12	4791	1713	13676	-7173	11045	19245	-8200
	11.3	2908	-7637	8262	-12990	855	14614	-13758
0.64	2.94	3984	6589	11305	-732	11613	13336	-1723
	7.12	496	-15938	1060	-16502	-14442	2443	-16884
	11.3	---	---	---	---	---	---	---
0.74	2.94	1235	-11016	3258	-13039	-9420	4102	-13522
	7.12	---	---	---	---	---	---	---
	11.3	---	---	---	---	---	---	---

Notes: Welfare is measured in million yen (2000 prices). --- denotes TBT_T not being defined.
The shaded area indicates the central case.

Table 8. Short-Run Welfare Analysis with Elimination of TBT (and Tariff) ($\varepsilon_s = 0.1$, Without Disease Transmission)

α	σ	Welfare Impact of TBT_T Removal				Welfare Impact of TBT_T +*Tariff* Removal		
		Tariff Revenue Change (1)	EV (2)	Producer Surplus Loss (3)	Net Welfare (1)+(2)-(3)	EV (4)	Producers Surplus Loss (5)	Net Welfare (4)-(5)
0.54	2.94	6844	78060	35670	49234	91231	39840	51391
	7.12	2714	17904	13638	6980	27052	19660	7392
	11.3	1213	6289	5387	2114	14130	11717	2413
0.64	2.94	3129	29296	16379	16047	34942	10484	24458
	7.12	255	1183	968	469	2523	1273	1250
	11.3	---	---	---	---	---	---	---
0.74	2.94	990	7571	4560	4001	9739	5939	3800
	7.12	---	---	---	---	---	---	---
	11.3	---	---	---	---	---	---	---

Notes: Welfare is measured in million yen (2000 prices). --- denotes TBT_T not being defined.
The shaded area indicates the central case.

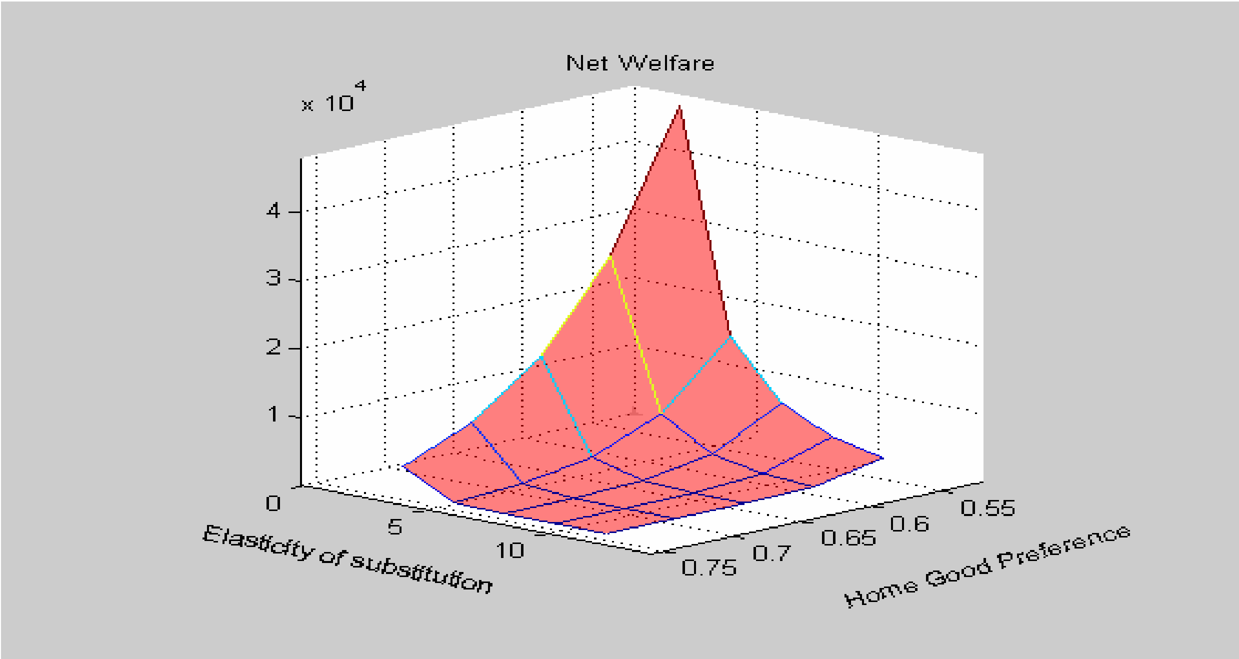
steeper domestic supply curve. Accordingly, EV (columns 2 and 4) increases relative to its level in the long-run case; imports and associated tariff revenues (column 1) do not expand as much; and the loss of producer surplus is more acute with this inelastic supply. Net welfare gains are mitigated by the larger losses of producer surplus.

