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Estimating the Elasticity of Substitution for Traded Products: Evidence from Japan

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Abstract

This paper estimates product-level elasticities of substitution for Japanese imports using HS6-digit trade data and the empirical framework developed by Feenstra (1994), incorporating the refinements proposed by Soderbery (2015). While much of the existing literature relies on estimates derived from U.S. data or global trade datasets, we focus explicitly on Japan and examine how methodological choices affect both estimated elasticities and the scope of products for which estimation is feasible.

A central contribution of this study is to analyse the role of reference country selection in elasticity estimation. We compare two alternative reference country rules: a product-specific reference country, defined as Japan's largest trading partner for each product, and a fixed reference country, namely the United States. Our results show that reference country choice affects not only the level and distribution of estimated elasticities, but also the extensive margin of products for which elasticities can be estimated.

We find that differences across reference country rules are relatively small for products in the lower and middle parts of the elasticity distribution, but become substantial in the upper tail. In particular, second-step estimates following Soderbery (2015) exhibit high sensitivity to both reference country choice and the treatment of extreme values. These findings underscore the importance of robustness in empirical estimation and caution against relying on elasticity estimates derived from a single reference country specification.

By providing systematic product-level elasticity estimates for Japan and highlighting the empirical importance of reference country selection, this study contributes to a deeper understanding of import structure, welfare analysis, and the quantitative evaluation of trade policy.

Keywords: Substitution elasticity; Reference country selection; HS6-digit trade data; Extensive margin; Trade policy analysis

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1 Introduction

The elasticity of substitution across traded products is a central structural parameter in international trade and macroeconomic models. It plays a crucial role in evaluating welfare effects, price responses, and the impact of trade policy. As a result, a large body of empirical research has attempted to estimate substitution elasticities for traded products, attracting sustained interest from both academic researchers and policymakers.

Seminal work by Feenstra (1994) laid the foundation for empirical estimation of trade elasticities using disaggregated import data. Subsequent studies, most notably Broda and Weinstein (2006), provided systematic estimates for the United States and demonstrated the substantial welfare gains from increased product variety. Later contributions, such as Soderbery (2015), addressed statistical biases inherent in earlier approaches and improved the robustness of elasticity estimates. More recently, large-scale projects led by CEPII, including Fontagné et al. (2022), have estimated substitution elasticities at the HS6-digit product level using global trade data.

Despite this progress, several important concerns remain unresolved. First, substitution elasticities may depend on country-specific import structures, implying that estimates obtained for the United States may not be directly applicable to other economies. Second, the validity of applying product-level elasticities estimated from global trade data to country-specific welfare analyses is not self-evident. Indeed, a meta-analysis by Bajzik et al. (2020) documents substantial dispersion in estimated elasticities across studies, while Boehm et al. (2023) show that results can vary considerably depending on the sample period and data coverage.

The estimation framework proposed by Feenstra (1994) assumes that substitution elasticities are constant over time. In reality, however, international trade is characterised by continuous entry and exit of trading partners, as well as the emergence of new products. Consequently, the measurement of trade elasticities should not be viewed as a one-time exercise, but rather as an object of ongoing empirical reassessment.

Motivated by these considerations, this paper estimates product-level elasticities of substitution for imported products in Japan using HS6-digit import data. In addition, building on the Feenstra (1994) methodology, we explicitly examine how the choice of reference country affects both the estimated elasticities and the set of products for which estimation is feasible. By linking reference country selection to both the level of estimated elasticities and the extensive margin of estimable products, this study reframes elasticity estimation as a joint problem of measurement and sample selection.

The following sections develop this argument step by step, beginning with a review of related literature and followed by the empirical framework and results.

2 Background

2.1 Changes in Global Trade Structure and the Role of Substitution Elasticity

Classical theories of international trade, such as the Ricardian model and the Heckscher–Ohlin (HO) framework, emphasise production efficiency and comparative advantage arising from differences in technology and factor endowments. In these models, trade patterns are primarily determined by supply-side conditions.

As technological progress accelerated and economies of scale became increasingly important, however, the determinants of global trade patterns gradually shifted. Analytical attention moved away from producer-centred efficiency towards consumer demand for product variety and changes in market structure. This transformation in perspective began in the late 1960s and 1970s.

Armington (1969) challenged the assumption of homogeneous goods by introducing the hypothesis that consumers differentiate products by country of origin. Subsequent contributions by Lancaster (1977) and Krugman (1979) formalised consumer preferences for variety and laid the foundation for the new trade theory. These studies demonstrate that product variety is not only a key source of consumer welfare, but also a major driver of observed trade patterns.

In particular, Krugman's (1979) monopolistic competition model integrates economies of scale with preferences for variety, thereby clarifying the central role of substitution elasticity in trade models. The elasticity of substitution measures the degree to which consumers are willing to substitute across varieties within a product category. At the same time, it directly determines the magnitude of welfare gains associated with an expansion in available varieties. As a result, substitution elasticity constitutes a fundamental structural parameter in empirical studies based on the new trade theory, with important implications for understanding global trade structure, price transmission, and the design of trade policy.

