Three essays on international economics

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DEDICATION

I dedicate this work to Eun Mi, Miso, Lachlan Woojoo, and my parents.

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ABSTRACT

This dissertation consists of two essays on trade and one on international finance. Chapter 2 studies how international trade lowers markups of multiple varieties produced by a discrete heterogeneous firm as a short-run equilibrium. Chapter 3 assesses a two-step estimation method recently used under the WTO Article 22.6 arbitration. Specifically, this paper focuses on the two latest arbitration cases using the Armington framework: Korea's large residential washers (LRW) (case DS464) and anti-dumping duty case involving China (case DS471). Chapter 4 considers how equity home bias is related to a country-level behavioral factor (unfamiliarity) when domestic investors have limited information about foreign equities.

CHAPTER 1. GENERAL INTRODUCTION

In this thesis, I explore several international economic issues. Specifically, I present two essays on trade and one on international finance.

Chapter 2 presents theoretical and simulation research in which I examine how international trade lowers markups of multiple varieties produced by a discrete heterogeneous firm as a short-run equilibrium. Notably, I employ head-to-head competition promoted by market liberalization. Using a structural simulation, I find that the liberalized market becomes pro-competitive such that a small number of productive firms survive by reducing markups and adjusting their range of products.

Chapter 3 examines how the World Trade Organization (WTO) handles arbitration in terms of nullification or impairment levels. I assess a two-step estimation method recently used under the WTO Article 22.6 arbitration. I focus on two recent arbitration cases using the Armington framework: Korea's Large Residential Washers (LRWs) case (DS464) and an anti-dumping duty case involving China (DS471). In my investigation, I find two critical issues in WTO's current arbitration: the Armington elasticity assumed is so low that Korea's calibrated LRW market share in the United States does not match the actual share; and, WTO mistakenly includes duties when calculating the damage level from the WTO-inconsistent duties in case DS471.

Chapter 4 is an empirical study of international finance in which I consider how equity home bias relates to a country-level behavioral factor (unfamiliarity) when domestic investors have limited information about foreign equities. First, I demonstrate that information friction on foreign equities has a positive relationship with equity home bias, allowing behavioral factors to work as a determinant. In the empirical analysis, I use a survey question in the World Value Survey to measure unfamiliarity and find a positive relationship between equity home bias and country-level unfamiliarity.

CHAPTER 2. SHORT-RUN EQUILIBRIUM OF INTERNATIONAL TRADE UNDER HETEROGENEOUS DISCRETE FIRMS WITH MULTIPLE CONTINUOUS VARIETIES

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2.1 Abstract

In this study, I demonstrate the impact of international trade on the markups of multiple varieties produced by productivity-differentiated discrete firms. Assuming fixed firm-level productivities across symmetric economies in the short-run, market liberalization introduces head-to-head competition among productive heterogeneous firms. In this pro-competitive market, productive firms survive by reducing markups, adjusting their range of products, and pricing competition with exporters with symmetric productivities, while inefficient firms fail to survive. Despite the importance of this topic, most trade studies identify long-run equilibrium properties in terms of prices, a range of varieties, and profits employing firm-level granularity and heterogeneity; however, they mute the short-run change in markups. Quantitative analysis results show that survivors in the liberalized market lower their markups and change the range of varieties in the short-run equilibrium.

2.2 Introduction

In liberalized markets, local firms respond to the introduction of productive exporters by lowering product markups and adjusting varieties to sustain business. As exporters expand in the domestic market, less productive firms struggle with lower revenue, as higher costs prevent them

from reducing product markups as much as efficient suppliers. When those inefficient firms face negative profits in the integrated market, they suspend business and exit the market, resulting in only efficient firms that provide a broader range of product varieties with lower markups surviving. In sum, the welfare of an economy rises from international trade due to the increasing number of products and lower prices of each variety.

Previous studies in international trade do not discuss the change in markups in the short-run; however, the models in those studies incorporate firm-level granularity and heterogeneity. For instance, Feenstra and Ma (2008) do not account for margin movement after bilateral trade under a heterogeneous and discrete firm environment and show the integrated market of international trade lowers markups of varieties within discrete and symmetric firms. Using an identical distribution of productivity among a fixed number of firms, Feenstra and Ma (2008) demonstrate that both market shares and markups do not change in the short-run regardless of market integration. However, they do not account for head-to-head competition between multiple firms in the short-run of international trade.

I demonstrate the impact of international trade on markups of multiple product varieties produced by a productivity-differentiated discrete firm. Using bilateral trade between symmetric economies incorporated in a simple framework without fixed and transportation costs, I find that productive firms in each economy survive head-to-head competition by reducing markups and adjusting product varieties. Using a nested constant elasticity of substitution (CES) demand system and a monopolistic competition environment, I investigate how firms choose the number of product varieties, the price of each variety, and how they relate to the market share in the short-run equilibrium.

No previous research provides quantitative results of markups decreasing due to international trade under heterogeneous discrete firms with multiple varieties. In the case of a continuum of firms, a firm's markup is invariant as a result of the zero-measured market share. Although this simple framework shows a concentration of resources on more productive firms and a higher threshold productivity due to the exit of the least productive and active firms in autarky, it cannot suffi-

ciently explain a firm's markup adjustment due to changes in market environment. Even though some studies account for all aspects of equilibrium from international trade except the changes in markups, they do not compare an individual firm's optimal choice between ex-ante and ex-post. For example, some only verify firm's ex-post behavior—the most productive firms surviving in the liberalized market have lower markups, higher expenditure, and higher profit.

Given the firm-level heterogeneity, only productive firms survive by lowering markups and adjusting their range of varieties in the short-run equilibrium of bilateral trade between symmetric economics. As head-to-head competition expels the least productive firms from the market, the number of domestic firms serving local markets reduces compared to autarky, which raises the intensity of a small number of productive firms after bilateral trade. Specifically, in the short-run equilibrium, the most productive firms take over the market share of the least productive firms active in the integrated market. Furthermore, the increase in the range of varieties by the surviving firms is not proportional to an increase in the size of the integrated market.

The rest of this paper proceeds as follows. Section 2.3 provides a review of previous literature. Section 2.4 outlines the theoretical framework and analytically demonstrates a firm's choice rule in equilibrium. Section 2.5 discusses quantitative results showing intensive competition when bilateral trade begins, which causes markups to fall. Section 2.6 offers concluding remarks.

2.3 Relation to Previous Literature

This study relates to previous pivotal studies on heterogeneous firms' behaviors when producing multiple varieties in the global market. I incorporate a framework that allows discrete firms (granularity) differentiated in productivity (heterogeneity) to produce multiple varieties. This paper is innovative in that it explores head-to-head competition that results in changes in markups and variety range in the short-run equilibrium of international trade. Therefore, I define the environment of international trade as active firms in autarky that retain productivity and face an integrated market in the short-run. [1]

[1] A general form of nested CES utility function allows an endogenous sectoral share. In the case of the Cobb-Douglas utility function on the top-tier preference, the sectoral share is fixed by an exogenous parameter.

2.3.1 Firm Heterogeneity in Production Efficiency

This paper is in the line of substantial research regarding heterogeneous firms in productivity and their behaviors in a monopolistic competitive market, à la Melitz (2003). Melitz (2003) builds a framework on the foundation that a continuum of potential firms decide whether to enter the market by comparing the expected entry cost and payoff. The entry cost is assumed as a sunk cost; and, unless the sunk cost exceeds the expected profit, the firm participates in the monopolistic competitive market and receives a draw of productivity. In autarky, the zero-cutoff profit productivity is determined uniquely, given a set of random productivity within firms that join the market. Each firm then makes a second-stage decision about whether or not to pay both fixed and variable costs and proceed with production. If the productivity of a firm is higher than the zero-cutoff, the firm survives the second stage and takes advantage of a non-negative profit from producing a single variety.

Melitz (2003) assumes that in the multilateral trade between symmetric economies, a fixed cost for exporting a variety is higher than that for serving a local market, which guarantees exporters higher zero-cutoff productivity. As a result, a productive firm serves its product to both domestic and foreign markets. Moreover, the existence of productive exporters in each market results in a higher zero-cutoff in equilibrium. This higher cutoff in equilibrium expels lower productivity domestic firms from the market. Melitz (2003) suggests a static equilibrium of international trade by incorporating differential productivity across firms. Given the heterogeneous firms in productivity, Ghironi and Melitz (2005), Das et al. (2007), Alessandria and Choi (2014) and Alessandria et al. (2014) investigate how firms respond to international trade dynamically. Konings and Vandenbussche (2008) suggests that trade policy can have a heterogeneous impact on firms relying on their assigned productivity.

2.3.2 Multiple Varieties Produced by a Firm

Maintaining a continuum of firms with differentiated economic productivity, Bernard et al. (2011) allow the zero-measured firm to produce multiple varieties and consider two stochastic

environments—firm-level random productivity (ability) and a firm-product-level random variable (attribute). If a firm decides to enter the market by paying the sunk cost, as demonstrated in Melitz (2003), it receives random draws of firm-level productivity and product-level consumer taste. Each firm can determine the range of a continuum of varieties and their prices. In equilibrium, a high-ability firm introduces high-attribute products in the global market, which replaces low-attribute domestic goods. This product-level reallocation raises zero-cutoff productivity in equilibrium in the integrated market between symmetric economies.

Feenstra and Ma (2008) and Dhingra (2013) depart from the zero-measured firms assumed in Melitz (2003) and Bernard et al. (2011); and, instead, account for multiple varieties within a relatively large firm. As each firm is large enough to be positively measured, it has pricing power on products. Along with a firm's ability to choose its range of varieties, these studies incorporate the cannibalization effect, which is a firm's opportunity costs from expanding a range of varieties. The existence of the cannibalization effect limits a firm's choice for a range of varieties to a finite number. Dhingra (2013) utilizes a linear demand system and lets the cost of production depend on the investment in innovation and argues that gains from trade depend on the focus of innovation, which is either expanding varieties or production processing. Although Dhingra (2013) concentrates on the theoretical framework of the industrial organization, Feenstra and Ma (2008) conducts structural experimentation to find the heterogeneous firm's dynamics in the integrated market between symmetric economies. Feenstra and Ma (2008) offer meaningful results that are consistent with the granular environment in the global economy—as the link between market size and number of firms is weak, market integration does not necessarily yield a marginal increase in the number of survivors. The small number of market survivors respond to the global market by expanding their range of varieties proportional to the aggregated market size. Since there is no change in the number of survivors in the market with the same productivity, the market share is persistent, as in the long-run equilibrium. Therefore, markups are constant regardless of the changes in the exogenous market size.

2.3.3 Discrete Firm

In the international trade literature investigating individual firm behavior, granularity consists of two necessary features: (a) a fat-tailed distribution of firms; and, (b) discreteness of firms. These two features let a small number of productive firms control markups and product scopes in response to changes in both domestic and foreign markets. As the law of large numbers is not valid under granularity, a single exporter can affect the aggregate economy.

Using Compustat data, Gabaix (2011) find sales from the top 50 firms in the United States share 24% of gross domestic product (GDP) and the next 50 firms share 5% of GDP, which suggests that we can associate firm-level shocks with aggregate economic phenomena. The main empirical results indicate that the firm-level shocks to the top 100 firms account for one-third of GDP fluctuations.

Di Giovanni and Levchenko (2012) expand the granular model in the spirit of Melitz (2003), though model-derived markups are constant regardless of productivity. Bernard et al. (2018) and Di Giovanni and Levchenko (2012) focus on a particular case of monopolistic competition. Di Giovanni and Levchenko (2012) suggest that the concept of granularity can help explain the high sensitivity of a small open economy to the aggregate fluctuations from firm-level idiosyncratic shock.

Eaton et al. (2012) also construct a granular model expanded from Melitz (2003) and Chaney (2008). They analytically compare how the discrete firm model is different from that of a continuum firm model in terms of optimal pricing.

Edmond et al. (2015) and Gaubert and Itskhoki (2018) amend the constant markup in Di Giovanni and Levchenko (2012). According to Amiti et al. (2019), there are strategic complementarities when firms set their prices. Gaubert and Itskhoki (2018) strictly follow the concept of granularity in developing their theoretical framework. Accounting for granularity and Zipf's law, they show how activities of a few discrete firms are associated with the sectoral comparative advantage. In general equilibrium, when combining two random draws in both sector- and firm-level productivity, Gaubert and Itskhoki (2018) find that granularity can explain 20% of the export volatility. [2] More-

[2] I follow Eaton et al. (2012) in introducing two random draws concerning firm-level productivity and number of promising sectoral entrants.

over, Gaubert and Itskhoki (2018) suggest mean reversion in the comparative advantage related to granularity. [3]

Feenstra and Ma (2008), Hottman et al. (2016), and Bernard et al. (2018) maintain various markups consistent with the concept of granularity and allow firms to internalize firm-level impacts on macro-level aggregates. Based on a nested CES demand system, they offer a pricing rule for products that depends on marginal costs and producer status in each market. Therefore, product price variation relies on the market status of each region despite an identical marginal cost. They suggest that, given the equilibrium factor and product prices, productive firms set a higher markup and a broader range of varieties among survivors. The drawback of those studies is that they do not investigate how an individual firm changes its optimal choices in the transition from autarky to international trade.

2.3.4 Contributions

In this paper, I account for both granularity and multiple products within firms. Even though Melitz (2003) and Gaubert and Itskhoki (2018) suggest meaningful academic insights on new trade theory by employing firm-level heterogeneity, they fail to account for the cannibalization effect from producing multiple products. Thus, the single-variety framework is advantageous in that one can reach the general equilibrium easily using the unique concept of average productivity to represent surviving firms. In reality, most firms produce multiple products that are imperfect substitutes for each other. Therefore, the optimal range of varieties is a crucial element to firm-level decision making, as adding the marginal number of varieties yields both benefit and cost. A marginal increase in the range of varieties allows firms to earn a higher market share, though they experience lower revenue from existing products.

Furthermore, I amend a conventional environment of international economics in the short-run to show a change in the markup of a variety. According to the conventional short-run concept, a new stage of pricing competition begins at the onset of international trade. Therefore, as all

[3] For example, Gaubert and Itskhoki (2018) point that the death of a granular firm can change the comparative advantage significantly.

potential firms in each economy need their productivity reassigned, it is not possible to determine whether active firms in autarky survive in the integrated market or whether those firms would change variety markups. In this study, I assume all survivors in autarky maintain productivity and compete with exporters from the symmetric economy in the short-run. This new definition of the short-run allows explanation of the lower markups after international trade.

2.4 Framework

This section introduces the theoretical framework and derives analytic properties in equilibrium.

2.4.1 Preference

The postulated demand system employs a nested CES utility function with discrete firms and a continuum of varieties. As in Bernard et al. (2018) and Feenstra and Ma (2008), the CES preference nested in the Cobb-Douglas utility function has two advantages. First, the insight of firms' behavior is consistent with granularity—firms are large enough to affect the sector but sufficiently small enough to not have an impact on the aggregate economy. Second, it provides computational convenience when finding firm-level optimal allocations, as they are independent of the sectoral share. Therefore, one can more straightforwardly calculate computational solutions with a fixed level of sectoral expenditure. [4] In the appendix, I incorporate a CES utility function at top-level demand as a generalized demand system.

Figure 2.1 shows the overview of the demand system of a represented consumer, which is a CES preference nested to the Cobb-Douglas utility function. Consumers in an economy choose the amount of sectoral consumption to maximize their utility, which is measured as aggregate demand. Moreover, symmetric economies have an identical amount of labor (L), and the wage (w) is fixed as one in both economies.

There are two sectors nested to the aggregate demand. The homogeneous sector (0) supplies a single product, and the heterogeneous sector provides differentiated goods. The weight on demand

[4] The Cobb-Douglas utility is a CES demand system with elasticity of substitution set as one.