Figures 1 and 2 illustrate the variation of estimates of long-run net welfare and import effects from removing the TBT as σ and α change and without disease transmission. The net welfare is EV plus change in tariff revenue net of loss of producer's surplus. The transparent horizontal plate is the zero plate, provided for reference. Figures 1 and 2 show that the net welfare and increase in imports increase as σ and α decrease. They decrease faster when σ and α are smaller (the surfaces are concave toward the origin [$\sigma = \alpha = 0$]). The net welfare eventually approaches zero when σ and α take on larger values.

5. Conclusions

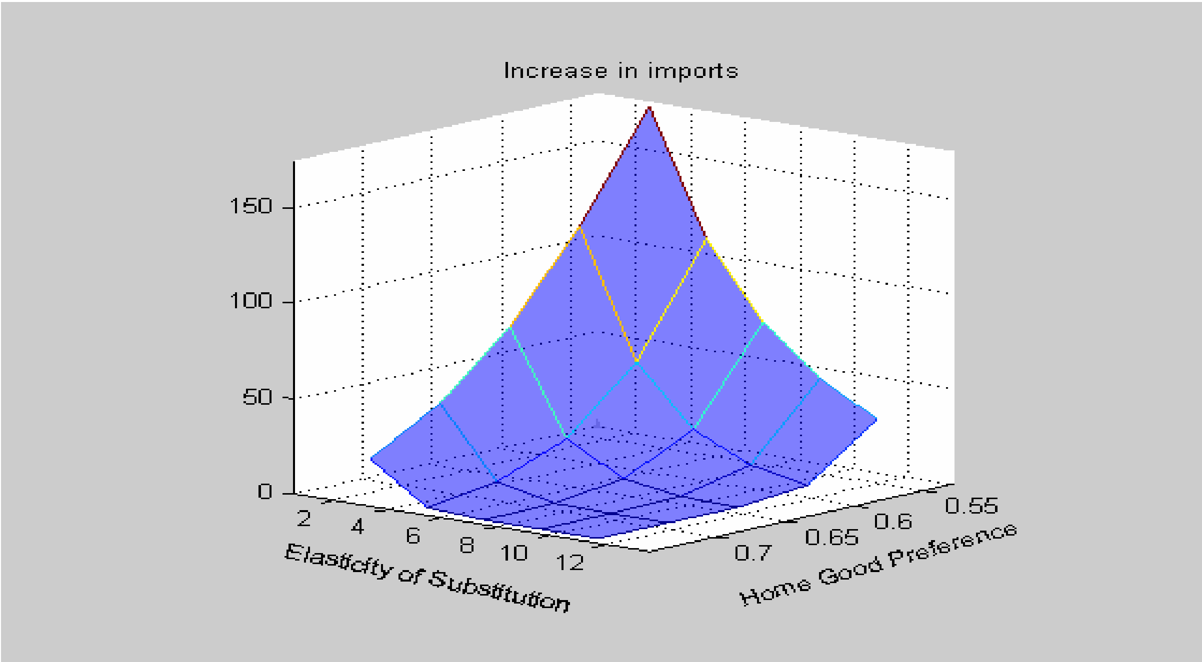
In this paper, we revamped the tariff equivalent of a TBT by relaxing the homogeneous commodity assumption, accounting for perceived quality of substitutes and trade costs. The latter are often larger than policy impediments and cannot be abstracted from them. Transportation and trade costs are structured on a per-unit basis rather than being ad valorem. Specific (as opposed to proportional) trade costs reduce the variability of the estimate of TBT with respect to the variability of import unit value across different reference years. Their influence on the TBT estimate is mitigated as the import unit value increases. Trade costs and imperfect substitution have offsetting influences in the computation of the estimate of the TBT. Since most previous applications have ignored these two aspects, these previous applications have somewhat mitigated the error implied by the two simplifications and dissimulated the inherent sensitivity of the TBT estimate to each of these underlying parameters.