2.2 The Role of Trade Elasticity in International Economics

Krugman (1979) was among the first to incorporate imperfect competition explicitly into international trade theory, demonstrating that monopolistic competition provides a powerful explanation for real-world trade patterns. Within this framework, the elasticity of substitution across varieties plays a central role. It governs not only consumers' willingness to substitute between differentiated products, but also the welfare effects arising from changes in the set of available varieties.

The 1990s witnessed rapid progress in global trade liberalisation, including the establishment of the WTO in 1995, the implementation of NAFTA in 1994, and the deepening of the European Single Market in 1993. These developments accelerated cross-border trade flows and expanded the range of products available to consumers. Under such conditions, traditional theories based solely on comparative advantage proved insufficient, and analytical focus shifted towards models emphasizing economies of scale and variety effects (Krugman, 1995; Feenstra, 1998).

On the empirical front, Feenstra (1994) proposed an innovative method for estimating substitution elasticicities based on changes in import unit values. This approach made it possible to quantify welfare gains from increased variety within the framework of the new trade theory, and it has since served as a cornerstone of the empirical trade literature.

Broda and Weinstein (2006) extended Feenstra's methodology and provided systematic estimates of substitution elasticities for U.S. imports. They also developed a framework for empirically measuring the welfare effects of changes in the number of imported varieties. Subsequently, Ossa (2015) incorporated substitution elasticities into quantitative trade models to analyse how international trade affects national welfare and to characterise the distribution of gains from trade negotiations.

More recently, substitution elasticities have been widely used in the evaluation of tariff policies. Soderbery (2018) derived optimal tariff rates using product-level elasticity estimates for U.S. trade data. Amiti, Redding, and Weinstein (2019) analysed the impact of tariff increases under the Trump administration, showing that substitution elasticity is a key determinant of welfare losses through price changes and variety substitution.

3 Literature Survey

3.1 Why Adopt the Feenstra (1994) Approach?

Since Krugman (1979) introduced the so-called "new trade theory," international trade research has evolved from traditional frameworks based on perfect competition and homogeneous goods towards models that explicitly incorporate imperfect competition, economies of scale, and product differentiation. This theoretical shift has played a crucial role in explaining empirically observed trade patterns, such as intra-industry trade and the expansion of product variety within industries.

Subsequent contributions further enriched this literature by introducing supply-side heterogeneity. Eaton and Kortum (2002) developed a Ricardian model with productivity dispersion across countries, while Melitz (2003) introduced firm-level heterogeneity and endogenous export participation. These models provide powerful tools for analysing changes in trade structure, welfare implications, and the effects of policy shocks by explicitly modelling differences in productivity across countries and firms.

Alongside these supply-side approaches, another important theoretical lineage is based on the Armington assumption. Under this hypothesis, consumers perceive products as differentiated by country of origin even within the same product category. Armington-type models describe substitution behaviour across country-specific varieties and place the elasticity of substitution at the core of the demand structure. In this framework, the elasticity governs how changes in prices and trade costs–such as tariffs, transport costs, and other trade barriers–translate into shifts in trade flows and consumer welfare.

Empirical studies of trade elasticities can broadly be divided into two main approaches. The first approach, exemplified by Melitz (2003) and Chaney (2008), relies on firm-level micro data to estimate productivity distributions and entry costs. While this approach captures firm heterogeneity in detail, it typically depends on strong assumptions about productivity distributions (e.g., Pareto distributions) and requires rich micro-level data, which are often unavailable or restricted in practice.

The second approach estimates trade elasticities using aggregate or product-level data within the framework of structural gravity models, incorporating bilateral trade flows, tariff data, and country fixed effects (Head and Mayer, 2015). Although widely used for policy simulations and large-scale quantitative analyses, this approach has limited ability to capture product-level entry and exit of trading partners.

In contrast, the central focus of this study is on how the entry and exit of exporting countries–namely, what we refer to as extensive-margin trade dynamics (Ijiri, 2022)–affect Japan's import structure at the product level. This objective calls for an empirical framework that can directly identify product-level dynamics, rather than relying solely on country-level aggregates.

Against this background, the estimation method proposed by Feenstra (1994) offers a framework that combines theoretical consistency with empirical flexibility. Assuming CES preferences, Feenstra's approach avoids direct estimation of unobservable price indices by constructing relative price and import share measures. This feature allows researchers to exploit entry and exit of exporting countries in disaggregated trade data to identify substitution and supply elasticities indirectly.

The Feenstra framework is not only consistent with Armington-type demand structures, but also capable of incorporating dynamic changes in product composition and trading partners. Moreover, it can be applied to various data structures–including time-series, cross-country, and industry-level analyses–and does not require firm-level micro data. For these reasons, it has become a standard empirical tool in the literature on trade elasticities and has been widely used by international organizations such as the WTO and the IMF for tariff policy simulations and welfare analyses.