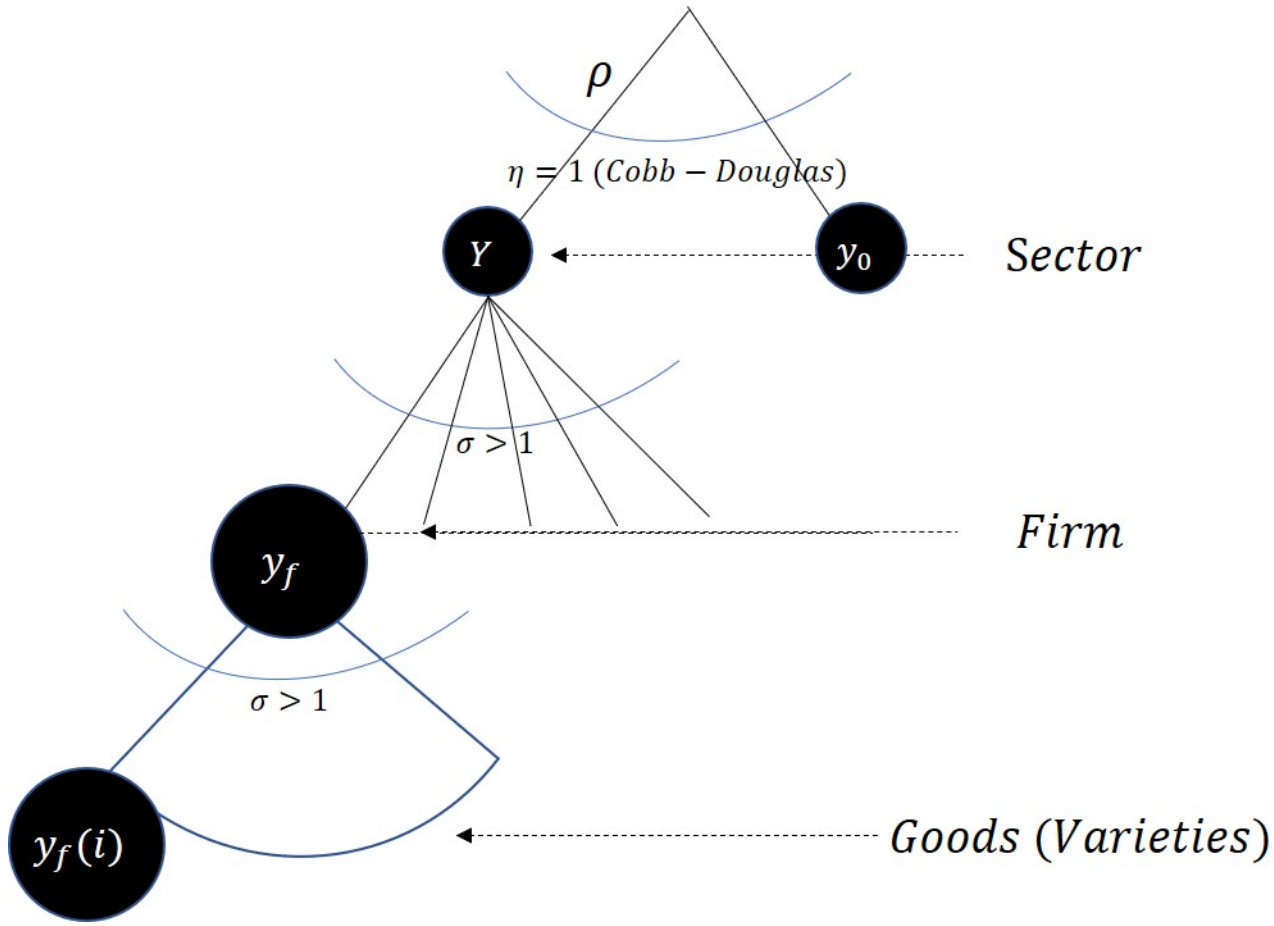

Figure 2.1: A Nested CES Demand System

for the heterogeneous sector is ρ, which is also the elasticity of sectoral demand. The elasticity of substitution unity in the sectoral demand implies the top-tier demand is the Cobb-Douglas preference. In that case, the expenditure share on the heterogeneous sector is invariant as ρ. The aggregate demand can be specified as:

$$U = y_0 + \rho \, ln \, (Y) \tag{2.1}$$

where U is the utility of the representative consumer; y_0 is the consumption of a homogeneous good; and, Y is an aggregate consumption of heterogeneous goods. Y is a CES aggregate across discrete firm-level demands, as in Equation (2.2):

$$Y = \left[\sum_{f \in \Omega} (y_f)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{2.2}$$

where y_f is a consumption index for firm f in the heterogeneous sector; $\sigma \, (> 1)$ is the elasticity of substitution in firm-level demand within the heterogeneous sector; and, Ω is a set of active firms in the heterogeneous sector in equilibrium. In Equation (2.2), there is no difference in taste appeals across firm-level demands. Therefore, I calculate the firm-level aggregate demand as a CES aggregate across continuous variety-level demand as:

$$y_f = \left[\int_{i \in \Omega_f} (y_f \, (i))^{\frac{\sigma-1}{\sigma}} \, di \right]^{\frac{\sigma}{\sigma-1}} \tag{2.3}$$

where $y_f \, (i)$ is consumption of variety i produced by firm f in the heterogeneous sector; and, Ω_f is a set of index of varieties that firm f in the heterogeneous sector produces ($\Omega_f = \{i \in \mathbb{R} \,|\, y_f(i) > 0\}$). If the same elasticity of substitution (σ) is applied to the variety-level demand, it reduces the computational burden. Specifically, given the symmetric production technology across varieties within a firm, the variety-level elasticity of substitution is redundant in a firm's optimal pricing rule.

I denote the number of varieties produced by firm f in the heterogeneous sector as $N_f = \int_{i \in \Omega_f} \mathbf{1}_f \, (i) \, di$, where $\mathbf{1}_f \, (i) = 1$ if $i \in \Omega_f$, zero otherwise.

Equation (2.4) describes the budget constraint of a representative consumer:

$$P_0 y_0 + \sum_{f \in \Omega} \left[\int_{i \in \Omega_f} \left[P_f(i) \times y_f(i) \right] di \right] \leq I \tag{2.4}$$

where I is the income of a representative consumer in the economy.

Utility maximization yields a sectoral price index dual to the sectoral demand function. In the heterogeneous sector, the sectoral price index (P), dual to the sectoral demand in Equation (2.2), is a CES aggregate across price indexes of the firm-level composite, such that:

$$P = \left[\sum_{f \in \Omega} (P_f)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{2.5}$$

The price of firm-level consumption, P_f, consists of prices of varieties produced by firm f, as in Equation (2.6):

$$P_f = \left[\int_{i \in \Omega_f} (P_f(i))^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}. \tag{2.6}$$

In equilibrium, the optimal allocations determine the firm-level expenditure share within the heterogeneous sector. [5] Equation (2.7) shows the expenditure share of the heterogeneous sector in the economy, which is fixed at ρ due to the Cobb-Douglas preference at the top-level demand:

$$S = \frac{\sum_{f \in \Omega} \left[\int_{i \in \Omega_f} \{P_f(i) y_f(i)\} di \right]}{I} = \rho. \tag{2.7}$$

Moreover, Equation (2.8) calculates the firm-level expenditure share within the heterogeneous sector:

$$S_f = \frac{\int_{i \in \Omega_f} \{P_f(i) y_f(i)\} di}{\sum_{g \in \Omega} \left[\int_{j \in \Omega_g} \{P_g(j) y_g(j)\} dj \right]} \tag{2.8}$$

[5] In the nested CES demand to the Cobb-Douglas utility function, the sectoral expenditure share within the economy is assumed as fixed ρ. In the generalized utility function, this sectoral expenditure share is also determined in equilibrium. The sectoral expenditure share is shown as an endogenous factor in the CES utility function at the top-level demand in the Appendix.

where R is the expenditure on the heterogeneous sector $R = \rho I$. Note that a summation symbol is applied to firm-level aggregation because the firms are treated as discrete. In contrast, as the varieties are supposed to be continuous, an integral is taken for aggregation. The expenditure on firm-level consumption in the heterogeneous sector is $E_f = \int_{i \in \Omega_f} \{P_f(i)\, y_f(i)\}\, di = RS_f = \rho I S_f$.

The expenditures and prices in equilibrium determine the Marshallian demand function at each level of consumption. In the heterogeneous sector, the sectoral demand function is:

$$Y = \rho I \frac{1}{P} = R \frac{1}{P}. \tag{2.9}$$

The demand function of firm-level composite is:

$$\begin{aligned} y_f &= \rho I S_f \frac{1}{P_f} \\ &= \rho I \frac{P_f^{1-\sigma}}{P^{1-\sigma}} \frac{1}{P_f} \end{aligned} \tag{2.10}$$

where $S_f = \frac{P_f^{1-\sigma}}{P^{1-\sigma}}$ is from the property of the CES utility function. It is worth documenting variety-level demand in the case of symmetric technologies across within-firm varieties while the variety-level consumption is continuous and zero-measured; thus, I convert the firm-level demand in Equation (2.3) to:

$$(y_f)^{\frac{\sigma-1}{\sigma}} = \int_{i \in \Omega_f} (y_f(i))^{\frac{\sigma-1}{\sigma}}\, di \tag{2.11}$$

Applying Equation (2.10) to Equation (2.11) allows derivation of:

$$\left[\rho I \frac{P_f^{1-\sigma}}{P^{1-\sigma}} \frac{1}{P_f}\right]^{\frac{\sigma-1}{\sigma}} = \int_{i \in \Omega_f} (y_f(i))^{\frac{\sigma-1}{\sigma}}\, di\ . \tag{2.12}$$

When technology is symmetric across varieties within firm f, the right-hand side of Equation (2.12) can be represented as the mass of variety:

$$\left[\rho I \frac{P_f^{1-\sigma}}{P^{1-\sigma}} \frac{1}{P_f}\right] = N_f\, [y_f(i)]^{\frac{\sigma-1}{\sigma}} \tag{2.13}$$

As $y_f(i)$ no longer depends on i, and $N_f = \int_{i\in\Omega_f} \mathbf{1}_f(i)\,di$ where $\mathbf{1}_f(i) = 1$ if $i \in \Omega_f$ and zero otherwise; then variety-level demand can be calculated as:

$$\begin{aligned} y_f(i) = y_{fi} &= \rho I S_f \frac{1}{P_f} (N_f)^{\frac{\sigma}{1-\sigma}} \;\; \forall i \in \Omega_f \\ &= \rho I S_f \frac{1}{N_f} \frac{1}{p_{fi}} \; . \end{aligned} \tag{2.14}$$

2.4.2 Technologies

Firms produce homogeneous goods using a constant return to scale technology with a unit of labor and trade the good without any trade costs. Also, there is no fixed cost for either entry or production. As the homogeneous good is treated as the numeraire ($P_0 = 1$), the price of the good is one. Therefore, the supplied quantity of the homogeneous good is w across economies because of $P_0 \times y_0 = y_0 = w \times 1$. Furthermore, as the wage in both symmetric economies is assumed to be one, the expenditure on this homogeneous good is one across economies. I account for the equilibria that all economies produce some of the homogeneous goods to simplify the analysis.

In the heterogeneous sector, there are M_e entrants in the market. In the short-run, the number of entrants (M_e) is fixed, so no sunk cost of entering the market is assumed. Each entrant is given random productivity drawn from the Pareto distribution, φ_f, following the cumulative distribution function of Equation (2.15): [6] [7]

$$Prob\left[\varphi_f < \varphi\right] = 1 - \left(\frac{\varphi^{min}}{\varphi}\right)^{\gamma} \tag{2.15}$$

where γ is a shape parameter of the Pareto distribution; and, φ^{min} is the lower support of random productivities. A higher γ implies that all productivities drawn are close to the lower bound φ^{min}. Productivities drawn are common knowledge among M_e firms; and, firms can determine whether

[6] As in Chaney (2008), assuming a Pareto distribution on firm sizes (productivities) has two advantages—it is analytically tractable and it approximates the firm sizes in the United States.

[7] According to Eaton et al. (2012), setting the restriction on the relationship between γ and σ ($\gamma > \sigma - 1$) is unnecessary in the discrete-firm case because the discrete case has no point for the integration over the distribution of prices. Also, as in Feenstra and Ma (2008), it is not possible to get a stationary equilibrium. In the granular environment, each random draw has a set of productivity, and there are potentially infinite draws, which implies different zero-cutoff profit (ZCP) conditions for each random productivity set.

to initiate production or exit the market depending on the expected profit. Surviving firms are assigned higher productivities so that they start production and benefit from a non-negative profit.

Surviving firms must account for two types of fixed costs related to producing the varieties: K_0, which is a fixed cost of initiating production and K_1, which is a fixed cost incurred when a firm adds a marginal variety to production. Both K_0 and K_1 are measured by the unit of labor and are identical across economies, firms, and varieties.

Random productivity φ_f defines a heterogeneous firm f that produces multiple varieties. As labor is the only production factor, firm f uses $(1/\varphi_f)$ units of labor to produce a unit of a variety. Therefore, when firm f produces $y_f(i)$ units of an individual variety i, the required labor units is $(y_f(i)/\varphi_f)$. Considering the wage (w), the marginal cost for firm f to produce a variety is $\frac{w}{\varphi_f}$, which is also the variable cost for producing a unit of a variety. Combining both fixed and variable costs, I calculate the total cost function as:

$$C_f = w\left[\frac{1}{\varphi_f}\left\{\int_{i\in\Omega_f} y_f(i)di\right\} + K_1\left\{\int_{i\in\Omega_f} \mathbf{1}_f(i)di\right\} + K_0\right] \tag{2.16}$$

$$where\ \ \mathbf{1}_f(i) = \begin{cases} 1 & if\ i \in \Omega_f \\ 0 & Otherwise \end{cases}.$$

In the case of symmetric technology across varieties within a firm, the supply of a variety i is independent of the index i. Therefore, one can denote the quantity of a variety as $y_f(i) = y_{fi}$. Moreover, the price of a variety is also the same across all varieties within a firm $(P_f(i) = P_{fi})$. Therefore, the total cost of firm f in the heterogeneous sector consists of:

$$C_f = w\left[\frac{1}{\varphi_f}N_f y_{fi} + K_1 N_f + K_0\right] \tag{2.17}$$

where N_f is the number of varieties produced by firm f in the heterogeneous sector. Then, the profit function of firm f in the heterogeneous sector can be specified as:

$$\Pi_f = \int_{i \in \Omega_f} \left[P_f(i) \times y_f(i) \right] di - C_f \tag{2.18}$$
$$= N_f \left(P_{fi} - \frac{w}{\varphi_f} \right) y_{fi} - w \left[K_1 N_f + K_0 \right] .$$

2.4.3 Optimal Conditions

In the monopolistic competitive market, active firms have market power on their varieties, and active firms set their optimality, which consists of the range of varieties (N_f) and the price of each variety (P_{fi}).

Given the optimal range of varieties (N_f), the first-order necessary condition to the price of a variety (P_{fi}) is a derivative of the profit function with respect to P_{fi}, such that:

$$y_{fi} + P_{fi} \frac{\partial y_{fi}}{\partial P_{fi}} = \frac{w}{\varphi_{zf}} \frac{\partial y_{fi}}{\partial P_{fi}} . \tag{2.19}$$

The left-hand side of Equation (2.19) is an additional benefit (or revenue) from a marginal increase in the price of a variety, which should be equal to the marginal cost on the right-hand side.

Combining the demand function of a variety, Equation (2.20) offers the optimal rule of pricing an individual variety produced by firm f:

$$P_{fi} = \frac{w}{\varphi_f} \mu_f = \frac{w}{\varphi_f} \frac{\epsilon_f}{\epsilon_f - 1} \; \forall i \in \Omega_f \tag{2.20}$$

where ϵ_f $(= \sigma + (1 - \sigma) S_f)$ is the demand elasticity for the firm-level composite good, which is also the demand elasticity of a variety in the symmetric technology case. Likewise, μ_f $(= \frac{\epsilon_f}{\epsilon_f - 1})$ is the markup of a variety, which is also the markup of the firm-level composite good. If a firm sets its variety price larger than the right-hand side of Equation (2.20) $(P_{fi} > \frac{w}{\varphi_f} \frac{\epsilon_f}{\epsilon_f - 1})$, the firm must lower its price as the marginal cost exceeds the marginal benefit. As the demand elasticity is

higher than one ($\epsilon_f > 1$), a 1% decrease in price results in a more-than-1% increase in the quantity demanded, which results in higher revenue. [8] [9]

Given the optimal price of the varieties (P_{fi}), the first-order condition corresponding to the number of varieties (N_f) is:

$$\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi} + N_f \left(P_{fi} - \frac{w}{\varphi_f}\right) \frac{\partial y_{fi}}{\partial N_f} = wK_1 \ . \tag{2.21}$$

The left-hand side of Equation (2.21) is the benefit from a marginal increase in the range of varieties, and the right-hand side offers the marginal cost of the range of varieties. Firms exiting the market face a marginal cost of adding a variety (wK_1) that is larger than the marginal benefit $N_f = 0$.

Note that the active firms producing varieties internalize a cannibalization effect in their marginal benefit of the range of varieties. Equation (2.21) shows the partial derivative of the Marshallian demand of a variety (y_{fi}) from Equation (2.14) with respect to the number of varieties (N_f):

$$\frac{\partial y_{fi}}{\partial N_f} = -\frac{y_{fi}}{N_f} + y_{fi} \frac{1}{S_f} \frac{\partial S_f}{\partial N_f} \ . \tag{2.22}$$

Equations (2.8) and (2.14) simplify $\frac{\partial S_f}{\partial N_f}$ as $\frac{S_f}{N_f}(1 - S_f)$. Then, Equation (2.21) transforms to Equation (2.23), and the second term of Equation (2.23) shows the cannibalization effect from the multiple varieties:

$$\underbrace{\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi}}_{Marginal\,benefit} - \underbrace{\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi} S_f}_{Cannibalization\ effect} = wK_1 \ . \tag{2.23}$$

A marginal increase in the range of varieties raises the market share, resulting in a higher price and markup. As the varieties are substitutes for each other ($\sigma > 1$), this higher markup reduces the revenue from each variety. [10] Equation (2.24) is a concise form of Equation (2.23):

[8] According to Equation (2.20), firms that exit from the market set their price at $P_{fi} = \frac{w}{\varphi_f} \frac{\sigma}{\sigma - 1}$, which is identical to the optimal pricing in a continuum of firms model, such as Melitz (2003).

[9] Zero pricing, $P_{fi} = 0$, holds only if $\frac{w}{\varphi_f} \frac{\epsilon_f}{\epsilon_f - 1}$ is non-positive.