Figure 1. Sensitivity of Net Welfare (EV+Tariff Revenue-Loss of Producers' Surplus) to σ and α with Elimination of TBT (Without Disease Transmission) (ε_s=1)



Note: For visual simplicity, the net welfare measure where TBT_T is not defined is set to be zero.

Figure 2. Increase in Imports' Sensitivity to σ and α with Elimination of the TBT (in tmt)



Note: For visual simplicity, the net welfare measure where TBT_T is not defined is set to be zero.

The rigorous investigation of the Japan-US apple dispute first validates the approach and indicates the importance of empirical estimates of the magnitude of preferences (α and σ), which we estimated econometrically. We then explored the sensitivity of the tariff equivalent estimate of the TBT with respect to these two parameters, varying their value around the central estimates we had obtained. The TBT estimate and welfare analysis based on it are sensitive to these parameters. The sensitivity to the consumers' home preference has some implications for gravity equation models that impose restrictions of equal preference/quality for imported and domestic goods. These models are likely to provide biased measures of trade impediments and should relax this assumption.

More importantly, our research raises interesting policy implications. A striking result in the analysis of the apple dispute is that the increase in apple imports would be small (in value) no matter what parameter estimates are used. It appears that the alleged damage in lost exports claimed by the United States at the WTO (US$143.4 million) is substantially overstated. The political economy of the case is also intriguing. Much political goodwill has been spent on this dispute relative to the small size of the potential direct gains in agricultural exports. Ancillary benefits may exist if the United States eventually succeeds in opening the Japanese market and establishes a reputation as a persistent negotiator. Other countries or protected industries may pay attention to the United States' resolve in opening markets and may refrain from engaging in costly disputes.

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Appendix 1. Estimation of Parameters σ and α

The derivation process for the elasticity of substitution σ and home-good preference parameter α is as follows. First, divide equation (2) by equation (3), then solve for p_I to get

$$p_I = \left(\frac{D}{I}\right)^{\frac{1}{\sigma}} \frac{1-\alpha}{\alpha} p_D . \tag{A1}$$

Since we do not observe p_I directly (because it is also a function of TBT_T), we substitute p_I into equation (2) and rearrange terms to obtain

$$\frac{M}{p_D D} - 1 = \left(\frac{I}{D}\right)^{1-\frac{1}{\sigma}} \left(\frac{1-\alpha}{\alpha}\right), \tag{A2}$$

where *M* is the expenditure on all apples. *I* is the aggregate imports since the individual imports from each country are too small to derive the parameters. We set *M* to be the expenditure on domestic apples plus the CIF price inclusive of import tariff, and T_R times the imported quantity *I* plus an assumed small TBT_2 (as 5% of the CIF price). The approximation of TBT_2 does not have much influence on the estimation of the parameters since the expenditure on imported apples is less than 0.35% of the total expenditure on average. ($I*TBT_2$) represents a very small percentage of the expenditure on all apples. We have varied TBT_2 from zero to 10% of the CIF price, and the estimation results remain close to the 5% case.