Taken together, these considerations suggest that the Feenstra (1994) approach is particularly well suited for analysing changes in import structure driven by entry and exit of trading partners, while maintaining both structural coherence and empirical robustness.

3.2 Empirical Applications of the Feenstra Framework

Feenstra (1994) was the first to provide a systematic method for estimating the elasticity of substitution in import demand using changes in import prices and market shares. By allowing consumer preferences to evolve over time and avoiding direct estimation of unobservable price indices, this method identifies demand elasticities from observed variation in import shares and unit values. As a structural approach grounded in equilibrium conditions between supply and demand, it laid the foundation for subsequent empirical research in international trade.

Broda and Weinstein (2006) extended Feenstra's framework to a broader set of imported products and provided systematic estimates of substitution elasticities. To address issues related to extreme or poorly behaved estimates, they proposed a mixed GMM estimator that improves numerical stability. Using this approach, they quantified the welfare gains associated with increased product variety in U.S. imports and demonstrated the economic significance of variety expansion.

Despite its contributions, the Broda and Weinstein (2006) methodology relies on grid-search procedures, which raise concerns regarding computational efficiency and estimation precision. To address these limitations, Soderbery (2015) proposed an alternative estimation strategy based on limited-information maximum likelihood (LIML). This approach mitigates small-sample bias in short panel data and improves the statistical properties of elasticity estimates. Soderbery's contribution represents a substantial improvement to the Feenstra / Broda–Weinstein (F/BW) framework from both theoretical and econometric perspectives.

Empirical studies focusing on Japan remain relatively limited, particularly at the disaggregated product level. Ito and Matsuura (2017), as well as Aoyagi, Ito, and Matsuura (2022), apply Soderbery's methodology to Japanese trade data in the context of welfare analysis. Using HS9-digit import data, these studies estimate substitution elasticities for Japanese imports and help fill an important gap in the literature.

3.3 Contributions of This Study

Building on the Feenstra (1994) and Broda and Weinstein (2006) framework–hereafter referred to as the Feenstra / Broda–Weinstein (F/BW) framework–this study applies the estimation method proposed by Soderbery (2015) to Japanese import data in order to estimate product-level substitution elasticities.

While numerous empirical studies estimate trade elasticities across countries, relatively few focus on Japan, and even fewer provide systematic product-level estimates. Existing studies using Japanese data typically rely on HS9-digit classifications, which offer highly detailed product information and are well suited for analysing changes in product variety. However, with annual data, such fine classifications often suffer from intermittent trade and short observation periods, which severely restrict the set of products for which elasticities can be estimated.

In contrast, this study focuses on HS6-digit import data. This choice reflects both theoretical considerations inherent in the Feenstra (1994) methodology and practical empirical constraints. The Feenstra framework requires the selection of a reference country in order to difference out common shocks and unobservable price indices. Ideally, the reference country should be a major and stable trading partner for each product (Mohler, 2009).

When product classifications are excessively disaggregated, the number of trading partners declines and trade relationships become more sporadic, making it difficult to identify an appropriate reference country. This issue is particularly severe at the HS9-digit level, where many products fail to satisfy the reference country requirement. As a result, the set of products for which elasticities can be estimated–the extensive margin–shrinks substantially, potentially undermining the representativeness and stability of the estimates.

By contrast, HS6-digit classifications strike a balance between product heterogeneity and empirical feasibility. They preserve meaningful product differentiation while ensuring the presence of multiple stable trading partners for most products. Moreover, HS6-digit is an internationally standardised classification widely used by UN Comtrade, the WTO, and CEPII, facilitating international comparisons and policy applications.

A further contribution of this study lies in its explicit examination of how reference country selection affects both estimated substitution elasticities and the set of products for which estimation is feasible. Specifically, we compare two reference country rules: (i) a *product-specific reference* that selects, for each product, Japan's largest import partner; and (ii) a *fixed reference* that uses the United States as the reference country for all products.

This comparison allows us to assess not only how reference country choice influences the level and distribution of estimated elasticities, but also how it expands or constrains the extensive margin of estimable products. By doing so, this study provides new evidence on an important but underexplored aspect of elasticity estimation and contributes to a deeper understanding of Japan's import structure and its implications for welfare and trade policy.

Despite its widespread use, little attention has been paid to how reference country selection shapes not only elasticity estimates but also the set of products that enter the estimation sample.

4 Model

This section presents the theoretical framework used to estimate product-level elasticities of substitution, following Feenstra (1994). The key feature of this approach is the use of reference country differencing, which eliminates unobservable price indices and common shocks. This strategy allows for the simultaneous identification of demand-side substitution elasticities and supply-side elasticities using only relative variation across exporting countries.