[10] In the general form of CES preference in the Appendix, there is an indirect cannibalization effect that reduces a firm's revenue from the interaction with the aggregate price index. The interaction with the price (P_{fi}) and number of varieties (N_f) within firms endogenously determines the sectoral shares.

$$\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi} \frac{\epsilon_f - 1}{\sigma - 1} = wK_1 \ . \tag{2.24}$$

Applying the optimal pricing rule of Equation (2.20) to Equation (2.24) results in Equation (2.25), which represents the quantity of a variety that an active firm supplies:

$$y_{fi} = \varphi_f \left(\sigma - 1\right) K_1 \ . \tag{2.25}$$

Equation (2.26) is the expanded form of the heterogeneous firm's market share, which is computed by applying the pricing rule of Equation (2.20) and the variety supply from Equation (2.25) to the firm-level market share from Equation (2.8):

$$\begin{aligned} S_f &= \tfrac{E_f}{R} \\ &= \tfrac{N_f P_{fi} y_{fi}}{R} \\ &= \underbrace{\frac{w}{\varphi_f} \frac{\epsilon_f}{\epsilon_f - 1}}_{=P_{fi}} \tfrac{N_{fi}}{\rho I} \underbrace{\varphi_f \left(\sigma - 1\right) K_1}_{=y_{fi}} \ . \end{aligned} \tag{2.26}$$

Accompanying the wage as unity ($w = 1$), the optimal range of varieties of an active firm f in the heterogeneous sector is:

$$N_f = \frac{R}{K_1} \frac{1}{\sigma - 1} \frac{\epsilon_f - 1}{\epsilon_f} S_f > 0 \tag{2.27}$$

where R is a sectoral expenditure as in $R = \rho I$ and $\epsilon_f = \sigma + (1 - \sigma) S_f$. [11]

2.4.4 Zero-cutoff Profit Condition and Short-run Equilibrium

2.4.4.1 Zero-Cutoff Profit Condition

In the existence of fixed costs (K_0 and K_1), not all M_e differentiated firms in the market are guaranteed to survive in equilibrium. Less productive firms with higher marginal costs may want to stop production instead of experiencing a negative profit from supplying a variety. Suppose that

[11] If variables other than market size (I) are fixed, N_f is proportional to the market size. Feenstra and Ma (2008) show the proportionality in the short-run effect of international trade between symmetric economies when the 'same' number of entered firms have 'identical' productivities regardless of the multilateral trade.

$M_o\,(\leq M_e)$ firms survive with non-negative profits in equilibrium. Given the aggregate income (I), the Bertrand-Nash equilibrium offers the optimal price and number of varieties for M_o survivors in the short-run equilibrium. [12]

Since the set of randomly drawn productivities determines a firm's decision about producing a variety, the number of active firms (M_o) depends on cutoff productivity, as in Melitz (2003) and Feenstra and Ma (2008). [13]

Among the M_o survivors, the cutoff (or zero-cutoff profit) productivity or threshold productivity refers to the productivity of the least productive firm(s). The inefficient firms whose productivity is lower than the cutoff productivity exit the market, and those firms are not an element of the M_o survivors.

This zero-cutoff profit (ZCP) productivity forms the following condition (hereafter ZCP condition). Given the set of M_e productivities, the Bertrand competition allows all M_o survivors to earn non-negative profits. In contrast, participation of the $M_o + 1^{\,th}$ productive firm has at least one firm face a negative profit. The ZCP condition determines the maximum number of surviving firms (M_o) that have non-negative profits. When productivity sorts entrants in descending order ($\varphi_1 \geq \varphi_2 \geq \cdots \geq \varphi_{M_e}$), the ZCP productivity belongs to the M_o^{th} productive firm when there are no trade costs or government interventions. Concisely, the ZCP condition is defined as:

$$\begin{cases} \Pi_f \geq 0 \; and \; S_f > 0 \quad for \; f \; = \; 1, \cdots, \; M_o \\ \Pi_f = 0 \; and \; S_f = 0 \quad for \; f \; = \; M_o + 1, \cdots, \; M_e \end{cases} \tag{2.28}$$

where Π_fs and S_fs are the profits and the market share, respectively, of surviving firm f in the heterogeneous sector. In the symmetric economies without trade costs or barriers, the ZCP condition directly determines the ZCP productivity (φ^{ZCP}) and the market share of the marginal firm (S^{ZCP}) in the short-run equilibrium.

[12] In the long-run, the number of entering firms (M_e) is endogenous and determined by a free-entry condition. Therefore, M_e is determined such that an ex-ante average profit equals the entry fee as a sunk cost (Melitz (2003); Feenstra and Ma (2008)).

[13] In symmetric economies without government interventions, a cutoff productivity corresponds to a threshold marginal cost as in Melitz (2003) and Feenstra and Ma (2008). Therefore, the cutoff productivity straightforwardly determines the number of surviving firms (M_o). If there are trade costs and government barriers such as tariffs, M_o does not rely on the productivities, but instead on a threshold marginal cost.

2.4.4.2 Short-run Equilibrium and Mechanism to Find Equilibrium

Given the set of productivities of the M_e firms, the ZCP condition offers ZCP productivity (φ^{ZCP}) and the market share of the marginal firm (S^{ZCP}). This condition determines: (a) which firms will proceed to produce based on the ZCP productivity; and, (b) survivors' market shares (S_f), which affect the optimality of M_o survivors, such as the price of a variety (P_{fi}) and range of the varieties (N_f). The short-run equilibrium is defined as:

Definition. (Short-run Equilibrium) *Given the set of productivities for M_e entrants in an economy with income (I), the Bertrand-Nash equilibrium consists of:*

1. A set of information about the ZCP condition in the heterogeneous sector $\{S^{ZCP},\ \varphi^{ZCP}\}$.
2. A vector of the optimality set by the M_o surviving firms, including the price of a variety, the range of varieties, and the firm-level market share $\{P_{fi},\ N_f,\ S_f\}_{f=1}^{M_o}$.
3. A sectoral price index within the economy P, which solves both utility and profit maximization simultaneously.

Feenstra and Ma (2008) introduce a mechanism to find the unique equilibrium in terms of φ^{ZCP}. [14] As the survivors produce their varieties, the optimal range of varieties (N_f) should be positive for those firms. From equations (2.14) and (2.25), the firm-level productivity can be converted to a function of the firm's properties as follows:

$$\varphi_f = \left[\frac{\sigma-1}{R}K_1\right]^{\frac{1}{\sigma-1}} \frac{1}{P}\left[\frac{\epsilon_f}{\epsilon_f-1}\right]^{\frac{\sigma}{\sigma-1}} . \tag{2.29}$$

Using ZCP productivity (φ^{ZCP}), an inverse of the relative productivity of a survivor (τ_f) can be calculated:

$$\tau_f = \frac{\varphi^{ZCP}}{\varphi_f} = \left[\frac{\frac{\epsilon_f}{\epsilon_f-1}}{\frac{\epsilon^{ZCP}}{\epsilon^{ZCP}-1}}\right]^{-\frac{\sigma}{\sigma-1}} \tag{2.30}$$

[14] In the Appendix, I also apply this mechanism to the generalized CES demand system environment.

where ϵ^{ZCP} is demand elasticity for the marginal firm's variety. Then, the survivor's market share becomes a function of τ_f and the market share of the marginal firm (S^{ZCP}): [15]

$$\begin{aligned} S_f &= S(\tau_f) \\ &= 1 - \frac{1}{\left\{\left(\sigma-1+\frac{1}{1-S^{ZCP}}\right)(\tau_f)^{-\frac{\sigma-1}{\sigma}}-(\sigma-1)\right\}} \end{aligned} . \tag{2.31}$$

Among the M_e firms, firms with $\tau_f > 1$ are less productive firms than marginal firms, thus $S_f = 0$ if $\tau_f > 1$. Assuming the market share of the marginal firm (S^{ZCP}) as an arbitrary value, the profit of each surviving firm is:

$$\begin{aligned} \Pi_f &= \Pi(\tau_f) \\ &= \frac{\{S(\tau_f)\}^2}{1+(\sigma-1)\{1-S(\tau_f)\}}R - wK_0 \ . \end{aligned} \tag{2.32}$$

All M_e elements in the productivity set are candidates of φ^{ZCP}. Therefore, an output table contains τ_fs, S_fs, and Π_fs for each candidate of φ^{ZCP}. Beginning with the highest productivity candidate (i.e., $\varphi^{ZCP} = \varphi_1$), one can calibrate the solution S^{ZCP} to satisfy the sum of market share across the survivors as unity. Then the least (M_o^{th}) productivity ($\varphi^{ZCP} = \varphi_{M_o}$) satisfies the sum of the market share as unity. [16] This M_o^{th} productive firm is the marginal firm in equilibrium, and S^{ZCP} denotes its market share. The market share of the marginal firm is the smallest among the survivors. For other candidates of φ^{ZCP}, such as $\varphi^{ZCP} = \varphi_j$ $j \in \{M_o + 1, \cdots, M_e\}$, there is no solution to satisfy the sum of the market share among the survivors as one. [17]

2.4.5 Properties of Firms' Behaviors

The short-run equilibrium determines the survivor's market share in the heterogeneous sector (S_f), the optimal price of a variety (P_{fi}), and the optimal range of varieties (N_f).

[15] As in Feenstra and Ma (2008), if there is no change in φ^{ZCP} and τ_f , then more highly productive firms benefit from a higher market share because $\frac{\partial S_f(\tau_f)}{\partial \tau_f} < 0$.

[16] This firm has the highest marginal cost for producing a variety among the M_o survivors.

[17] In the Cobb-Douglas utility function at the top-level demand, one can disregard finding the optimal sectoral share process because it is fixed as ρ.

Regarding the optimal pricing (P_{fi}), the short-run equilibrium offers: (a) an increasing markup (μ_f); and, (b) a decreasing price of a variety (P_{fi}) in productivity (φ_f) among the M_o survivors. Given the fixed sectoral share (ρ), the survivor's market share (S_f) decreases in the inverse of relative productivity to the ZCP productivity (τ_f), which leads to a lower demand elasticity for a firm-level composite good (ϵ_f). This lower demand elasticity leads to a higher markup of varieties. [18]

The optimal range of varieties (N_f) is proportional to the market size (I) only if there is no update on the ZCP condition. [19] Given the market size (I), a productive firm with a higher market share produces a broader range of varieties. In contrast, as in Equation (2.27), the existence of the inverse of markup prevents the optimal range of varieties from expanding proportionally to the firm-level market share. [20]

2.4.6 Short-run Equilibrium of International Trade

In this section, I introduce the environment of bilateral trade in the short-run and define the short-run equilibrium in the integrated market in the context of this framework. Using the concept of the short-run equilibrium, I identify the effects of international trade on firm optimality.

2.4.6.1 The Environment of International Trade in the Short-run

In this paper, I assume international trade is bilateral trade between symmetric economies. Both economies share the set of the firm-level productivity and labor income ($I = wL$) with wage

[18] In contrast, as in the Appendix, the generalized nested CES preference can not guarantee a decreasing price of varieties in productivity. A change in sectoral share (S_z) can amplify the markup of the varieties for a higher productivity firm. If the amplification affects the price of varieties, a higher price of varieties for a higher productivity firm is possible when the effect dominates the effect from the lower marginal cost (or, the higher relative productivity). The computational solution in the Appendix demonstrates this case.

[19] When there is no update on the ZCP condition, both the firm-level market share (S_f) and the markup of varieties (μ_f) are fixed. In contrast, the international trade allowing head-to-head competition results in updating both the market size (I) and the ZCP condition. The combination of these two effects prevents the optimal range of varieties from expanding proportionally.

[20] In the extreme case of monopoly, the monopolist minimizes its range of variety despite being the only firm serving in the market. As the monopolist already excises the highest markup on its existing products, it does not have an incentive to internalize the cannibalization effect from various products, which is consistent with the inverted U-shape relationship between the number of varieties and the firm's market share in Feenstra and Ma (2008).

as unity ($w = 1$). When bilateral trade begins, each heterogeneous survivor in autarky faces a larger market, from I to $I^W = 2I$.

As in Feenstra and Ma (2008), the environment of international trade is simplified such that the fixed cost is only for expanding the marginal range of variety (wK_1), which is K_1 when the wage is one. Furthermore, the market is perfectly integrated between two symmetric economies. All survivors do not have to pay a fixed cost to introduce their product to a foreign market and varieties can be freely traded without iceberg trade costs or duties. Moreover, the one-time fixed cost for producing a variety (K_0) is zero.

Unlike previous studies, including those in Feenstra and Ma (2008), I assume the survivors in autarky maintain productivity in the short-run after the markets are liberalized. [21] The survivors in autarky are treated as the only entrants at the time of market liberalization because the inefficient entrants in autarky must be already expelled if those productivities are lower than the ZCP productivity. If M_e^W is the number of entrants at the time of international trade, M_e^W is double the number of survivors in the autarky ($M_e^W = 2M_o$). The M_o firms from each economy should account for the existence of M_o competitors from the trade partner, and a pair of two entrants from two different economies share productivity. This head-to-head competitive environment promotes intensive competition in the integrated market.

In the environment described above, the M_e^W entrants decide whether to produce or exit and set their optimality.

2.4.6.2 Short-run Equilibrium of Market Liberalization and Firm's Behavior

When the markets are liberalized, the intensive competition among M_e^W ($= 2M_o$) entrants in the integrated market updates the ZCP condition. The updated ZCP condition indicates the ZCP productivity ($\varphi^{W,ZCP}$) and the market share of the marginal firm ($S^{W,ZCP}$) in the integrated

[21] Feenstra and Ma (2008) assume that the environment of the integrated market is identical to one in autarky. Both the integrated market and autarky share the number of entrants ($M_e^W = M_e$); however, Feenstra and Ma (2008) focus on the steady-state and do not account for the fact that multiple firms with the same productivity can exist right after market liberalization. Therefore, each firm may be exclusively assigned one new productivity, and the distribution of firm-level productivity among those firms is invariant regardless of international trade, which results in a constant markup and proportional expansion of variety range to market size, as there is no update in the ZCP condition.

market. Based on the updated ZCP condition of the global market, the short-run equilibrium of international trade can be defined as:

Definition. (Short-run Equilibrium of the Trade Liberalization) *Given fixed firm-level productivity of $M_e^W = 2M_o$ firms surviving in autarky in the symmetric economies with I income, the M_e^W firms face head-to-head competition in the integrated market with I^W $(= 2I)$. The Bertrand-Nash equilibrium of trade liberalization in the short-run consists of:*

1. A set of information about the ZCP condition in the heterogeneous sector $\{S^{W,ZCP},\ \varphi^{W,ZCP}\}$.
2. A vector of the optimality set by the M_o^W surviving firms in the integrated market, including the price of a variety, the range of varieties, and the firm-level market share $\{P_{fi},\ N_f,\ S_f\}_{f=1}^{M_o^W}$.
3. A sectoral price index within the integrated economy P, which solves both utility and profit maximization simultaneously in the integrated market.

Despite the double market size, the integrated market is more pro-competition. Head-to-head competition in the integrated market updates the productivity distribution among the M_e^W entrants, which implies that productive firms must compete with each other and it renews the ZCP condition in the integrated market.

The intensive competition among productive firms in the integrated market raises the ZCP productivity ($\varphi^{W,ZCP} > \varphi^{ZCP}$). According to the environment of international trade described, all M_e^W entrants have higher productivity than the ZCP productivity in autarky (φ^{ZCP}). In this environment of market liberalization with intensive competition, negative expected profits may expel the least productive firms that are among the M_e^W entering firms, which implies that the range of productivity for those expelled firms is between φ^{ZCP} and $\varphi^{W,ZCP}$.

The higher ZCP productivity in the integrated market affects the firm-level market shares and markups of the varieties through various channels. As a direct effect, a higher ZCP productivity raises the inverse of relative productivities, as in Equation (2.30), which results in varities having lower market share and markups. In contrast, note that there are indirect changes in the market shares among the M_o^W survivors in the integrated market. The survivors increase their range

of variety when they take over the market shares of expelled firms. This expansion results in indirectly increasing the market share as well as the cannibalization effect. Furthermore, the intensive competition among survivors allows the most productive firms to take over the share of less productive survivors. In addition to the fact that productive firms have to account for head-to-head competition with equally productive foreign firms, the direct impact may dominate the indirect effects. In sum, the updated ZCP productivity of market liberalization lowers the firm-level market share. Furthermore, it lowers markups of the varieties among the survivors in the integrated market.

The changes in market shares and markups update the optimal range of varieties; however, the updated ZCP condition in the integrated market prevents the range of varieties from expanding proportionally to the market size.

In contrast, Feenstra and Ma (2008) argue that there is no update on the ZCP condition despite the market liberalization. In Feenstra and Ma (2008), the cannibalization effect is marginal to the firm's behavior compared to the impact of expanding the market size. Therefore, in the short-run equilibrium of international trade, the firm-level market share is not changed at the onset of international trade. Moreover, the survivors are allowed to expand the range of varieties proportional to the market size.

2.5 Quantitative Analysis

I treat heterogeneous firms as discrete, though they are not small enough relative to the market; therefore, the discreteness assumption prevents applying the law of large numbers to the theoretical framework.

The major drawback of the granular heterogeneous firm environment is unavailability of closed-form solutions in equilibrium. According to Feenstra and Ma (2008), the discreteness in treating the heterogeneous firms fails to offer the closed-form of average productivity or revenue among the survivors in equilibrium. Therefore, quantitative analysis is an alternative way to identify the properties of the short-run equilibrium in international trade.