After taking natural logarithms, (A2) becomes

$$\ln\left(\frac{M}{p_D D} - 1\right) = \left(1 - \frac{1}{\sigma}\right) \ln\left(\frac{I}{D}\right) + \ln\left(\frac{1-\alpha}{\alpha}\right). \tag{A3}$$

Given a series of 2000-2004 monthly data of *M, D, I,* and p_D from Monthly Statistics of Japan, Japan Customs; and MAFF, we run two-stage least-square regression (2SLS) on (A3) since the right-hand-side variable $\ln(I/D)$ is endogenously determined.[12] Using the regression coefficient of $\ln(I/D)$ and intercept, we recover σ and α. We have 42 data points since for some of the months the imports are zero. Since *I/D* and apple expenditure are endogenous, we develop an instrument for $\ln(I/D)$ using exogenous price p_{CIF} and the Japanese real wage index, RWI, and years dummy variables in the first stage. We regress $\ln(I/D)$ on year dummy variables *year1* (2000), *year2* (2001 and so on), *year3*, *year4*, p_{CIF}, p_{CIF}^2, RWI, and RWI^2. The results of the instrument estimation are shown in Table A1.

[12] The Hausman Test was conducted, and the P-value for the test found to be <0.01, so $\ln(I/D)$ is endogenous. The estimation procedure used addresses the endogeneity.

Table A1. First-Stage Estimation Results of the 2SLS

Variable	Estimated Coefficients	Standard Deviation
Constant	16.649*	2.281
year1	-2.474*	0.304
year2	-5.306*	0.613
year3	-2.457*	0.325
year4	-2.674*	0.333
p_{CIF}	-0.091*	0.020
p_{CIF}^2	0.00026*	0.00004
RWI	-0.01890*	0.00442
RWI^2	0.00004*	0.00001

Note: * The coefficients significant at 1%.

The R^2 of the regression is 0.9334 and adjusted R^2 is 0.9172, indicating a good fit. We developed alternative instruments using other exogenous variables such as monthly dummy variables, higher orders of CIF price, and *RWI*. Results are very robust to variation in instruments. From the regression results above, we get the fitted value of $\ln\left(I/D\right)$, $\ln\widehat{(I/D)}$. In the second stage, we regress the left-hand side of (A3) on $\ln\widehat{(I/D)}$. The results are as follows.

Table A2. Second-Stage Estimation Results of the 2SLS

Variable	Estimated Coefficients	Standard Deviation
Intercept	-0.579*	0.220
$\ln\widehat{(I/D)}$	0.860*	0.041

Note: * means the coefficient is significant at 1%.

The R^2 and adjusted R^2 of the regression are 0.8982 and 0.8957, respectively. Combining the results in Table A2 and equation (A3) allows us to obtain $\hat{\sigma}$ and $\hat{\alpha}$, results reported in Table A3. The estimates' standard deviations are calculated using the Delta method (Greene).

Table A3. Estimated Results of σ and α

Parameter	Estimated Value	Approximate Standard Deviation
σ	7.12*	2.09
α	0.64*	0.05

Note: * means the coefficient is significant at 1%.

We also used nonlinear least squares on the second stage of the estimation; the results were $\hat{\sigma}_n$ =7.15 and $\hat{\alpha}_n$ =0.67, quite close to those obtained using 2SLS.

Appendix 2. Sensitivity Elasticities of TBT_T to Underlying Determinants

To measure the sensitivity of the TBT_T to assumptions on unobservables, we hold "observed" variables *D, I*, P_D, P_{US}, and T_R constant and obtain the following sensitivity elasticities of the TBT with respect to its determinants σ, and α, $\varepsilon_{(.)} = \frac{\partial \ln TBT_T}{\partial \ln(\cdot)}$:

$$\varepsilon_\sigma = \frac{\partial \ln TBT_T}{\partial \ln \sigma} = -\frac{p_D \frac{1-\alpha}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}} \ln\left(\frac{D}{I}\right)\frac{1}{\sigma}}{TBT_T} < 0 \text{ if } D > I, \tag{A4}$$

$$\varepsilon_\alpha = \frac{\partial \ln TBT}{\partial \ln \alpha} = -\frac{p_D \frac{1}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}}}{TBT_T} < -1. \tag{A5}$$