The identifying variation in this framework is obtained from relative movements in prices and import shares across exporting countries within a product, after common components are differenced out using a reference country.

4.1 Consumer Preferences and Demand Structure

We assume that Japanese consumers derive utility from imported products differentiated by country of origin at the HS6-digit product level. Even within the same product category, products originating from different countries are treated as distinct varieties. This assumption follows the Armington (1969) hypothesis and is particularly appropriate for highly disaggregated trade data, where products are close substitutes but remain imperfectly substitutable across source countries.

Let q_{gct} denote the quantity consumed of product g imported from country c in year t. Subutility for product g is represented by the following CES function:

$$U_{gt} = \left(\sum_{c \in \mathcal{C}_{gt}} d_{gct}^{\frac{1}{\sigma_g}} q_{gct}^{\frac{\sigma_g - 1}{\sigma_g}} \right)^{\frac{\sigma_g}{\sigma_g - 1}}, \quad \sigma_g > 1, \tag{1}$$

where $\sigma_g > 1$ denotes the elasticity of substitution across source countries for product g. The term d_{gct} captures consumers' preferences and perceived quality of product g produced in country c. $\mathcal{C}_{gt}$ denotes the set of exporting countries supplying product g to Japan in year t.

Under CES preferences, consumers shift demand towards varieties whose relative prices decline. The magnitude of this response is governed by σ_g, which therefore serves as a central structural parameter measuring the sensitivity of the import composition to price changes.

The import share of country c for product g in year t, denoted s_{gct}, is given by

$$s_{gct} = \frac{d_{gct} p_{gct}^{1-\sigma_g}}{\sum_{k \in \mathcal{C}_{gt}} d_{gkt} p_{gkt}^{1-\sigma_g}}, \tag{2}$$

where p_{gct} is the import price of product g from country c. This expression shows that import shares are determined as a function of relative prices; however, the right-hand side contains an unobservable price index. As a result, σ_g cannot be directly estimated from this equation alone.

4.2 Import Demand and Supply

Under the CES preference structure, the import demand function for product g sourced from country c is given by

$$q_{gct} = d_{gct} \left(\frac{p_{gct}}{P_{gt}} \right)^{-\sigma_g} Q_{gt}, \tag{3}$$

where p_{gct} denotes the import price of product g from country c, P_{gt} is the CES price index for product g, and Q_{gt} represents total consumption of that product.

The import share of country c for product g can be expressed as

$$s_{gct} \equiv \frac{p_{gct} q_{gct}}{P_{gt} Q_{gt}} = \frac{p_{gct} q_{gct}}{\sum_{c' \in \Omega_{gt}} p_{gc't} q_{gc't}}.$$

Using this expression, the demand function in equation (3) can be rewritten in terms of import shares as

$$\ln s_{gct} = \ln d_{gct} + (\sigma_g - 1) \ln \left(\frac{P_{gt}}{p_{gct}} \right). \tag{4}$$

Taking logarithms of the import-share demand function in equation (4) and differencing it relative to period $t-1$ yields

$$\Delta \ln s_{gct} = \varphi_{gt} - (\sigma_g - 1) \Delta \ln p_{gct} + \varepsilon_{gct}, \tag{5}$$

where $\varphi_{gt} \equiv (\sigma_g - 1) \Delta \ln P_{gt}$ and $\varepsilon_{gct} \equiv \Delta \ln d_{gct}$. The term φ_{gt} contains the product-level price index and is common across exporting countries.

On the supply side, following Feenstra (1994), we specify the supply curve as

$$p_{gct} = v_{gct} q_{gct}^{\omega_g}, \tag{6}$$

where v_{gct} captures the effects of technological change and other factors influencing production, and ω_g denotes the elasticity of export supply with respect to quantity. Taking logarithms and differencing relative to period $t-1$ yields

$$\Delta \ln p_{gct} = \psi_{gt} + \frac{\omega_g}{1+\omega_g} \Delta \ln s_{gct} + \delta_{gct}, \tag{7}$$

where $\psi_{gt} \equiv \frac{\omega_g}{1+\omega_g} \Delta \ln(Q_{gt} P_{gt})$ and $\delta_{gct} \equiv \frac{\omega_g}{1+\omega_g} \Delta \ln v_{gct}$.

Both the demand and supply relationships contain unobservable price indices and common shocks, which complicate direct estimation. The next subsection clarifies the role of reference country differencing in addressing these issues.

4.3 Reference-Country Differencing and Estimation Equation

The identifying variation in this framework is obtained from relative movements across exporting countries within a product, making the choice of reference country a central empirical decision. The core insight of Feenstra (1994) is that differencing relative to a reference country k within the same product removes unobservable common components. Specifically, for product g in year t, we define the following log differences between exporting country c and the reference country k:

$$\Delta^k \ln s_{gct} \equiv \Delta \ln s_{gct} - \Delta \ln s_{gkt}, \tag{8}$$

$$\Delta^k \ln p_{gct} \equiv \Delta \ln p_{gct} - \Delta \ln p_{gkt}. \tag{9}$$

This transformation eliminates product-level price indices, aggregate demand components, and common time shocks, isolating only relative movements in prices and import shares across exporting countries.