For the quantitative analysis, I first replicate the results of Feenstra and Ma (2008), in which the market environment is invariant except for the market size. Then, given the relevant parameters and firm-level productivities in Feenstra and Ma (2008), the quantitative analysis follows the framework and procedure in Feenstra and Ma (2008) except for the environment of market liberalization applied to the framework. This means that the revised environment described in the previous section is applied to the framework. In the next step, the different productivity sets, the samples drawn from a Pareto distribution, offer the quantitative results in the short-run equilibrium of international trade.

2.5.1 Quantitative Results of the Short-run Equilibrium in Feenstra and Ma (2008)

As the Cobb-Douglas utility function at the top-level preference fixes the sectoral share as ρ, Feenstra and Ma (2008) defines the bilateral trade between two symmetric economies as only doubling the market size in the heterogeneous sector from R $(= \rho I = 1000)$ in autarky to R^W $(= \rho I^W = 2000)$.

In the equilibrium of international trade, the firm-level market share can be achieved by applying the ZCP condition of market liberalization to Equation (2.31). Equation (2.33) represents the firm-level market share in the integrated market.

$$S_f = S(\tau_f) = 1 - \frac{1}{\left\{\left(\sigma - 1 + \frac{1}{1-S^{W,ZCP}}\right)(\tau_f)^{-\frac{\sigma-1}{\sigma}} - (\sigma - 1)\right\}} \tag{2.33}$$

Application of this share to Equation (2.32) reveals the profit of the survivors in the integrated market.

In this analysis, the random sample of the productivities utilized in Feenstra and Ma (2008) is maintained until the novel samples are introduced later.

First, given the set of productivity of randomly drawn M_e entrants, Equation (2.30) determines the ratio of marginal costs (or the inverse of relative productivities, $(\tau_f s)$) for each candidate of ZCP productivity. Table 2.1 shows the computed inverse of relative productivities for each candidate of ZCP productivity (φ^{ZCP}).

Table 2.1: Firm's Relative Productivity Ratio τ_f

Firm	Productivity	τ_f						
		$\varphi^{ZCP} =$ 0.202	$\varphi^{ZCP} =$ 0.224	$\varphi^{ZCP} =$ 0.2345	$\varphi^{ZCP} =$ 0.235	$\varphi^{ZCP} =$ 0.237	$\varphi^{ZCP} =$ 0.267	$\varphi^{ZCP} =$ 0.279
1	0.279	0.723	0.802	0.840	0.841	0.850	0.956	1
2	0.267	0.756	0.839	0.879	0.880	0.889	1	1.046
3	0.237	0.851	0.944	0.988	0.990	1	1.125	1.177
4	0.235	0.859	0.953	0.998	1	1.010	1.136	1.189
5	0.235	0.861	0.955	1	1.002	1.012	1.138	1.191
6	0.224	0.901	1	1.047	1.049	1.060	1.192	1.247
7	0.202	1	1.109	1.162	1.164	1.175	1.322	1.384

Second, given the arbitrary marginal firm's market share as the initial point (S^{ZCP}), Equation (2.31) gives the tentative firm-level market share as a function of the inverse of relative productivities ($\tau_f s$). [22] According to the ZCP condition, the firm-level market share with inverse of relative productivities higher than one ($\tau_f > 1$) is zero ($S_f = 0$). Table 2.2 shows the tentative market share when the marginal firm's market share is assumed as 0.5% ($S^{ZCP} = 0.5\%$).

Third, starting with the highest marginal productivity candidate (e.g.,$\varphi^{ZCP} = 0.279$), the sequential non-linear programming provides the solution (S^{ZCP}), which satisfies the sum of the survivor's market share as unity for each ZCP productivity candidate. In the short-run equilibrium, among M_e entrants, the least productive firm has market share S^{ZCP} as a results of a non-linear solver with the restriction of the sum of the survivors' market shares as unity. The non-linear programming fails to find a valid S^{ZCP} for the lower ZCP productivity candidates than φ^{ZCP} in the equilibrium. In the case of Feenstra and Ma (2008), with seven entrants, the short-run equilibrium indicates that five survivors are in the market, and the ZCP productivity indicates that the marginal firm assigned is 0.2345 ($\varphi^{ZCP} = 0.2345$).

[22] In this step, the marginal firm's market share (S^{ZCP}) may be set as any number between zero and one.

Table 2.2: Example of Firm Market Shares Determined by the Productivity Thresholds in Step 2

Firm	Productivity	Market Shares						
		$\varphi^{ZCP} =$ 0.202	$\varphi^{ZCP} =$ 0.224	$\varphi^{ZCP} =$ 0.2345	$\varphi^{ZCP} =$ 0.235	$\varphi^{ZCP} =$ 0.237	$\varphi^{ZCP} =$ 0.267	$\varphi^{ZCP} =$ 0.279
1	0.279	65.2%	54.9%	48.6%	48.3%	46.8%	19.1%	0.5%
2	0.267	61.2%	48.7%	40.8%	40.4%	38.4%	0.5%	0.0%
3	0.237	46.5%	23.2%	6.0%	5.2%	0.5%	0.0%	0.0%
4	0.235	44.9%	20.0%	1.4%	0.5%	0.0%	0.0%	0.0%
5	0.235	44.5%	19.4%	0.5%	0.0%	0.0%	0.0%	0.0%
6	0.224	35.4%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
7	0.202	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sum of Market Shares		298.2%	166.7%	97.4%	94.5%	85.7%	19.6%	0.5%

Note: Initial market share of the threshold firm is assumed as 0.5%.

Table 2.3: Firms' Market Shares by Productivity Threshold

Firm	Productivity	Market Shares						
		$\varphi^{ZCP} =$ 0.279	$\varphi^{ZCP} =$ 0.267	$\varphi^{ZCP} =$ 0.237	$\varphi^{ZCP} =$ 0.235	$\varphi^{ZCP} =$ 0.2345	$\varphi^{ZCP} =$ 0.224	$\varphi^{ZCP} =$ 0.202
1	0.279	100.0%	53.3%	49.5%	49.0%	**48.9%**		
2	0.267	0.0%	46.7%	41.9%	41.3%	**41.1%**		
3	0.237	0.0%	0.0%	8.6%	7.1%	**6.7%**	Fail to	Fail to
4	0.235	0.0%	0.0%	0.0%	2.6%	**2.1%**	find	find
5	0.235	0.0%	0.0%	0.0%	0.0%	**1.2%**	S^{ZCP}	S^{ZCP}
6	0.224	0.0%	0.0%	0.0%	0.0%	**0.0%**		
7	0.202	0.0%	0.0%	0.0%	0.0%	**0.0%**		
$S^{ZCP} = S^{W,ZCP}$		100.0%	46.7%	8.6%	2.6%	**1.2%**		
Sum of Market Shares		100.0%	100.0%	100.0%	100.0%	**100.0%**		

Fourth, the value of the short-run equilibrium from the previous step determines the surviving firm's optimality in terms of price and the range of variety in the market. [23]

Feenstra and Ma (2008) assume that international trade still retains the number of entrants ($M_e = M_e^W = 7$) and an identical set of productivity as in autarky. Therefore, at the beginning of international trade, seven new firms enter the integrated market, and the productivity distribution across the entrants is the same as in autarky. The concept in Feenstra and Ma (2008) fails to account for the head-to-head competition between the two entrants assigned the same productivity. Therefore, the ZCP condition is stable regardless of the market liberalization ($\varphi^{W,ZCP} = \varphi^{ZCP}$), which implies that the market share of the five survivors ($S^f = S^{W,f}$) is the same in autarky, including the marginal firm ($S^{ZCP} = S^{W,ZCP}$).

As a result, due to the stable market share, for each corresponding firm-level productivity the markup of the varieties is the same in autarky despite the market liberalization. Also, as there is no update to the ZCP condition and the profits and the number of varieties double in the bilateral trade between symmetric economies.

2.5.2 Comparison and Quantitative Results of Revised Environment of Market Liberalization

While Feenstra and Ma (2008) finds that the number of entrants in the integrated market is the same as in autarky, I account for a more rigorous environment in which the survivors in both symmetric economies maintain their productivity and become entrants of the liberalized market in the short-run.

This new environment of international trade revises the distribution of firm-level productivity. Given the example in Feenstra and Ma (2008), as five firms in each economy serve in autarky, there are 10 entrants in the integrated market ($M_e^W = 2M_o = 10$). Figure 2.2 compares the

[23] As in Feenstra and Ma (2008), I assume the sectoral market size is 1,000 in autarky and 2,000 in the integrated market. Also, the fixed cost of extending a range of the varieties is set as five ($K_1 = 5$) and the elasticity of substitution employed is six ($\sigma = 6$).

environment of international trade to the one in Feenstra and Ma (2008) in terms of the distribution of productivity among entrants in the integrated market.

Although there is a change in the environment of international trade, other features representing the market are the same as in Feenstra and Ma (2008). The partial equilibrium analysis treats the (sectoral) market size as an exogenous variable (2,000) in the integrated market ($R^W = \rho I^W = 2000$).

This quantitative analysis maintains those parameters. For example, the elasticity of substitution across varieties is six ($\sigma = 6$) and the fixed cost of marginally expanding the range of the varieties is five ($K_1 = 5$).

Under the revised environment of international trade, the ten entrants compete with each other. The intensive head-to-head competition may expel the least productive firms, which results in a higher ZCP productivity ($\varphi^{W,ZCP} > \varphi^{ZCP}$). For example, in the case of bilateral trade between the symmetric economy with the productivity as in Feenstra and Ma (2008), only four of ten entrants survive shortly after market liberalization, which means that the first- and second-most productive firms survive in each economy. The introduction of foreign competitors sharing the same productivity reduces the market share of the local survivors and lowers markups of the varieties in international trade. Table 2.4 compares the firm-level market share in the short-run equilibrium of international trade.

Table 2.5 shows detailed information about the short-run equilibrium of international trade.

Intensive competition among the ten productive entrants in the integrated market prevents Firm 3˜5s in each economy from getting a non-negative profit in the short-run equilibrium of international trade. The ZCP productivity increases from $\varphi^{ZCP} = 0.202$ to $\varphi^{W,ZCP} = 0.267$, which implies concentration of resources on more productive firms in each economy. As in Figure 2.3, the bilateral trade updates the market share of the marginal firms from $S^{ZCP} = 1.2\%$ to $S^{W,ZCP} = 18.3\%$. Due to head-to-head competition among productive firms, the updated ZCP condition reduces the survivors' market shares in the integrated market. In this example, the market share of Firm 1 in each economy falls to 32% and Firm 2s' market share reduces to 18%.

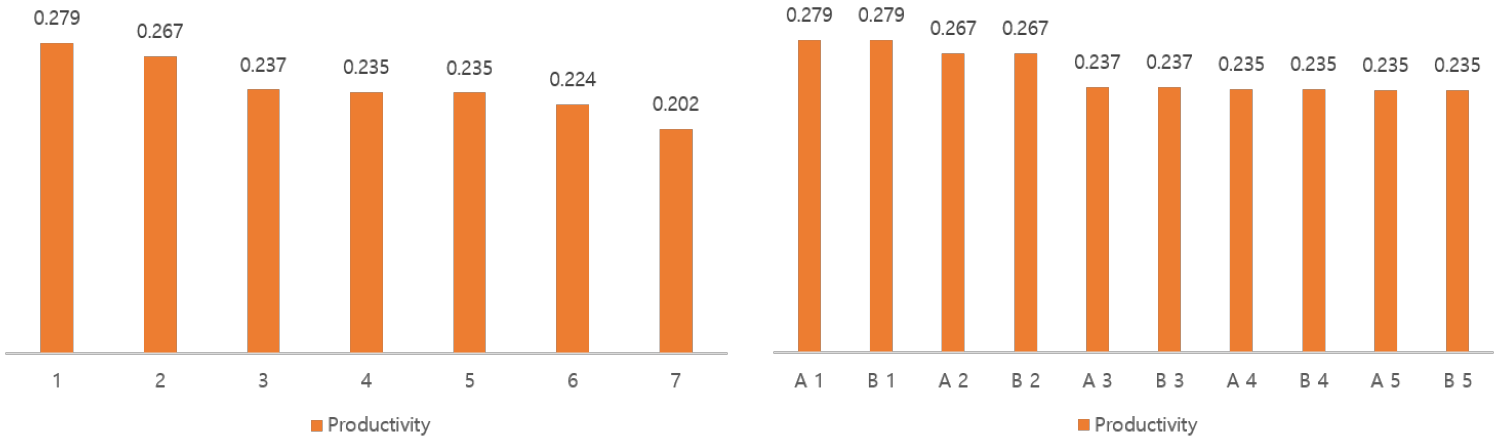

Figure 2.2: Productivity Distribution in the Integrated Market in Feenstra and Ma (2008) (Left) and the Revised Environment of Market Liberalization (Right)

Table 2.4: Summary: Comparison of the Effects of International Trade between Environments

Firm	Productivity	Revised Environment			Feenstra and Ma (2008)	
		Autarky	Trade	Active	Autarky = Trade	Active
1	0.279	48.9%	31.7%	Yes	48.9%	Yes
2	0.267	41.1%	18.3%	Yes	41.1%	Yes
3	0.235	6.7%	0.0%	No	6.7%	Yes
4	0.235	2.1%	0.0%	No	2.1%	Yes
5	0.202	1.2%	0.0%	No	1.2%	Yes
6	0.224	0.0%	Already Stop in Autarky		0.0%	No
7	0.202	0.0%	Already Stop in Autarky		0.0%	No
S^{ZCP}		1.2%	18.3%		1.2%	

Table 2.5: Summary: Short-run Equilibrium of International Trade in Each Economy

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
Before	1	0.279	48.9%	67.12	14.05	4.98	1.39	Yes
	2	0.267	41.1%	42.80	12.27	5.02	1.34	Yes
	3	0.235	6.7%	0.79	2.21	5.12	1.21	Yes
	4	0.235	2.1%	0.08	0.71	5.13	1.20	Yes
	5	0.202	1.2%	0.03	0.41	5.13	1.20	Yes
	6	0.224	0.0%	0.00	0.00	-	-	No
	7	0.202	0.0%	0.00	0.00	-	-	No
	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
After	1	0.279	31.7%	45.47	19.61	4.63	1.29	Yes
	2	0.267	18.3%	13.20	11.77	4.66	1.24	Yes
	3	0.235	0.0%	0.00	0.00	-	-	No
	4	0.235	0.0%	0.00	0.00	-	-	No
	5	0.202	0.0%	0.00	0.00	-	-	No
	6	0.224	Already Stop in Autarky					
	7	0.202	Already Stop in Autarky					

The decreasing rate of market share for Firm 2 is higher than the change in Firm 1s' share, which suggests that the loss of market share is higher for less productive survivors because productive foreign competitors take the market share that would benefit less productive local firms in autarky.

The profits of the survivors are affected by the market liberalization through two channels—international trade, which expands the market size that increases survivors' profits; and, head-to-head competition, which creates a smaller market size and reduces profits. Figure 2.4 shows the changes in profit in the short-run equilibrium of market liberalization. In this example, all survivors in the integrated market face a lower profit after bilateral trade, which implies that the decreasing effect from a smaller market share dominates the increasing effect of larger market size. Firm 1s' profit falls to 45.47, which is more than half of its profit in autarky. Firm 2s' profit falls to one-third of their profit in autarky, which relates to the loss of market share due to the inclusion of more productive foreign competitors.

Although the optimal range of varieties depends on the changes in market size and firm-level market share, the aggregate range of varieties in the market is expanded after market liberalization. As in Equation (2.27), when including the cannibalization effects that all the survivors internalize, a larger market size (R) raises the optimal range of varieties, while the smaller market share from head-to-head competition prevents survivors from expanding variety range. In this example, the dominating effect from the two factors differs depending on the firm's productivity. As Figure 2.5 shows, more productive firms (Firm 1s) expand their range of varieties to 19.6, while less productive firms (Firm 2s) reduce to 11.8. Also, due to the existence of two opposing impacts, Firm 1s' expanding range of varieties is not proportional to the market size. The introduction of productive competitors raises the aggregate range of varieties to 62.76 in the integrated market despite the loss of varieties from the expelled survivors in autarky.

Figure 2.6 shows the changes in prices and markups of varieties in the short-run equilibrium of international trade. The market liberalization reduces both the variety-level price and markups for both survivors. In this example of the Cobb-Douglas utility function at top-level preference, the

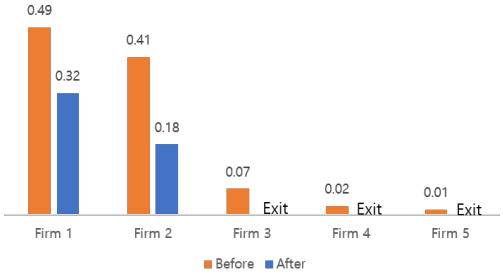

Figure 2.3: Market Share Short-run Equilibrium after International Trade based on Revised Market Liberalization Environment

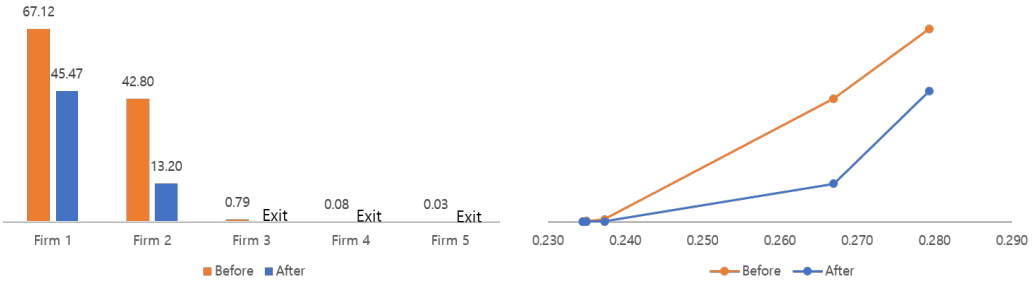

Figure 2.4: Short-run Profit Changes and Threshold Productivity based on Revised Market Liberalization Environment

survivors with higher productivity enjoy a lower price, which is consistent with previous studies. Also, less productive firms struggle with a higher rate of decrease in the markups of varieties.