Elasticity ε_σ is negative and large in absolute value for small values of σ and converges to zero as σ increases. Elasticity ε_α is negative and in absolute value is the largest of the sensitivity measures; it decreases as goods *D* and *I* become closer substitutes but remains larger than 1. Hence, we can identify a taxonomy of cases. If goods *D* and *I* are known to be poor substitutes (presumption of small σ), the TBT_T estimate will be very sensitive to the value of σ and parameter α and to chosen reference prices and quantities. However, if goods *D* and *I* are known to be very close substitutes (with presumption of high σ), TBT_T will be much less sensitive to pinning down the exact elasticity of substitution, and to reference data volumes *D* and *I*. Sensitivity to chosen reference prices and preference parameter α will still be important and larger than 1 in absolute value.

We further explore this sensitivity in the empirical application. Reference data used to calibrate (7) also matter greatly. To measure the sensitivity of TBT to the chosen reference data, we derive similar elasticities with respect to quantity volumes *D* and *I*, relative prices P_D and P_{US}, and transportation cost T_R and Tariff:

$$\varepsilon_D = \frac{\partial \ln TBT_T}{\partial \ln D} = \frac{p_D \frac{1}{\sigma}\frac{1-\alpha}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}}}{TBT_T} > 0, \tag{A6}$$

$$\varepsilon_I = \frac{\partial \ln TBT_T}{\partial \ln I} = -\frac{p_D \frac{1}{\sigma}\frac{1-\alpha}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}}}{TBT_T} < 0, \tag{A7}$$

$$\varepsilon_{p_D} = \frac{\partial \ln TBT_T}{\partial \ln p_D} = -\frac{p_D \frac{1-\alpha}{\alpha}\left(\frac{D}{I}\right)^{\frac{1}{\sigma}}}{TBT_T} > 1, \tag{A8}$$

$$\varepsilon_{T_R} = \frac{\partial \ln TBT_T}{\partial \ln(T_R + IT_R)} = -\frac{T_R + IT_R}{TBT_T} < 0, \tag{A9}$$

and

$$\varepsilon_{Tariff} = \frac{\partial \ln TBT_T}{\partial \ln Tariff} = -\frac{Tariff}{TBT_T} < 0. \tag{A10}$$

The measures ε_D and ε_I are equal and opposite in sign and also depend on the value of σ. The values decrease in absolute value as D and I become closer substitutes. Sensitivity measure ε_{P_D} is larger than 1 but smaller than ε_α by a factor of (1-α). It decreases as goods are closer substitutes but remains larger or equal to 1. The sensitivity measures ε_{T_R} and ε_{tariff} will be small (large) in absolute value if the transportation costs, T_R, and the tariff were to be small (large) and if the estimate of the TBT_T were to be large (small). Sensitivity to changes in internal transportation or transaction costs and the tariff rate will depend on their initial values and could be large for protected and poorly integrated sectors. Table A4 provides the estimated elasticities of TBT_T discussed above and in the main text.

Table A4. Elasticity of TBT_T (σ =7.12; α =0.64)

$T_R + IT_R$ (yen/kg)	ε_{T_R}	D (tmt)	ε_D	I (mt)	ε_I	p_D (yen/kg)	ε_{p_D}	Tariff (yen/kg)	ε_{Tariff}
17.5	-0.040	600	0.534	200	-0.370	210	3.64	18.72	-0.156
35.0	-0.082	640	0.521	280	-0.401	220	3.25	24.96	-0.218
52.5	-0.129	660	0.515	320	-0.416	230	2.96	31.20	-0.280
78.3	-0.207	700	0.504	400	-0.444	240	2.74	37.44	-0.343
87.5	-0.235	720	0.499	440	-0.457	250	2.56	40.56	-0.374
105.0	-0.296	740	0.494	480	-0.470	260	2.41	43.68	-0.405
122.5	-0.364	760	0.490	520	-0.483	265	2.35	46.80	-0.436

Note: Analysis is for year 2000.