Applying this reference country differencing to the demand and supply equations yields

$$\Delta^k \ln s_{gct} = -(\sigma_g - 1)\, \Delta^k \ln p_{gct} + \varepsilon^k_{gct}, \tag{10}$$

$$\Delta^k \ln p_{gct} = \frac{\omega_g}{1+\omega_g}\, \Delta^k \ln s_{gct} + \delta^k_{gct}, \tag{11}$$

where ε^k_{gct} and δ^k_{gct} denote relative demand and supply shocks, respectively.

Combining these two structural equations yields the following estimating equation, which takes a quadratic form in relative import shares and prices, as shown by Feenstra (1994):

$$Y_{gct} = \theta_{1g} X_{1gct} + \theta_{2g} X_{2gct} + u_{gct}, \tag{12}$$

where

$$
\begin{aligned}
Y_{gct} &\equiv \left(\Delta^k \ln p_{gct}\right)^2, \\
X_{1gct} &\equiv \left(\Delta^k \ln s_{gct}\right)^2, \\
X_{2gct} &\equiv \Delta^k \ln s_{gct}\, \Delta^k \ln p_{gct}, \\
u_{gct} &\equiv \frac{\varepsilon^k_{gct}\, \delta^k_{gct}}{\sigma_g - 1}, \\
\theta_{1g} &\equiv \frac{\rho_g}{(\sigma_g - 1)^2(1-\rho_g)}, \\
\theta_{2g} &\equiv \frac{2\rho_g - 1}{(\sigma_g - 1)(1-\rho_g)}, \\
\rho_g &\equiv \frac{\omega_g(\sigma_g - 1)}{1 + \omega_g \sigma_g} \in \left[0, \frac{\sigma_g - 1}{\sigma_g}\right].
\end{aligned}
$$

Estimating equation (12) allows us to jointly recover the product-level elasticity of substitution σ_g and the supply elasticity ω_g by mapping the estimated coefficients θ_{1g} and θ_{2g} back to the underlying structural parameters.

In Feenstra (1994), the reference country k is chosen as the largest trading partner for the importing country. Mohler (2009) examines the stability of this reference country selection rule and shows that choosing a major import partner as the reference country yields more stable estimates.

Nevertheless, as is clear from the structural equations, the estimates depend critically on the appropriateness of the reference country. If the reference country experiences country-specific shocks that do not spill over to the importing country–such as short-run events (e.g., the SARS outbreak in China in 2003) or long-run shocks (e.g., economic sanctions on Russia, post-1991 economic reforms in India, or the discovery of natural resources in a given country)–these shocks may be mistakenly removed as global shocks through the differencing procedure, leading to biased estimates or increased variance.

Accordingly, in the subsequent estimation of σ_g, we adopt two reference country selection rules: (i) a product-specific rule that chooses the major import partner for each product as the reference country, and (ii) a rule that selects the largest overall trading partner as the reference country. We compare the resulting estimates across these two approaches.

Based on this theoretical framework, the next section describes the data and estimation strategy used in the empirical analysis.

5 Data

5.1 Data Sources

This study uses annual Japanese import data from the United Nations Comtrade database covering the period from 1996 to 2023 to estimate elasticities of substitution for imported products.

Compared with monthly data, annual data involve a smaller number of time observations. However, they offer the advantage of allowing a broader set of reference-countries, which is particularly important in the context of the Feenstra (1994) methodology.

In the Feenstra framework, the reference country must satisfy specific conditions, and not all countries consistently report monthly trade data. Using annual data therefore makes it possible to cover a wider range of products and trading partners, thereby improving the overall coverage of the estimation. Over the sample period, the Japanese import data include 4,199 distinct HS6-digit products and a total of 3,234,776 observations. The objective of this study is to estimate substitution elasticities for Japanese imports as systematically as possible based on this dataset.

The Comtrade database reports three alternative measures of trade values: FOB value (free on board), CIF value (cost, insurance, and freight), and Primary value. From a theoretical perspective, CIF values are closest to the concept of import costs implied by the model. In practice, however, both FOB and CIF values suffer from missing observations for certain products and years. A comparison across the three value measures indicates that differences are relatively small overall. Given the trade-off between data completeness and conceptual accuracy, this study uses Primary values to compute import shares in order to maximise sample coverage and data reliability.

5.2 Construction of Product-Level Data

The unit of analysis is defined by the combination of product g at the HS6-digit level, exporting country c, and year t. For each observation, we construct measures of import value, import quantity, import unit value, and within-product import shares.