In sum, the quantitative analysis incorporating the revised environment offers more reasonable gains from trade. In the short-run, international trade reallocates resources to more productive firms, which intensifies head-to-head competition. Therefore, the survivors in the liberalized market set lower markups and variety prices. Although the firm-level range of varieties is determined by the changes in both market size and firm-level market share, international trade extends the aggregate range of varieties, which results in the love of variety. As a result, each economy gains from trade.

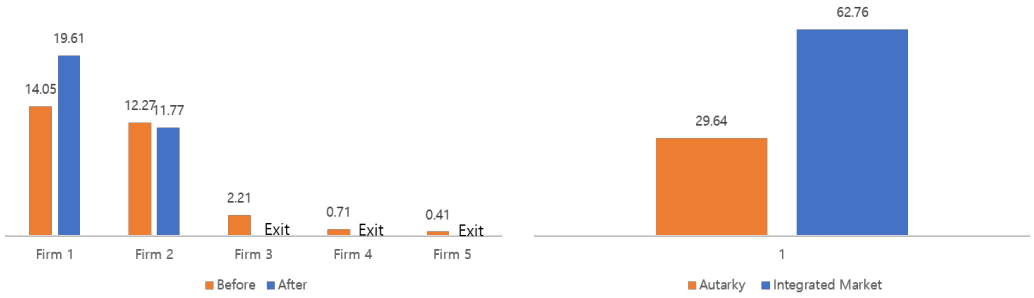

Figure 2.5: Short-run Changes of Firm's Varieties (Left) and Total Number of Varieties in Each Economy (Right) based on the Revised Market Liberalization Environment

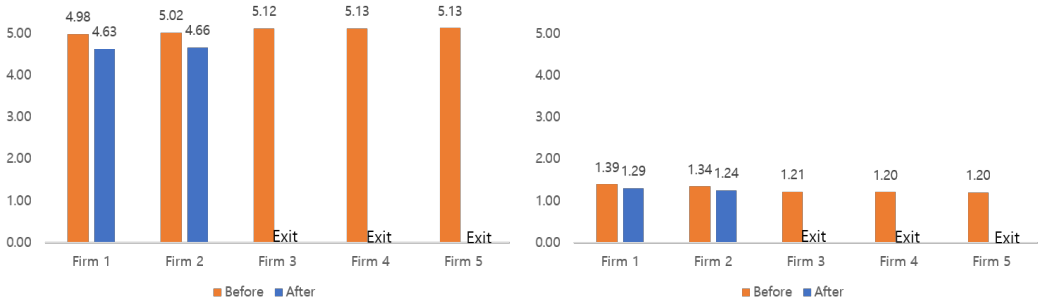

Figure 2.6: Short-run Changes of Prices (Left) and Markups (Right) of a Variety based on Revised Market Liberalization Environment

2.5.3 Sampling for New Sets of Firm-level Productivity

Under granularity, the specific sample of the productivity set is not able to represent a continuous form of a Pareto distribution with the shape of γ and the lower support of φ^{min}. The short-run equilibrium is not stationary, thus each quantitative analysis relies on randomly drawing the random productivity set.

I also conduct a quantitative analysis using three new productivity sets drawn using the clustered and systematic sampling method. The samples are generated from Pareto distribution with the same parameters (γ, φ^{min}), and each of the three new sets consist of productivity for ten entrants ($M_e = 10$) in autarky.

Using the Pareto distribution with $\gamma = 5$ (Shape) and $\varphi^{min} = 0.2$ (Lower bound) as in Feenstra and Ma (2008), I generate 500,000 random productivities. After sorting by decreasing order, I cluster the generated sample into ten groups of 50,000 productivities each. The first group consists of the 50,000 highest productivities, while the tenth group consists of the 50,000 smallest productivities.

The new productivity set consists of ten productivities, each of which is drawn from each cluster. The first set (Example 1) is the productivity set in which each element is the highest within the clusters. A higher shape parameter ($\gamma > 1$) in the Pareto distribution may render an extremely high random productivity as an outlier. Therefore, the variance of this new set is highest among the three new productivity sets. In contrast, the elements of the second set (Example 2) are the smallest productivities in each group, which gives the smallest variance within the example. In the third set (Example 3), the elements are the median productivities in each cluster. Table 2.6 and Figure 2.7 show the summary of the three new sets of productivities for ten entrants.

Assuming the 500,000 samples form a continuous form of the Pareto distribution, Example 3 is the discrete sample set that represents the continuous form of the distribution in terms of mean and variance. For Example 1, the mean and variance are higher due to the extreme element of 2.406. In Example 2, the variance is lower than that of the continuous distribution because the productivities are concentrated on the smallest support, $\varphi^{min} = 0.2$.

Table 2.6: Example Sets of Quantitative Analysis Productivities

Firm	Productivity		
	Example 1 (Highest of each cluster)	Example 2 (Smallest of each cluster)	Example 3 (Median of each cluster)
1	2.406	0.317	0.364
2	0.317	0.276	0.293
3	0.276	0.254	0.264
4	0.254	0.240	0.247
5	0.240	0.230	0.235
6	0.230	0.221	0.225
7	0.221	0.215	0.218
8	0.215	0.209	0.212
9	0.209	0.204	0.207
10	0.204	0.200	0.202
Variance	0.470	0.001	0.002
Mean	0.457	0.237	0.247

Note: I assume $\gamma = 5$ (Shape) and $\varphi^{min} = 0.2$ (Lower bound). For the set of 50,000 productivities, the variance is 0.004 and the mean is 0.250.

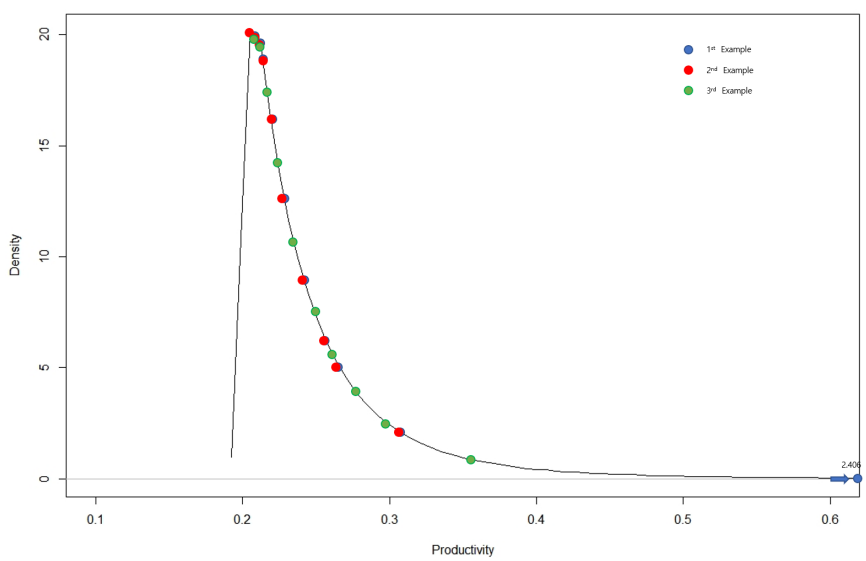

Figure 2.7: Sample Productivities for Quantitative Analysis Mapped on Kernel of Pareto Distribution with $\gamma = 5$ (Shape) and $\varphi^{min} = 0.2$ (Lower bound)

Table 2.7: Summary: Short-run Equilibrium of the International Trade in Each Economy (Example 1 Set of Productivities)

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
Before	1	2.406	96.4%	787.0	5.9	2.72	6.54	Yes
	2	0.317	3.6%	0.2	1.2	3.81	1.21	Yes
	3	0.276	0.0%	0.0	0.0	-	-	No
	4	0.254	0.0%	0.0	0.0	-	-	No
	5	0.240	0.0%	0.0	0.0	-	-	No
	6	0.230	0.0%	0.0	0.0	-	-	No
	7	0.221	0.0%	0.0	0.0	-	-	No
	8	0.215	0.0%	0.0	0.0	-	-	No
	9	0.209	0.0%	0.0	0.0	-	-	No
	10	0.204	0.0%	0.0	0.0	-	-	No
After	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
	1	2.406	50.0%	142.9	28.6	0.58	1.40	Yes
	2	0.317	0.0%	0.0	0.0	-	-	No

2.5.4 Quantitative Analysis using Example Sets

Using the three new sets of productivities formed by the clustered and systematic sampling method, I employ the same parameters as in the previous analysis, such as the elasticity of substitution across varieties ($\sigma = 6$) and the fixed cost of marginally expanding the range of the varieties ($K_1 = 5$). Furthermore, the wage is fixed as unity ($w = 1$).

With the competition among the entrants ($M_e = 10$) in autarky and the sectoral market size of 1,000 ($R = \rho I = 1000$), the short-run equilibrium suggests the number of survivors (M_o) in autarky in each economy and the survivors' corresponding productivities ($\varphi_f s$). When bilateral trade begins, the M_o survivors in autarky of each economy become the entrants of the integrated market with doubled market size ($R^W = \rho I^W = 2000$). Therefore, the number of entrants in the integrated market is the sum of the survivors in autarky ($M_e^W = 2M_o$). The competition among M_e^W offers the short-run equilibrium of international trade.

Table 2.8: Summary: Short-run Equilibrium of the International Trade in Each Economy (Example 2 Set of Productivities)

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
Before	1	0.317	56.9%	102.7	15.5	4.62	1.46	Yes
	2	0.276	34.4%	27.6	10.5	4.73	1.30	Yes
	3	0.254	8.7%	1.4	2.9	4.79	1.22	Yes
	4	0.240	0.0%	0.0	0.0	-	-	No
	5	0.230	0.0%	0.0	0.0	-	-	No
	6	0.221	0.0%	0.0	0.0	-	-	No
	7	0.215	0.0%	0.0	0.0	-	-	No
	8	0.209	0.0%	0.0	0.0	-	-	No
	9	0.204	0.0%	0.0	0.0	-	-	No
	10	0.200	0.0%	0.0	0.0	-	-	No
	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
After	1	0.317	44.4%	104.6	26.14	4.29	1.36	Yes
	2	0.276	5.6%	1.1	3.67	4.39	1.21	Yes
	3	0.254	0.0%	0.0	0.00	-	-	No

Table 2.9: Summary: Short-run Equilibrium of the International Trade in Each Economy (Example 3 Set of Productivities)

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
Before	1	0.364	64.9%	153.1	16.54	4.31	1.57	Yes
	2	0.293	35.0%	28.8	10.70	4.47	1.31	Yes
	3	0.264	0.1%	0.0	0.03	4.55	1.20	Yes
	4	0.247	0.0%	0.0	0.00	-	-	No
	5	0.235	0.0%	0.0	0.00	-	-	No
	6	0.225	0.0%	0.0	0.00	-	-	No
	7	0.218	0.0%	0.0	0.00	-	-	No
	8	0.212	0.0%	0.0	0.00	-	-	No
	9	0.207	0.0%	0.0	0.00	-	-	No
	10	0.202	0.0%	0.0	0.00	-	-	No
	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active
After	1	0.364	50.0%	142.86	28.57	3.84	1.40	Yes
	2	0.293	0.0%	0.00	0.00	-	-	No
	3	0.264	0.0%	0.00	0.00	-	-	No

As shown in Tables 2.7–2.9, when employing the new environment in the computational model, the quantitative analysis results also support the pro-competitive liberalized market from the head-to-head competition. In the short-run, international trade concentrates resources on the more productive firms such that the least productive survivors in autarky are expelled.

In each example, the pro-competitive market environment and the introduction of foreign productive competitors reduce the firm-level market share, resulting in lower variety markups and prices. While the optimal range of varieties is determined by the interaction between the changes in market size and firm-level market share, the aggregate range of variety is extended, which results in gains from trade. For example, Example 2 shows that productive firms set a lower price and higher markup of varieties than less efficient competitors. Furthermore, the rate falling markup is smaller for the most productive firms.

2.6 Conclusion

In this study, I demonstrate lowering markups in the short-run equilibrium of international trade when discrete firms are heterogeneous and allowed to produce multiple varieties, which departs from the environment defined in Feenstra and Ma (2008). Therefore, I assume the survivors in autarky maintain their productivity in the short-run at the onset of international trade. Since the least productive firms in autarky are expelled from the local market, the survivors in autarky are the entrants in the liberalized market.

In setting the framework, I employ a nested CES demand system and a monopolistic competition across heterogeneous firms. Assuming symmetric technology across the varieties within firms, firm profit maximization offers analytic forms of the optimal price and range of varieties. Incorporating the ZCP condition, survivors' market shares suggest how survivor optimality relates to firm-level market share. Since granularity prevents the derivation of closed-forms of the firm-level optimality, I utilize a quantitative analysis incorporating the revised environment of international trade. The results from the quantitative analysis show the effect of international trade on markups, the number of varieties, prices, and profits.

These results suggest that the pro-competitive market environment and the introduction of foreign productive competitors reduce the firm-level market share, which results in lower markups and prices of varieties. While the optimal range of varieties is determined by the interaction between the changes in market size and firm-level market share, the aggregate range of variety is extended, which results in gains from trade.

2.7 Appendix: The Case of a Generalized Demand System

The Cobb-Douglas utility function at the top-tier preference is a particular form of general CES preference at this level. When the sectoral is treated as an exogenous parameter, assuming the Cobb-Douglas utility function offers three benefits: (a) the optimal allocations set by the survivors are independent of the sectoral share; (b) the Cobb-Douglas utility function reduces the computational burden in quantitative analysis; and, (c) the Cobb-Douglas utility assumption for the aggregate demand fits the spirit of the granularity—a firm has market power within the sector while it is small in the aggregate economy.

Here I relax the strict assumption of the Cobb-Douglas utility function at the top-tier preference. Given the previous assumptions and parameters across the symmetric economies, I introduce a generalized CES demand system to replace the Cobb-Douglas utility function, which implies that the sectoral share is determined endogenously not exogenously. In the generalized CES demand system, a firm's choice may affect the aggregate economy. The introduction of this generalized demand system may have implications for analyzing the oligopoly market.

I start the generalized case by specifying the CES preference for the aggregate demand. The demonstration of a firm's optimality defines the equilibrium, including the endogenous sectoral share within the aggregate economy. Like the Cobb-Douglas set up, this method relies on the quantitative analysis as the firms are not continuous. The computational solution offers intensive competition when the bilateral trade begins, resulting in gains from trade.

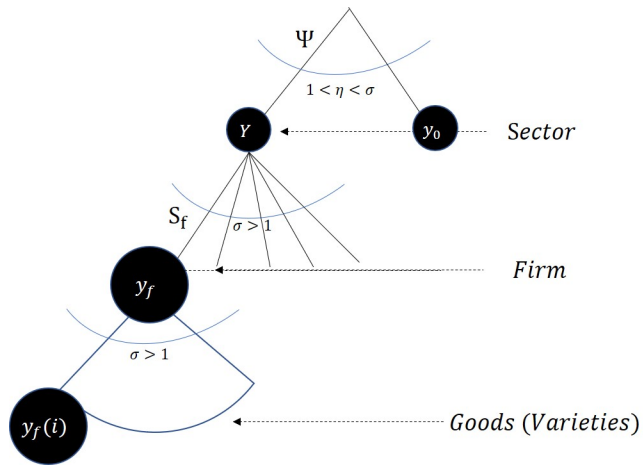

Figure 2.8: Generalized Nested CES Demand System

Demand

As mentioned, I define international trade as the bilateral trade between symmetric economies. Therefore, both economies have the same labor size (L) and wage as unity ($w = 1$). The labor income is for market size I, which is different from the previous specification in which the heterogeneous sector size defines the market size. Figure 2.8 outlines the demand system of a represented consumer with a generalized CES preference.

As in Section 2.4, two sectoral demands form the aggregate demand. In the generalized case, there are two types of elasticities of substitution—η denotes the elasticity of substitution across the sectoral composite goods, and $\eta > 1$ while $\eta < \sigma$. Like the Cobb-Douglas utility at the top-tier demand, σ (> 1) measures the elasticity of substitution across both the firm-level and variety demands. Given the budget constraint of Equation (2.4), the utility maximization offers: (a) price index; (b) Marshallian demand function; and, (c) expenditure share at each demand level. Table 2.10 summarizes the demand system of this framework.

Unlike the Cobb-Douglas utility at the top-tier level, a firm is large from the perspective of the aggregate economy; therefore, firm-level choices affect the aggregate economy. The sectoral share (Ψ) is endogenous as a function of the price index of sectoral demand (P). Also, Ψ and P relate to

Table 2.10: Demand System of a General Form of CES Preference

Level	Demand	Price Index
Aggregate	$U = \left[(y_0)^{\frac{\eta-1}{\eta}} + (Y)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$	$\mathbb{P} = \left[P_0^{1-\eta} + (P)^{1-\eta}\right]^{\frac{1}{1-\eta}}$
Sectoral	$Y = \left[\sum_{f\in\Omega}(y_f)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$	$P = \left[\sum_{f\in\Omega}(P_f)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$
Firm	$y_f = \left[\int_{i\in\Omega_f}(y_f(i))^{\frac{\sigma-1}{\sigma}}\,di\right]^{\frac{\sigma}{\sigma-1}}$	$P_f = \left[\int_{i\in\Omega_f}(P_f(i))^{1-\sigma}\,di\right]^{\frac{1}{1-\sigma}}$
Variety	$y_f(i)$	$P_f(i)$
Variety (Symmetric Technology)	y_{fi}	P_{fi}
Level	**Marshallian Demand**	**Expenditure Share**
Aggregate	$U = \frac{wL}{\mathbb{P}}$	-
Sectoral	$Y = I\frac{P^{1-\eta}}{\mathbb{P}^{1-\eta}}\frac{1}{P}$	$\Psi = \frac{P^{1-\eta}}{\mathbb{P}^{1-\eta}} = \frac{P^{1-\eta}}{P_0^{1-\eta}+P^{1-\eta}}$
Firm	$y_f = I\frac{P^{1-\eta}}{\mathbb{P}^{1-\eta}}\frac{P_f^{1-\sigma}}{P^{1-\sigma}}\frac{1}{P}$	$S_f = \frac{P_f^{1-\sigma}}{P^{1-\sigma}} = \frac{\int_{i\in\Omega_f}\{P_f(i)\,y_f(i)\}\,di}{\sum_{g\in\Omega}\left[\int_{j\in\Omega_g}\{P_g(j)\,y_g(j)\}\,dj\right]}$
Variety	$y_f(i) = I\frac{P^{1-\eta}}{\mathbb{P}^{1-\eta}}\frac{P_f^{1-\sigma}}{P^{1-\sigma}}\frac{\{P_f(i)\}^{1-\sigma}}{P_f^{1-\sigma}}\frac{1}{P_f(i)}$	-
Variety (Symmetric Technology)	$y_{fi} = I\frac{P^{1-\eta}}{\mathbb{P}^{1-\eta}}\frac{P_f^{1-\sigma}}{P^{1-\sigma}}\frac{1}{N_f}\frac{1}{P_{fi}}$	-

the price index for the aggregate demand ($\mathbb{P}$). Samsung-Korea is an example of firm-level decision making that may have an impact on economies.

Technologies

This section follows the details described in Section 2.4. The homogeneous sector relies on constant return to scale technology and produces a numeraire using a unit of labor. The M_e heterogeneous entrants are assigned a random productivity according to Equation (2.15). With the total cost as in Equation (2.17), the profit function for a firm in the heterogeneous sector is described as Equation (2.18).

In the monopolistic competition among the discrete firms, each firm chooses the optimal range of varieties (N_f) and the price of varieties (P_{fi}) that maximizes the profits. The optimal pricing rule is the same as in Equation (2.20), except the demand elasticity for a firm-level good or a variety (ϵ_f). The optimal pricing rule can be rewritten as:

$$P_{fi} = \frac{w}{\varphi_f}\mu_f = \frac{w}{\varphi_f}\frac{\epsilon_f}{\epsilon_f - 1} \; \forall i \in \Omega_f \tag{2.34}$$

where $\epsilon_f (= \sigma + (\eta - \sigma)S_f + (1-\eta)S_f\Psi)$ is the elasticity of substitution. When the sectoral goods are substituted for each other ($\eta > 1$), an increase in sectoral share (Ψ) reduces the demand elasticity (ϵ_f) if the firm's market share S_f is not changed, which relates to a higher markup of the firm's varieties.

In the optimal condition for the range of varieties, the cannibalization effect can be decomposed into direct and indirect effects, such as:

$$\begin{aligned} &\underbrace{\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi}}_{Direct\,marginal\,benefit} + \underbrace{\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi}\frac{1-\eta}{1-\sigma}S_f}_{Indirect\,marginal\,benefit} \\ &- \underbrace{\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi}S_f}_{Direct\,cannibalization} - \underbrace{\left(P_{fi} - \frac{w}{\varphi_f}\right) y_{fi}\frac{1-\eta}{1-\sigma}S_f\Psi}_{Indirect\,cannibalization} = wK_1 \; . \end{aligned} \tag{2.35}$$

In Equation (2.35), direct cannibalization relates to the reduced revenue within the heterogeneous sector. Furthermore, the indirect cannibalization reduces the firm's revenue through the

interaction with the aggregate price index ($\mathbb{P}$) due to a change in the endogenous sectoral share (Ψ). [24]

Following the procedure between Equations (2.24) and (2.26) suggests the optimal number of varieties that active firms produce in the market, such that:

$$N_f = \frac{I\Psi}{K_1}\frac{1}{\sigma-1}\frac{\epsilon_f - 1}{\epsilon_f}S_f > 0 \ . \tag{2.36}$$

Equation (2.36) shows that a change in the heterogeneous sectoral share (Ψ) affects the range of varieties. Unlike the Cobb-Douglas utility at the top-tier preference, a change in the market environment affects the number of varieties (N_f) through three channels: (a) the revised market environment alters the firm's market share (S_f); (b) the market share associates to an inverse of the markup; and, (c) the sectoral share (Ψ) is also changed as the firm is large.

ZCP condition

As discussed in Section 2.4, the ZCP condition offers information to reach the short-run equilibrium in which survivors do not struggle with a negative profit. Given the productivity set for the M_e entrants, the Bertrand competition gives the M_o survivors non-negative profits. In contrast, including the $M_o + 1^{th}$ productive firm in the survivors results in a negative profit for at least one survivor. If the ZCP condition is satisfied, M_o gives the maximum number of survivors with non-negative profits in the market. As a result, M_o^{th} productivity is the ZCP productivity when sorting firms' productivity by descending order, such as $\varphi_1 \geq \varphi_2 \geq \cdots \geq \varphi_{M_e}$. The zero-cutoff profit (ZCP) condition is:

$$\begin{cases} \Pi_f \geq 0 \ and \ S_f > 0 & for \ f \ = \ 1, \cdots, M_o \\ \Pi_f = 0 \ and \ S_f = 0 & for \ f \ = \ M_o + 1, \cdots, M_e \end{cases} \tag{2.37}$$

[24] When the sectoral goods are complementary ($0 < \eta < 1$), the sign of the net indirect effect is negative, which means the indirect cannibalization effect dominates the indirect marginal benefit from extending variety range. In sum, the net marginal benefit from extending the variety range is ambiguous at some N_fs, as the sign depends on the parameters.

where Π_fs and S_fs are the profits and the market share, respectively, of heterogeneous firm f surviving in the market.

In the generalized CES demand system, the endogenous sectoral share (Ψ) in equilibrium relates to the threshold condition. For example, the sectoral market share (Ψ) also affects the market share of the marginal firm S^{ZCP}. Moreover, this sectoral share (Ψ) is associated with the firm's optimality in equilibrium, such as the optimal price (P_f) and range of varieties (N_f). Thus, it is complicated to obtain the ZCP condition. Therefore, in contrast to the Cobb-Douglas case in which the equilibrium can follow the ZCP condition, the elements of the ZCP condition (φ^{ZCP}, S^{ZCP}) and the equilibrium, including the sectoral share (Ψ), are simultaneously determined.

Short-run Equilibrium and Mechanism

Due to simultaneity in determining both the ZCP condition and equilibrium, the short-run equilibrium is redefined as:

Definition. (Short-run Equilibrium: Generalized CES Utility Function) *Given the set of productivity for M_e entrants in an economy with income (I), the Bertrand-Nash equilibrium consists of:*

1. A set of information about the ZCP condition in the heterogeneous sector $\{S^{ZCP},\ \varphi^{ZCP}\}$.
2. A vector of the optimality set by M_o surviving firms, including the price of a variety, the range of varieties, and the firm-level market share $\{P_{fi},\ N_f,\ S_f\}_{f=1}^{M_o}$.
3. A set of a sectoral price index and a sectoral expenditure share within an economy $\{P,\ \Psi\}$.
4. An aggregate price index $\mathbb{P}$ that solves both utility and profit maximization simultaneously.

Because of this simultaneity, the generalized CES demand system also requires extra steps to determine both the ZCP condition and equilibrium. The mechanism starts by introducing an inverse of the relative productivity of a survivor (τ_f), as in Equations (2.29) and (2.30). Then, Equation (2.38) suggests the firm's market share as a function of the inverse of the relative productivity (τ_f), the market share of the marginal firm (S^{ZCP}), and the sectoral share (Ψ):

$$S_f = S(\tau_f)$$
$$= \frac{1}{(\sigma-\eta)+(\eta-1)\Psi}\left[\sigma - \frac{\sigma+(\eta-\sigma)S^{ZCP}+(1-\eta)\Psi S^{ZCP}}{1+\{\sigma+(\eta-\sigma)S^{ZCP}+(1-\eta)\Psi S^{ZCP}\}\left\{(\tau_f)^{-\frac{\sigma-1}{\sigma}}-1\right\}}\right] . \tag{2.38}$$

Among the M_e entered firms, the firms with $\tau_f > 1$ are less productive than the marginal firm, so they suspend producing goods ($S_f = 0 \; if \; \tau_f > 1$). Given arbitrary S^{ZCP} and Ψ, the profit of each survivor can be described as:

$$\Pi_f = \Pi(\tau_f)$$
$$= \frac{\left(S(\tau_f)\right)^2}{\Psi S(\tau_f)+(\sigma-\eta)\left(1-S(\tau_f)\right)+\eta\left(1-\Psi S(\tau_f)\right)}\frac{(\sigma-\eta)+(\eta-1)\Psi}{\sigma-1}I\Psi \tag{2.39}$$

where the fixed cost for inaugurating production is assumed as zero ($K_1 = 0$).

There are two constraints that the mechanism for the generalized CES demand system must consider: (a) the market-clearing condition associated with the market share of the marginal firm (S^{ZCP})—the sum of the survivors' market shares should be equal to one; and, (b) the equivalency of the sectoral market share to the computed share $\Psi = \frac{P^{1-\eta}}{1+P^{1-\eta}}$.

Accounting for the constraints, the non-linear programming suggests two solutions (S^{ZCP}, Ψ) satisfying both the ZCP condition and the definition of equilibrium.

Market Liberalization

As in the example with the Cobb-Douglas utility function at the top-tier preference, the revised environment of market liberalization is adopted to define the equilibrium of international trade. Two symmetric economies, with identical income (I) and firm-level productivity set, begin bilateral trade that forms the double-sized liberalized (or integrated) market ($I^W = 2I$). The bilateral trade scenario is simplified by assuming that there is no additional fixed cost for exporting goods, fixed cost for the initial production ($K_0 = 0$), iceberg trade cost, nor duties such as tariffs.

Regarding the entrants, the M_o survivors in autarky are assumed to maintain their original productivity when they enter the liberalized market. As a result, the $M_e^W (= 2M_o)$ entrants determine

whether to produce in the integrated market. As it is bilateral trade among the two symmetric economies, two firms from different regions share productivity.

Moreover, the sectoral share within the economy (Ψ) and the productivity of marginal firm (S^{ZCP}) are assumed to have less impact on the survivor's market share S_f than the updated inverse of the relative productivity of international trade. The changes in Ψ and S^{ZCP} depend on the random set of productivity among the survivors, an assumption the results from the quantitative analysis support.

The market liberalization between the two symmetric economies updates both the ZCP condition and the short-run equilibrium simultaneously, which determines the optimality of the survivors in the integrated market. The updated ZCP condition consists of the ZCP productivity ($\varphi^{W,ZCP}$) and the market share of the marginal firm ($S^{W,ZCP}$) in the liberalized market. Furthermore, the updated short-run equilibrium offers the revised sectoral share of expenditure (Ψ^W). In the general case, the short-run equilibrium of the trade liberalization is defined as:

Definition. (Short-run Equilibrium of the Trade Liberalization: Generalized CES Utility Function) *Given the fixed firm-level productivity of $M_e^W = 2M_o$ firms surviving in autarky in the symmetric economies with income I, the M_e^W firms face head-to-head competition in the integrated market with $I^W(= 2I)$. The Bertrand-Nash equilibrium of trade liberalization in the short-run consists of:*

1. A set of information about the ZCP condition in the heterogeneous sector $\{S^{W,ZCP},\ \varphi^{W,ZCP}\}$.
2. A vector of the optimality set by the M_o^W surviving firms in the integrated market, including the price of a variety, the range of varieties, and the firm-level market share $\{P_{fi},\ N_f,\ S_f\}_{f=1}^{M_o}$.
3. A set of a sectoral price index and a sectoral expenditure share within an economy $\{P,\ \Psi^W\}$.
4. An aggregate price index $\mathbb{P}$, which solves both utility and profit maximization simultaneously.

Quantitative Analysis

Quantitative analysis numerically demonstrates the partial equilibrium of international trade in the short-run. The analysis utilizes the three new productivity sets drawn in Section 2.5 through the clustered and systematic sampling method. Moreover, most of the analysis settings in the generalized case incorporate those in the Cobb-Douglas utility function at the top-tier preference. [25]

The distinctive features in the generalized case are the indication of the market size and the introduction of the elasticity of substitution across the sectoral composite goods. As the sectoral market share (Ψ) is endogenous, international trade doubles not the sectoral market size but the aggregate market size. Therefore, the sectoral market size cannot represent the market size in an economy. Instead, the generalized case accounts for the aggregate market size measured by labor income. In this quantitative analysis, the employed market sizes are $I = 2000$ ($= wL$) in autarky and $I^W = 4000$ ($= 2I = 2wL$) in the integrated market.

Furthermore, the sectoral elasticity of substitution is assumed as two ($\eta = 2$), which is reasonable in that the sectoral elasticity of substitution is usually less than the firm-level elasticity of substitution within a sector.

Tables 2.11–2.13 report the short-run equilibrium of international trade. Like the Cobb-Douglas utility function case, the liberalized market is more pro-competitive. Head-to-head competition reallocates resources to more productive firms among the M_e^W entrants, which deprives monopolistic market power of the most productive firms (Example 1) or expels the least productive firms from the liberalized market (Examples 2 and 3) in the short-run. As a result, the quantitative analysis determines that only the most productive firms survive in the liberalized market.

The market liberalization results in a higher expenditure share in the heterogeneous sector (Ψ). The head-to-head competition lowers the optimal price of a variety, which offers a lower sectoral price index. As the sectoral goods are substitutes for each other with a higher elasticity of

[25] As in Section 2.5. The fixed cost for initiating production is zero ($K_0 = 0$), the cost for marginally expanding the range of varieties is five ($K_1 = 5$), and the elasticity of substitution across the firm-level demands is assumed as six ($\sigma = 6$).

substitution ($\eta > 1$), a lower sectoral price index suggests increases in both market size and share in the heterogeneous sector. From Examples 2 and 3, sectoral shares increase from 26.9% to 32.8% and from 27.7% to 36.3%, respectively.

In the liberalized market, the survivors reduce markup and price of a variety, and the aggregate range of variety expands. Notably, in Example 1, the pro-competitive market makes the former monopolists (Firm 1s) expand the range of variety to maintain market power and revenue in the integrated market.

In contrast to previous studies, when there is a higher elasticity of substitution across the sectoral composite goods ($\eta > 1$), a more highly productive firm may set a 'higher' price and markup. A higher sectoral share (Ψ) in the liberalized market lowers the firm-level demand elasticity (ϵ_f). Therefore, productive firms set a higher markup and price when the difference in productivity (or marginal cost) is less than the difference in markups among the survivors.