The import share of country c for product g in year t, denoted s_{gct}, is defined as

$$s_{gct} = \frac{V_{gct}}{\sum_{k \in C_{gt}} V_{gkt}}, \tag{11}$$

where V_{gct} denotes the import value of product g from country c in year t, and C_{gt} is the set of exporting countries supplying product g to Japan in that year.

Import unit values are computed as

$$p_{gct} = \frac{V_{gct}}{Q_{gct}}, \tag{12}$$

where Q_{gct} denotes the reported import quantity.

Observations for which import quantities are missing or reported as zero are excluded from the analysis, since unit values cannot be defined in such cases.

5.3 Sample Restrictions and Data Processing

The Feenstra (1994) estimation procedure relies on changes in import shares and import prices over time. Accordingly, each product must be observed for at least two consecutive periods in order to be included in the analysis. The sample is therefore restricted to products for which imports are observed in consecutive years.

To mitigate the influence of extreme price movements and potential measurement errors, we apply outlier treatment to the log changes in import unit values and import shares. Specifically, for each product, we compute the distribution of log changes and exclude observations lying above the 99th percentile or below the 1st percentile.

In addition, observations with extremely small import values may exert disproportionate influence due to measurement error. As a robustness check, we therefore exclude observations for which within-product import shares fall below a specified threshold.

5.4 Reference-Country Selection Rules

To examine how reference country choice affects estimated substitution elasticities, this study adopts two alternative reference country selection rules.

The first rule is the *Product-Specific Reference* (PSR). Under this rule, for each product g, a single reference country is selected based on a predetermined base period t_0. Specifically, the exporting country with the largest import value in the base year t_0 is chosen as the reference country and remains fixed throughout the entire sample period.This approach uses the country that plays the most important role in Japan's import structure at the base period as the benchmark, thereby avoiding time-varying reference selection and ensuring consistency across years.

The second rule is the *Fixed Reference: U.S.*. Under this rule, the reference country is fixed as the United States for all products and all years. This choice enhances comparability with existing studies and serves as a benchmark that avoids potential endogeneity in reference country selection.

By comparing the distributions of estimated substitution elasticities and the number of products for which estimation is feasible under these two rules, we systematically assess the impact of reference country selection on empirical results.

6 Results

This section reports the estimation results for product-level elasticities of substitution (σ) for Japanese imports. Based on the theoretical framework of Feenstra (1994), and incorporating the refinements proposed by Soderbery (2015), we estimate elasticities for HS6-digit products under alternative reference country rules. In the Feenstra framework, time-specific effects are eliminated by differencing relative to a reference country exporting the same product. Because the choice of reference country may affect estimated elasticities, this section systematically examines how reference country selection influences both the level and distribution of estimated elasticities, as well as the set of products for which estimation is feasible.

Specifically, we consider two reference country rules: (i) a *Product-Specific Reference* (PSR), defined as Japan's largest import partner for each product, and (ii) a *Fixed Reference* (FR), which fixes the United States as the reference country for all products. By comparing these two rules, we assess the robustness and empirical validity of estimated substitution elasticities.

6.1 Descriptive Statistics by Reference-Country Rule

Table 1: Baseline estimates of substitution elasticity (σ) at HS6-digit: comparison of reference country rules

Estimate	N	10th	50th	80th	90th	95th	99th	Mean
Panel A: Feasible First Step.								
Product-Specific Reference	2774	1.349	2.555	6.061	10.497	18.383	92.645	11.386
Fixed Reference, FR: U.S.	2944	1.318	2.233	4.844	7.895	12.820	72.269	6.810
Difference		0.031	0.322	1.217	2.602	5.563	20.376	4.576
Relative Difference (%)		2.3%	12.6%	20.1%	24.8%	30.3%	22.0%	40.2%
Panel B: Including the Infeasible First Step.								
Product-Specific Reference	3506	1.273	2.234	5.736	11.023	26.233	620.308	36.913
Fixed Reference, FR: U.S.	3727	1.261	2.087	4.758	8.490	18.382	512.673	31.236
Difference		0.012	0.147	0.978	2.533	7.851	107.635	5.677
Relative Difference (%)		0.9%	6.6%	17.1%	23.0%	29.9%	17.4%	15.4%

Notes: PSR = Product-Specific Reference; FR = Fixed Reference (U.S.).
Difference is defined as $\max(\sigma^{\text{PSR}}, \sigma^{\text{FR}}) - \min(\sigma^{\text{PSR}}, \sigma^{\text{FR}})$.
Percent Difference is defined as $\left[\max(\sigma^{\text{PSR}}, \sigma^{\text{FR}}) - \min(\sigma^{\text{PSR}}, \sigma^{\text{FR}})\right] / \max(\sigma^{\text{PSR}}, \sigma^{\text{FR}}) \times 100$.

Table 1 reports descriptive statistics for estimated substitution elasticities under the two reference country rules. Across both panels, differences between PSR and FR: U.S. estimates are small in the lower part of the distribution but increase markedly toward the upper tail. For instance, under the Feasible First Step condition,[1] the difference at the 10th percentile is approximately 0.031, whereas it reaches 2.602 at the 90th percentile. Similar patterns emerge when infeasible first-step observations are included.