Table 2.11: Summary: Short-run Equilibrium of International Trade in Each Economy (CES, Example 1 Set of Productivities)

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active	Sectoral Share	Sectoral Price Index
Before	1	2.406	100.0%	699.8	13.7	1.35	3.25	Yes	55.5%	0.80
	2	0.317	0.0%	0.0	0.0	-	-	No		
	3	0.276	0.0%	0.0	0.0	-	-	No		
	4	0.254	0.0%	0.0	0.0	-	-	No		
	5	0.240	0.0%	0.0	0.0	-	-	No		
	6	0.230	0.0%	0.0	0.0	-	-	No		
	7	0.221	0.0%	0.0	0.0	-	-	No		
	8	0.215	0.0%	0.0	0.0	-	-	No		
	9	0.209	0.0%	0.0	0.0	-	-	No		
	10	0.204	0.0%	0.0	0.0	-	-	No		
After	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active	Sectoral Share	Sectoral Price Index
	1	2.406	50.0%	217.1	46.8	0.58	1.39	Yes	81.1%	0.23

Table 2.12: Summary: Short-run Equilibrium of International Trade in Each Economy (CES, Example 2 Set of Productivities)

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active	Sectoral Share	Sectoral Price Index
Before	1	0.317	70.3%	75.8	10.9	4.73	1.50	Yes	26.9%	2.72
	2	0.276	29.7%	8.5	3.4	4.59	1.27	Yes		
	3	0.254	0.0%	0.0	0.0	-	-	No		
	4	0.240	0.0%	0.0	0.0	-	-	No		
	5	0.230	0.0%	0.0	0.0	-	-	No		
	6	0.221	0.0%	0.0	0.0	-	-	No		
	7	0.215	0.0%	0.0	0.0	-	-	No		
	8	0.209	0.0%	0.0	0.0	-	-	No		
	9	0.204	0.0%	0.0	0.0	-	-	No		
	10	0.200	0.0%	0.0	0.0	-	-	No		
After	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active	Sectoral Share	Sectoral Price Index
	1	0.317	50.0%	74.0	19.40	4.27	1.35	Yes	32.8%	2.05
	2	0.276	0.0%	0.0	0.00	-	-	No		

Table 2.13: Summary: Short-run Equilibrium of International Trade in Each Economy (CES, Example 3 Set of Productivities)

	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active	Sectoral Share	Sectoral Price Index
Before	1	0.364	80.9%	122.2	10.87	4.53	1.65	Yes	27.7%	2.61
	2	0.293	19.1%	3.3	3.41	4.24	1.24	Yes		
	3	0.264	0.0%	0.0	0.00	-	-	No		
	4	0.247	0.0%	0.0	0.00	-	-	No		
	5	0.235	0.0%	0.0	0.00	-	-	No		
	6	0.225	0.0%	0.0	0.00	-	-	No		
	7	0.218	0.0%	0.0	0.00	-	-	No		
	8	0.212	0.0%	0.0	0.00	-	-	No		
	9	0.207	0.0%	0.0	0.00	-	-	No		
	10	0.202	0.0%	0.0	0.00	-	-	No		
After	Firm	Productivity	Market Share	Profit	Number of Varieties	Variety Price	Markup	Active	Sectoral Share	Sectoral Price Index
	1	0.364	50.0%	82.95	21.43	3.72	1.35	Yes	36.3%	1.75
	2	0.293	0.0%	0.00	0.00	-	-	No		

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CHAPTER 3. ASSESSING DAMAGES IN WORLD TRADE ORGANIZATION DISPUTE SETTLEMENTS

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3.1 Abstract

In this study, I examine new methods used in World Trade Organization Article 22.6 arbitration. Arbitration determines the level of nullification or impairment associated with WTO-inconsistent anti-dumping and countervailing duties. Specifically, I analyze two current arbitration cases employing the Armington framework: Korea's large residential washers case (case DS464) and an anti-dumping duty case involving China (case DS471). My investigation suggests two issues in the arbitration. First, in case DS464, the Armington elasticity is 4, which is so low that Korea's calibrated gross 17.7% share of the U.S. large residential washer market is much higher than the actual share of 6.5%. Moreover, this case underestimates the level of nullification or impairment. Second, in case DS471, the reporting level of nullification or impairment includes not only a change in shipment value, but also a difference in implied duties. Replicating the DS464 case model to case DS471 shows that DS471 incorporates a decrease in the duty payment of (U.S.) $27.1 million in the estimated level of nullification or impairment. The sensitivity analysis identifies that a higher Armington elasticity (greater than 4) not only reduces the gap between Korea's calibrated and actual share of the market, but it also allows more modest results. Furthermore, the level of nullification or impairment is modest across various supply elasticities, which range from 6 to 8. Finally, given the assumed parameters of case DS464, the estimation model incorporates both duties together.

In this model, the estimated nullification or impairment ($81.7 million) is 3.7% smaller than that from the separate computation in case DS464.

3.2 Introduction

In the last twenty years, the World Trade Organization (WTO) has dealt with seventeen cases of Article 22.6 arbitration. Arbitration determines the level of nullification or impairment (NoI) associated with WTO-inconsistent anti-dumping and countervailing duties. [1] [2]

Even though the WTO has contributed objective arbitration with scientific methods in most cases, recent evidence shows a disputable NoI level associated with groundless parameters or inconsistent reporting standards across cases. For instance, the conventional elasticity of substitution does not reflect the exact decline of market share caused by the WTO-inconsistent duties, and, as a result, underestimates the NoI level. Furthermore, the latest arbitration reports an NoI level that includes a change in the value of duties, which is inconsistent with previous cases reporting NoIs containing only a change in the value of the shipment. This study accounts for new methods used under WTO Article 22.6 arbitration. Specifically, two arbitration cases employing the Armington framework: Korea's large residential washers (LRW) (case DS464, WTO (2019b)) and an anti-dumping duty case involving China (case DS471, WTO (2019c)). The Armington model and a mixed complementary problem (MCP) serve as the microfoundations for the partial equilibrium model, which introduces a legal context for the DS464 case. After discussing the theoretical and legal backgrounds, I describe the Armington model and the two-step procedure to calculate the NoI in cases DS464 and DS471. Replication of the DS464 case suggests the first issue with WTO's arbitration is the elasticity of substitution across regional components (the Armington elasticity). Application of the DS464 data to the DS471 framework results in an inconsistency in the NoI

[1] Article 22 in Understanding on Rules and Procedures Governing the Settlement of Disputes (hereafter dispute settlement understanding) describes compensation and suspension of concessions. According to Article 22.6, the member concerned can request authorization from the WTO Dispute Settlement Board to suspend concessions or other obligations when it fails to agree on a satisfactory compensation within a reasonable period of time with the member accused of excising the WTO-inconsistent duties.

[2] NoI is any damage to the complainant's advantages from its WTO membership through the respondent's change in trade policy or its excise of WTO-inconsistent duties.

reporting measure despite the identical estimation procedures. Furthermore, the sensitivity analysis accounts for one and two standard deviations around the original estimates incorporated in the arbitration, and it considers a case in which both anti-dumping and countervailing duties are included in the estimation model simultaneously.

With Balistreri et al. (2020), this paper is one of a few attempts to comprehensively evaluate the WTO's current arbitration employing the Armington model. Previous studies handle the WTO's arbitration with a different framework—before the DS464 case, most arbitration cases relied on the widely recognized framework stemming from Bagwell and Staiger (1990). Bagwell and Staiger (1990) defines the level of damage as a change in welfare, a sum of consumer surplus (CS), producer surplus (PS), and revenue from duties (RT). Based on the framework in Bagwell and Staiger (1990), retaliation studies, such as Bown and Ruta (2010), Bown and Reynolds (2017), and Grossman and Sykes (2011), expand a framework where the level of damage is defined as a political-weighted sum of CS, PS, and RT. [3] In case DS464, Korea's government relied on the perfect substitutes model in Bown and Ruta (2010) to estimate damages from the WTO-inconsistent duties excised by the United States.

My investigation suggests two issues in the arbitration. First, the Armington elasticity in the DS464 case is 4, which is so low that Korea's hypothesized share in the U.S. LRW market (17.7%) is much higher than the actual share (6.5%). Second, replicating case DS464 with the DS471 framework suggests that DS471 arbitration includes a decrease in the duty payments in the NoI. Both of these issues result in underestimating the NoI level.

The sensitivity analysis shows that a higher Armington elasticity not only reduces the gap between the calibrated and actual shares of Korea's 2017 U.S. LRW market share, but also suggests modest results. When the Armington elasticity is 30, Korea's benchmark 2017 calibrated LRW market share is 13.3%, which is smaller than the baseline 17.7% when the Armington elasticity is 4. Korea's actual 2017 U.S. LRW market share is 6.5%; thus, a higher Armington elasticity leads to a lower difference between the calibrated and actual shares. Regarding the deviation, an

[3] According to Bown and Ruta (2010), the political-weight sum gives a higher-than-unity weight on organized special interests such as PS and RT.

increase in the Armington elasticity from 28 to 30 results in a 0.7% increase in NoI, which is smaller than the 27.9% increase from an Armington elasticity between 3 and 5. On the supply side, the NoI level is modest across various supply elasticities. An increase in the supply elasticities from 6 to 8 yields a 5.5% increase in the baseline NoI level when the default Armington elasticity is 4. Moreover, given the parameters of case DS464, the estimation model incorporates both duties together. In this model, the estimated NoI ($81.7 million) is 3.7% smaller than the NoI from the separate computation in case DS464.

The rest of this paper is structured as follows. Section 3.3 details the partial equilibrium microfoundations. Section 3.4 provides a legal background of estimating NoI in Korea's LRW case. Section 3.5 discusses the calibration and replication results of Korea's LRW case. Section 3.6 details the sensitivity analysis. Section 3.7 provides concluding remarks.

3.3 The Partial Equilibrium Trade Model

3.3.1 The Armington Model

The Armington (1969) model is a framework recently employed in WTO arbitration cases. The model assumes imperfect substitution across regional components. The elasticity of substitution across regional components, the so-called Armington elasticity, is an essential parameter to evaluate trade effects (McDaniel and Balistreri (2002)).

3.3.2 Mixed Complementary Problem Programming

The Armington model requires non-linear programming to solve the system. This study employs an MCP algorithm, which is significantly advantageous in that its complementary conditions align with intuition in economics.

The Armington model system consists of four equations with the complementary conditions. Equation (3.1) describes the aggregate demand and its complementary relationship with the aggregate price index:

$$0 \leq Q - \kappa P^{\theta} \ \perp \ P \geq 0 \tag{3.1}$$

where κ is a parameter representing the aggregate demand shifter; and, θ is the price elasticity of aggregate demand.

The regional components are nested in the aggregate demand with the Armington elasticity (σ). Therefore, Equation (3.2) shows the aggregate price index dual to the aggregate demand in equilibrium:

$$0 \leq \left[\sum_r (\omega_r)^\sigma \{(1+t_r)p_r\}^{1-\sigma} \right]^{\frac{1}{1-\sigma}} - P \ \perp \ Q \geq 0 \tag{3.2}$$

where r is an index representing a region; ω_r is a regional component demand shifter; p_r is the price of the regional component; and, t_r is an ad-valorem duty rate excised on a unit of goods produced in region r.

The following two equations are associated with a regional component. Market clearance in equilibrium implies that the import demand should be equal to the export supply at a positive value of price as described in Equation (3.3):

$$0 \leq X_r - (\omega_r)^\sigma \{\frac{(1+t_r)p_r}{P}\}^{-\sigma} Q \ \perp \ p_r \geq 0 \tag{3.3}$$

where X_r is the quantity regional component produced in region r.

Equation (3.4) describes the supply function of regional components and the complementary relationship with import demand:

$$0 \leq \lambda_r (p_r)^{\epsilon_r} - X_r \ \perp \ X_r \geq 0 \tag{3.4}$$

where λ_r is a supply shifter for the regional component associated with technology; and, ϵ_r is the supply elasticity for a component produced in region r.

3.4 Legal Context: Case DS464

WTO case DS464 focuses on Korea's LRWs in the U.S. market. The case began with Korea's request for consultation from the WTO's Dispute Settlement Body (DSB) regarding the United States' duties excised on LRWs imported from South Korea in 2013. [4]

[4] In February 2013, the U.S. Department of Commerce assigned anti-dumping duties, as a less-than-fair-value margin rate, on LRWs imported from South Korea (82.41% for Daewoo products, 13.02% for LG products, 9.29%

In September 2016, the DSB adopted the Appellate Body's (AB) decision and determined that the duties excised by the United States were WTO-inconsistent according to the anti-dumping agreement and the agreement of subsidies and countervailing measures. First, the AB pointed out that the United States used the weighted average-to-transaction ("W-T") methodology to investigate Korea's LRW export price, which was criticized as an inconsistent compared to the weighted average-to-weighted average ("W-W") and transaction-transaction ("T-T") methodologies. Second, the United States' use of zeroing methodology was not WTO-consistent. The AB criticized that zeroing could amplify the anti-dumping duty rate under the W-T methodology. [5] Third, the AB found that the countervailing duties excised by the United States were higher than Korea's subsidization margin, which is also WTO-inconsistent. [6]

The DSB advised the United States to implement its decision by December 26, 2017; however, the United States failed to do so within the specified time frame. [7] Therefore, in January 2018, Korea called for authorization to suspend export duties on LRWs in the U.S. market according to Article 22.6 of the dispute settlement understanding. Korea suggested $711 million in damages from the United States' non-compliance to the DSB. The United States objected to Korea's level of proposed damages, which resulted in arbitration under Articles 22.6 and 22.7.

Arbitrators had to determine a reasonable quantitative method to determine the NoI level; however, there was no consensus on the estimation model. Therefore, arbitrators evaluated the frameworks suggested by both Korea and the United States.

for Samsung products, and 11.86% for all others). WTO determined the rate of countervailing duties determined was 72.30% for Daewoo, 0.01% for LG, and 1.85% for all others, including Samsung products (USITC (2017a)). WTO arbitrators referred to weighted average duties for anti-dumping and countervailing rates of 11.86% and 0.58%, respectively.

[5] Zeroing is a methodology to measure anti-dumping duties on import products where the difference between the foreign domestic price and the U.S. import price (adjusted for freight and insurance costs) is zero. When applying zeroing, the negative difference is excluded in calculating the anti-dumping rate, which results in overestimated anti-dumping duties.

[6] The United States inappropriately claimed that Samsung's worldwide products applied certain Korean subsidies, even though those subsidies were only for Samsung's digital appliances in Korea's market.

[7] According to recent communications on case DS464, the United States claims it has implemented the DSB's decision, as USDOC published a revocation notice for both duties in the U.S. Federal Register on May 6, 2019. (Doc#: 20-5611, https://docs.wto.org/dol2fe/Pages/FE_Search/FE_S_S009-DP.aspx?language=E&CatalogueIdList=265818,265111,264488,261342,260563,259527,258795,257833,257068,256054&CurrentCatalogueIdIndex=0&FullTextHash=&HasEnglishRecord=True&HasFrenchRecord=True&HasSpanishRecord=True).

Korea claimed that the United States' COMPAS framework based on the Armington model is inappropriate for measuring NoI level because it assumes a fixed number of varieties and a highly sensitive elasticity, and due to a lack of previous Article 22.6 arbitration cases conducted using the Armington model. [8] Instead, Korea supported using the model in Bown and Ruta (2010), due to the simple procedure for calculating NoI level and the advantage of removing external factors of indirect trade impact. Furthermore, Korea noted the United States proposed using the Bown and Ruta (2010) model in case DS430.

To calculate NoI level, Korea proposed employing its 2011 U.S. LRW market share to determine its 2017 LRW import value, as the 2012 duties did not affect its 2011 export share. Thus, by Korea's suggestion, its LRW market share pre-DSB suggestion implementation in 2017 can be found by applying the WTO-inconsistent rates to its 2011 U.S. LRW market share.

The United States refuted Korea's suggestions and insisted on using the Armington framework. The United States documented many quantitative trade models that widely incorporate regional components; and, as Korea failed to prove comparative advantage in the U.S. LRW market, the United States argued that gains from trade, including comparative advantage, could not be topics in the arbitration. Moreover, the United States criticized Korea's assumption that LRWs are homogeneous goods with perfect substitutability. The United States asserted that the Armington framework offers accuracy in estimating NoI level, as the Armington model incorporating imperfect substitution across producers relates to how a small number of producers cover the U.S. LRW market.

In contrast to Korea's proposal, the United States proposed using Korea's 2017 LRW import share to determine total import value and calculate the 2017 import value share of Korea's LRWs not affected by the WTO-inconsistent duties. Thus, both parties agreed that 2017 was the year in which the reasonable period of time for the United States to implement the DSB's decision ended.

[8] COMPAS allows a regional component as the only variety of a specific industry produced in a region, and it assumes that there are only three varieties within the framework—domestic products, subject imports, and non-subject imports. Korea argued that the extreme assumptions employed in the Armington model prevent identifying major gains from trade, such as comparative advantage and love of variety, which results in underestimating NoI. Moreover, Korea questioned the accuracy of NoI from the Armington-based COMPAS framework because a small change in the Armington elasticity yields high fluctuation in calculated NoI.

To estimate the NoI level in case DS464, the arbitrator used Korea's 2011 U.S. LRW market share and employed the Armington model, which allowed accounting for a small number of suppliers with product differentiation in the U.S. LRW market rather than the perfect substitution model in Bown and Ruta (2010). [9] The arbitrator agreed to incorporate Korea's 2011 U.S. LRW market share as they worried that use of 2017's already reduced trade shares would result in both counter-intuitive outcomes, such as a higher inconsistent duty rate and a lower NoI level, despite the severe decline in trade caused by the WTO-inconsistent duties, and it could overlook that longer inconsistent duties may lead to a lower NoI level.

In sum, the arbitration utilizes a two-step estimation to calculate the NoI level. First, it calculates Korea's 2012 U.S. LRW market share under the WTO-inconsistent duties using Korea's 2011 U.S. LRW market share. Second, it estimates the NoI level by incorporating Korea's calibrated 2012 market share and duties consistent with WTO agreements.

3.5 Calibration and Replication of Case DS464

Based on the system of the Armington framework, which consists of Equations (3.1)–(3.4), the WTO suggested two computational models: (a) a conventional model (M1) in case DS464 that employs normalized net prices (or shipping prices); and, (b) an alternative model (M3) in case DS471 that relies on normalized gross prices, including duty rates. An additional model (M2), applies gross prices to the conventional model. Furthermore, there are two regions across the models: (a) Korea (KOR), the region in which the product is subject to the WTO-inconsistent duties; and (b) the United States (OTH).