Mean values further illustrate the importance of extreme observations. Under the Feasible First Step condition, the mean elasticity under PSR is 11.386, compared with 6.810 under FR: U.S., yielding a difference of 4.576. When infeasible observations are included, mean elasticities increase substantially, and the difference widens to 5.677. These results indicate that reference country choice has particularly large effects on estimated elasticities in the upper tail of the distribution.

6.2 The Extensive Margin of Estimable Products

The descriptive statistics above compare elasticity distributions conditional on successful estimation. However, not all products can be estimated under both reference country rules. Reference-country selection therefore also affects the *extensive margin*, defined here as the set of products for which substitution elasticities can be estimated.

[1] Following Soderbery (2015), the Feasible First Step condition requires that parameters implied by the first-stage estimation fall within theoretically admissible ranges. Observations that fail to satisfy this condition are included only in Panel B for comparison.

Under the fixed reference country rule (FR: U.S.), 760 products for which elasticities are estimable under PSR become infeasible. Conversely, under the product-specific reference rule, 415 products that are estimable under FR: U.S. cannot be estimated. Thus, each reference country rule excludes a non-negligible but distinct subset of products.

This finding implies that reference country selection influences not only the level and distribution of estimated elasticities, but also the composition of the product sample itself. Reliance on a single reference country rule can therefore substantially restrict product coverage. Allowing reference countries to vary by product expands the range of products for which elasticities are estimable, particularly in cases where a fixed reference country fails to satisfy the stability requirements of the Feenstra framework.

6.3 Statistical Tests of Differences Across Reference-Country Rules

To formally assess whether differences in estimated elasticities are statistically meaningful, we conduct hypothesis tests comparing σ estimated under PSR and FR: U.S. The null hypothesis is given by

$$H_0 : \sigma_g^{PSR} - \sigma_g^{FR} = 0.$$

Following the estimation procedure, we perform tests for three groups of estimates: the overall sample, first-step estimates, and second-step estimates corresponding to the Soderbery (2015) procedure. Results are reported in Table 2.

Table 2: Stepwise one-sample t-tests for differences in σ (PSR vs. FR: U.S.)

	N	Mean	t	p	95% CI
Panel A: Full Sample					
Overall	2,921	0.707	0.079	0.936	[−16.808, 18.222]
First-step	1,969	5.720	1.475	0.140	[−1.886, 13.325]
Second-step	173	−63.019	−0.914	0.362	[−199.050, 73.012]
Panel B: Difference-Based Trimming (99%)					
Overall	2,889	−23.568	−3.814	< 0.001	[−35.685, −11.452]
First-step	1,962	−1.562	−0.882	0.378	[−5.034, 1.910]
Second-step	171	−117.295	−2.370	0.019	[−214.989, −19.601]
Panel C: Sigma-Based Trimming (99%)					
Overall	2,865	2.146	2.779	0.006	[0.632, 3.660]
First-step	1,935	1.051	4.776	< 0.001	[0.619, 1.482]
Second-step	170	−56.950	−1.785	0.076	[−119.935, 6.030]

Panel A shows that without trimming, extreme observations inflate variance and prevent rejection of the null hypothesis. Panels B and C demonstrate that inference is highly sensitive to the treatment of outliers. In particular, second-step estimates exhibit substantial instability, and even the sign of the estimated difference can change depending on the trimming criterion.

6.4 Distributional Differences and Quantile Analysis

To further investigate the structure of these differences, we examine the distribution of elasticity differences across quantiles. Table 3 reports quantiles of absolute and relative differences between PSR and FR: U.S. estimates after trimming the top 1% of σ values.

Table 3: Distribution of differences in σ between PSR and FR: U.S. (HS6-digit, Japan, 1996–2023)

	N	25th	50th	75th	90th	95th	99th
Panel A: Difference							
Overall	2,865	0.464	1.470	4.376	13.385	29.481	221.171
First-step	1,935	0.479	1.483	4.031	10.404	18.645	50.167
Second-step	170	0.396	1.597	7.800	303.129	781.939	2,355.580
Panel B: Relative Difference (%)							
Overall	2,865	21.234	43.273	68.612	86.138	93.420	99.103
First-step	1,935	20.719	42.238	66.514	82.131	89.605	95.567
Second-step	170	20.746	49.205	81.335	99.162	99.794	99.948

The median difference in the overall sample is approximately 1.47, indicating close agreement for most products. However, differences increase sharply in the upper tail, exceeding 200 at the 99th percentile. This pattern is especially pronounced for second-step estimates, which display extreme dispersion in the upper tail.

Table 4: Percentile distribution of estimated trade elasticities across PSR–FR deviation intervals

	N	25th	50th	75th	90th	95th	99th
Panel A: Overall (0–20%)							
PSR	681	1.405	1.727	2.408	3.553	5.349	9.890
FR	681	1.405	1.708	2.457	3.725	5.411	9.679
Panel B: Overall (20–40%)							
PSR	667	1.552	2.055	2.943	4.600	7.285	384.501
FR	667	1.553	1.966	2.792	4.706	6.865	120.228
Panel C: Overall (40–60%)							
PSR	582	1.865	2.847	4.171	6.480	10.897	253.741
FR	582	1.566	2.356	3.583	5.555	8.690	30.079
Panel D: Overall (60–80%)							
PSR	538	1.735	4.226	6.274	9.010	13.606	162.315
FR	538	1.584	2.945	5.511	8.394	13.459	168.200
Panel E: Overall (80–100%)							
PSR	396	1.827	9.177	20.876	42.229	72.785	132.127
FR	396	1.468	2.661	12.694	37.994	79.120	136.619

As the relative deviation between PSR and FR: U.S. increases, estimated elasticities rise sharply, particularly in the upper quantiles. These results indicate that large discrepancies across reference country rules are closely associated with products exhibiting very high substitution elasticities.

6.5 Construction of the CBR Elasticity and Capped Estimates

The results above demonstrate that reference country selection introduces substantial uncertainty into elasticity estimates, particularly in the upper tail of the distribution, and that reliance on a single reference country rule can restrict product coverage. Motivated by these findings, we construct a *Conservative Baseline Reference* (CBR) elasticity that integrates information from both reference country rules.

For products for which σ can be estimated under both PSR and FR: U.S., the CBR is defined as

$$\sigma_g^{CBR} = \min\left(\sigma_g^{PSR},\ \sigma_g^{FR}\right).$$

For products that are estimable under only one reference country rule, the corresponding estimate is retained.

By construction, the CBR includes the union of products estimable under either reference country rule. As a result, σ^{CBR} is available for 3,997 products, compared with 3,506 products under PSR and 3,727 products under FR: U.S., indicating a substantial expansion in product coverage.

Following Broda and Weinstein (2006), we impose a common upper bound on estimated elasticities ($\sigma \leq 131.5$) to prevent extreme values from exerting disproportionate influence on descriptive statistics and subsequent welfare analysis. Table 5 reports the distribution of capped elasticities under PSR, FR: U.S., and CBR.

Table 5: Capped substitution elasticity estimates (σ) at HS6-digt: PSR vs. FR: U.S. vs. CBR

	N	10th	50th	80th	90th	95th	99th	Mean
PSR	3,506	1.273	2.324	5.736	11.023	26.233	131.500	7.810
FR: U.S.	3,727	1.261	2.087	4.758	8.490	18.382	131.500	6.970
CBR	3,997	1.188	1.741	2.986	4.855	7.766	116.940	4.115

Notes: PSR = Product-Specific Reference; FR = Fixed Reference (U.S.); CBR = Conservative Baseline Reference elasticity. All estimates are capped at $\sigma = 131.5$ following Broda and Weinstein (2006).

7 Conclusion

This study estimates product-level elasticities of substitution for Japanese imports using HS6-digit trade data and the empirical framework developed by Feenstra (1994), incorporating the refinements proposed by Soderbery (2015). In contrast to much of the existing literature, which relies either on U.S.-based estimates or on global trade data, this paper focuses explicitly on Japan and examines how methodological choices affect both estimated elasticities and the scope of products for which estimation is feasible.

Our analysis highlights the importance of reference country selection in the estimation of substitution elasticities. By comparing a product-specific reference country rule with a fixed reference country rule using the United States, we show that reference country choice influences not only the level and distribution of estimated elasticities, but also the extensive margin of estimable products. Allowing reference countries to vary by product expands the set of products for which elasticities can be estimated, particularly in cases where a fixed reference country fails to satisfy the stability requirements of the Feenstra framework.

The results further indicate that differences across reference country rules are relatively small for products located in the lower and middle parts of the elasticity distribution. However, for products in the upper tail, estimated elasticities can diverge substantially depending on the reference country rule and the treatment of extreme values. In particular, second-step estimates following Soderbery (2015) exhibit high sensitivity to both reference country choice and outlier treatment, underscoring the need for careful robustness analysis.

These findings have important implications for empirical research and policy analysis. First, elasticity estimates derived under a single reference country rule should be interpreted with caution, especially when applied to welfare or policy simulations that are sensitive to high elasticity values. Secondly, combining multiple reference country rules or constructing integrated baseline measures may provide a more robust empirical foundation for applied trade analysis.

Overall, this study contributes to the literature by providing systematic product-level estimates of substitution elasticities for Japan and by demonstrating that reference country selection plays a critical role in both the magnitude and coverage of elasticity estimates. Future research may extend this framework to other countries or explore alternative methods for aggregating elasticity estimates in the presence of reference country uncertainty.

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