Given the computational models, the two-step estimation begins with replicating a benchmark. The benchmark in the first step requires three exogenous data—the United States' 2011 market size of a product, a 2011 component-level market size, and benchmark prices of regional components. Then, applying the data of the WTO-inconsistent duties, anti-dumping, and countervailing duties

[9] The arbitrator evaluated the perfect substitution model in Bown and Ruta (2010) as as extreme case of the Armington model with an infinite Armington elasticity. They also stated that the lack of a previous Article 22.6 arbitration incorporating the Armington model does not support its preclusion.

Table 3.1: Relevant Variables

		Conventional: Net (M1)	Conventional: Gross (M2)	Alternative: Gross (M3)
Aggregate quantity:	Q	√	√	√
Aggregate price index:	P	√	√	√
Conventional Models				
Quantity of regional component:	X_r	√	√	
Price of regional component (Net):	p_r	√		
Price of regional component (Gross):	$\tilde{p}_r$		√	
Alternative Normalization				
Quantity of regional component:	$\hat{X}_r$			√
Price of regional component (Gross):	$\hat{p}_r$			√

Notes: $r \in \{KOR, OTH\}$

to a model, the simulation results offer counterfactual market shares under the WTO-inconsistent duties. In the second step, it is necessary to replicate an additional benchmark with the following information: (a) the actual size of the 2017 U.S. LRW market; (b) the component-level hypothetical benchmark market size; (c) the WTO-inconsistent duty rates; and, (d) benchmark prices. In the benchmark of the second step, the hypothetical market size for each regional component is computed by multiplying the United States' actual 2017 LRW market size by the counterfactual market share computed in the first stage. Finally, the counterfactual results from reduced duty rates consistent with the WTO's standards provide a simulated value of exports that are not affected by WTO-inconsistent duties. The NoI is the difference between the benchmark and counterfactual value of Korea's LRW exports in the second stage estimation.

Tables 3.1 and 3.2 define relevant variables and algebraic partial equilibrium conditions, respectively, for each model. Table 3.3 describes data resulting from each model and Table 3.4 focuses on the calibrated results from the replication with the estimation model and the definition of NoI in case DS471 (M3'). As discussed later, there is a WTO error in defining the NoI level in case DS471. Therefore, the corrected NoI level is attached at the end of Table 3.4.

Table 3.2: Algebraic Partial Equilibrium Conditions

	Conventional: Net (M1)	Conventional: Gross (M2)	Alternative: Gross (M3)
Aggregate demand function:			
$Q = \kappa P^{\theta}$	$\surd$	$\surd$	$\surd$
Aggregate price index:			
$P = \left[\sum_r (\omega_r)^{\sigma}\{(1+t_r)p_r\}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$	$\surd$		
$P = \left[\sum_r (\omega_r)^{\sigma}\{\tilde{p}_r\}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$		$\surd$	
$P = \left[\sum_r (\hat{\omega}_r)^{\sigma}\{\hat{p}_r\}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$			$\surd$
Supply function of each component:			
$X_r = \lambda_r (p_r)^{\epsilon_r}$	$\surd$		
$X_r = \lambda_r (\frac{\tilde{p}_r}{1+t_r})^{\epsilon_r}$		$\surd$	
$\hat{X}_r = \hat{\lambda}_r (\frac{\hat{p}_r}{1+t_r})^{\epsilon_r}$			$\surd$
Market clear condition for each component:			
$X_r = M_r \equiv (\omega_r)^{\sigma}\{\frac{(1+t_r)p_r}{P}\}^{-\sigma} Q$	$\surd$		
$X_r = M_r \equiv (\omega_r)^{\sigma}\{\frac{\tilde{p}_r}{P}\}^{-\sigma} Q$		$\surd$	
$\hat{X}_r = \hat{M}_r \equiv (\hat{\omega}_r)^{\sigma}\{\frac{\hat{p}_r}{P}\}^{-\sigma} Q$			$\surd$

Notes: $r \in \{KOR, OTH\}$, and $t^0_{OTH} = t_{OTH} = 0$

Table 3.8 in Appendix A shows the calibration strategies for corresponding parameters. Given the equilibrium conditions and the fixed parameters, Korea's LRW import share is calibrated as the proportion of the gross demand value of Korea's LRWs in the U.S. LRW market. In the calibration, the benchmark quantities of regional components are found by applying the benchmark gross prices, $\tilde{p}^0_r$ for the conventional models or $\hat{p}^0_r$ for the alternative model, to the value of regional components in the U.S. market. The parameters of both demand and supply shifting coefficients are computed by normalizing the benchmark variables to one. For example, the ratio of counterfactual to benchmark demand ($= M_r/M^0_r$) offers the value of demand shifting coefficients, such as ω_r or $\hat{\omega}_r$. In addition, the supply-side shifters, such as λ_r or $\hat{\lambda}_r$, are achieved by the standardized quantity of supply with the quantity at the benchmark ($= X_r/X^0_r$).

The replication of both cases incorporating the Armington framework provokes two significant issues in estimating the NoI level. First, in case DS464, the assumption of an Armington elasticity of 4. This low elasticity of substitution differentiates Korea's actual 2017 LRW market share from the

Table 3.3: Data Calibrated from Estimation Models: Case DS464

	Korea 2017				Others (incl. U.S.) 2017			
	Price	Quantity	Value of Imports	NoI	Price	Quantity	Value of Imports	NoI
Conventional: Net price (M1)								
Benchmark	1	588.3	588.3		1	3060.4	3060.4	
Counterfactual	1.017	651.5	662.7		0.997	3007.8	2999.1	
NoI				74.4				-
NoI+Δ Duties				47.3				-
Conventional: Gross price (M2)								
Benchmark	1.119	588.3	588.3		1	3060.4	3060.4	
Counterfactual	1.083	651.5	662.7		0.997	3007.8	2999.1	
NoI				74.4				-
NoI+Δ Duties				47.3				-
Alternative: Gross price (M3)								
Benchmark	1	658.0	588.3		1	3060.4	3060.4	
Counterfactual	0.968	728.8	662.7		0.997	3007.8	2999.1	
NoI				74.4				-
NoI+Δ Duties				47.3				-

[a.] Unit quantity: millions; unit value: (U.S.) $million.
[b.] Table 3.9 describes data for the countervailing duties case.
[c.] Results are calibrated values at the second stage estimations.
[d.] Values are rounded to the nearest first decimal.
[f.] As calibrated in this sutdy, models (M1)–(M3) define the value of imports as the shipment value, while the case DS471 model measures the value of imports as the gross value of imports, including duties.

Table 3.4: Calibrated Data Comparison: Case DS471 Model and Corrected Case DS471 Model

	Korea 2017				Others (incl. U.S.) 2017			
	Price	Quantity	Value of Imports	NoI	Price	Quantity	Value of Imports	NoI
Alternative: Gross price model incorporated in DS471 (M3')								
Benchmark	1	658.0	588.3		1	3060.4	3060.4	
Counterfactual	0.968	728.8	662.7		0.997	3007.8	2999.1	
Reported NoI				47.3				-
ΔDuties				−27.1				-
Corrected NoI				74.4				-

Notes: The model incorporated in DS471 (M3') measures the value of imports as a gross value of imports, including the amount of duty, using STATA. Therefore, I also recalculate the correct NoI level using STATA.

counterfactual share from the first-stage computation. According to WTO (2019b), the elasticity of substitution across regional components in the actual computation referred to the United States' recent safeguard investigation of LRWs described in USITC (2017a). [10] Given the United States' proposed Armington elasticity of 4, Koreas calibrated share of LRW exports, including duties, is 17.7%, which is higher than the actual market share of 6.5% based on USITC's suggested data. [11] This lower level of Korea's actual 2017 LRW market share implies that LRWs are more highly substitutable products than argued by the United States. Moreover, a higher Armington elasticity could satisfy the definition of reference year when estimating the amount of NoI because the higher elasticity yields a hypothesized 2017 LRW market share for Korea that is closer to actuality.

The second issue is the error in reporting the NoI level in case DS471, which is associated with the normalized gross prices incorporated in the case. In contrast to DS471, DS464 employs the conventional model with net price normalization (model M1 in Table 3.3) despite the same Armington framework as case DS471. Given the shipment value of regional components is a measure for the value of imports, the straightforward calibration in M1 offers the estimated level of NoI as a change in shipment value, excluding a decreasing amount of duties ($74.4 million). Case DS471 employs the alternative model with normalized gross benchmark prices (M3 and M3') and defines the value of imports as the sum of the payments in duties and shipments. Therefore, the NoI level is $47.3 million, which includes a change in duties, as in Table 3.4, such that the reported NoI value could be lower than the actual value of damage measured by a change in the shipment value. [12]

Due to the NoI level reporting error in case DS471, the equilibrium price and quantity depend on the model, though each component's expenditure and the NoI have identical values, as in Table 3.3. In the conventional models (M1 and M2), the benchmark gross price of Korea's LRWs in the second

[10] Using a survey of stakeholders in the U.S. LRW market, the USITC found that the Armington elasticity of LRWs is between 3 and 5. The United States supported this Armington elasticity by citing Soderbery (2015), in which the elasticity of substitution of LRWs ranges from 2.2 to 4.3 (WTO (2019b)). Korea failed to support an elasticity of substitution greater than 4 for LRWs.

[11] Based on the U.S. proposal to the WTO (WTO (2019a)), Korea's actual 2017 import value can be computed as $243.7 million by multiplying Korea's import share in total LRW imports (15.5%) with the actual LRWs import value based on 10-digit Harmonized Tariff Schedule subheadings ($1.573 billion). Applying U.S. market size for LRWs ($3.718 billion), one can calculate Korea's actual 2017 U.S. LRW market share as 6.5%.

[12] In the case of the WTO-inconsistent countervailing duty, the NoI level is $10.4 million. The gross measure of damage value is $6.0 million when it includes a change in duty, as in Table 3.9.

stage is higher than the U.S. LRW price. In contrast, the gross prices for both regional components are normalized as unity in the alternative model (M3). This difference causes a discrepancy in counterfactual price and quantity across the partial equilibrium models. Korea's benchmark in 2017 for LRWs is 588.3 million units in the conventional models and 658.1 million units in the alternative model. Likewise, in the counterfactual scenario, the equilibrium price and quantity differ between the conventional and alternative models, despite the identical amount of imports measured by the shipment value.

Furthermore, the NoI level reporting error made arbitration of case DS471 include the duty amounts into the benchmark quantity of a regional component. Therefore, in case DS471, the benchmark quantity of each regional component measures the gross demand. Given the aggregate market size and demand for each regional component, the benchmark quantity of regional components should be a shipment quantity equivalent to the actual units of LRWs supplied to the U.S. market, which can be calculated by dividing the gross demand of each regional LRW by a gross price. For example, in the conventional model with normalized net prices (M1), the benchmark quantities are shipment quantities, and the gross demand of each regional component can be straightforwardly decomposed into the values of imports and duties as a monetary value. In the alternative model (M3), the gross prices at the benchmark are normalized as unity across products. Thus, in M3, the measure of duties can be treated as a unit of LRWs.

3.6 Sensitivity Analysis

I conduct a standard sensitivity analysis to investigate how the level of NoI responds to a change in the Armington elasticity (σ) or supply elasticity (ϵ_r). The sensitivity analysis employs the conventional model with normalized net prices of regional components (M1). The arbitrator in case DS464 suggested an NoI level calculated from a separate estimation procedure that assumed no WTO-inconsistent countervailing duty levied during the period of investigation, and, therefore it excludes the scenario of simultaneously levied duties. Thus, in this section, the revised estimation procedure accounts for those duties together and suggests a feasible NoI level.

3.6.1 Elasticity of Import Substitution (Armington Elasticity)

In case DS464, the United States suggested an Armington elasticity of 4, which the arbitrator adopted as Korea failed to recommend an elasticity higher than 4. The elasticity resulted in a gap between Korea's actual 2017 U.S. LRW marekt share (6.5%) and the calibrated share (17.7%) in terms of gross value of imports including duties.

Figure 3.1 and Table 3.5 describe the quantitative results related to the WTO-inconsistent anti-dumping duty from various Armington elasticities (σ). In case DS464, an increase in the Armington elasticity from 3 (4) to 4 (5) raises the NoI level by 15.7% (10.5%), which is consistent with the range from the United States' sensitivity analysis (16.5%–19.9%) (WTO (2019b)).

An Armington elasticity higher than the baseline ($\sigma = 4$) not only reduces the gap between Korea's calibrated and actual shares of the 2017 U.S. LRW market, it also allows for more modest results. Korea's 2017 calibrated market share at the benchmark is 13.3% with an Armington elasticity of 30, which is closer to the actual 2017 market share (6.5%) than the computed baseline benchmark share of 17.7%. Moreover, an increase in the Armington elasticity from 28 to 30 raises the NoI level by 0.7%, which implies that the results are more robust with higher Armington elasticities than around the baseline ($\sigma \in [3, 5]$).

3.6.2 Elasticity of Regional Component Supply

In case DS464 (WTO (2019b)), Korea cited a USITC report about Chinese LRW exports (USITC (2017b)) in which supply elasticity ranged from 6 to 8. The United States argued the parameter was 6 based on the USITC's global safeguard investigation of LRWs (USITC (2017a)). The arbitration incorporated the United States' suggestion as it was the latest reference.

Table 3.6 reports quantitative analysis results for WTO-inconsistent anti-dumping duties from various supply elasticities (ϵ_r) using the conventional model (M1) as an estimation framework and an Armington elasticity of 4 ($\sigma = 4$).

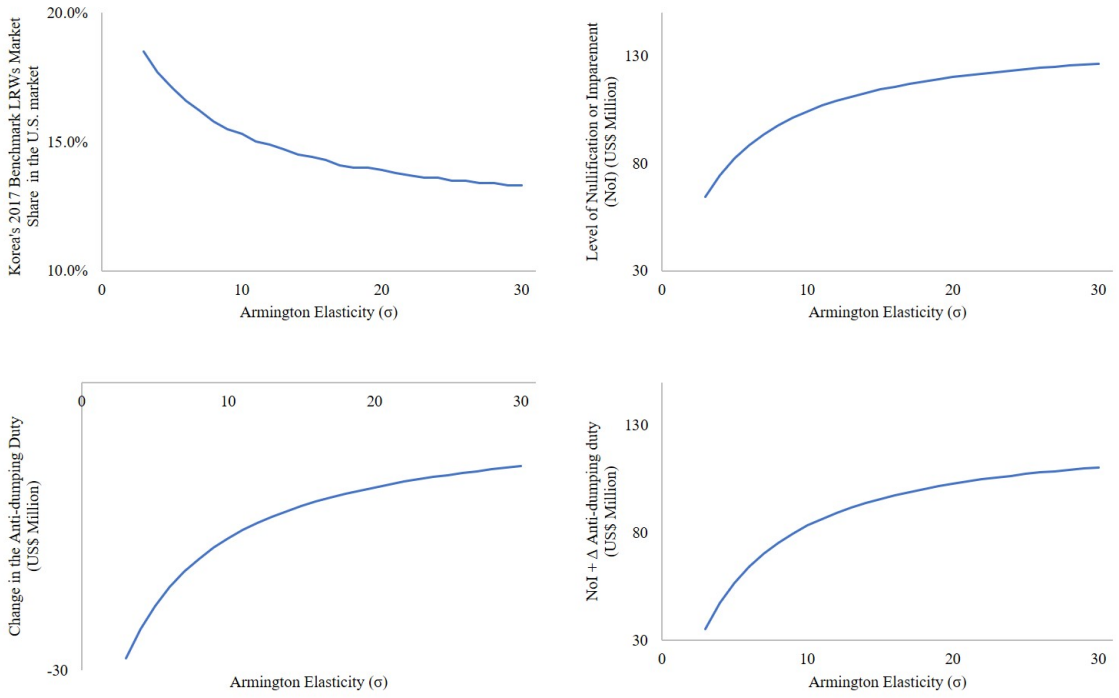

Figure 3.1: Change in Korea's 2017 Benchmark Market Share and NoI across Armington Elasticities: Anti-dumping Duty in Case DS464

Table 3.5: Change in Equilibrium and NoI across Armington Elasticities: Anti-dumping Duty in Case DS464

	$\sigma = 4$ (Baseline)		$\sigma = 10$		$\sigma = 20$		$\sigma = 30$	
	Korea	Others	Korea	Others	Korea	Others	Korea	Others
Benchmark in 2017								
Price	1	1	1	1	1	1	1	1
Quantity	588.3	3060.4	507.6	3150.6	460.8	3202.9	441.2	3224.8
Value of Shipment	588.3	3060.4	507.6	3150.6	460.8	3202.9	441.2	3224.8
Market Share	17.7%	82.3%	15.3%	84.7%	13.9%	86.1%	13.3%	86.7%
Implied Duty	69.8	0	60.2	0	54.7	0	52.3	0
Counterfactual in 2017								
Price	1.017	0.997	1.027	0.996	1.034	0.995	1.037	0.995
Quantity	651.5	3007.8	595.7	3068.2	562.0	3104.6	547.5	3120.2
Value of Shipment	662.7	2999.1	611.9	3054.7	581.0	3088.5	567.5	3103.1
Market Share	19.0%	81.0%	17.6%	82.4%	16.7%	83.3%	16.3%	83.7%
Implied Duty	42.6	0	39.3	0	37.4	0	36.5	0
NoI (U.S. $million)	74.4		104.2		120.1		126.3	

a. Unit quantity: millions; unit value: (U.S.) $million.
b. Table 3.10 describes results for the countervailing duty case.
c. Results are computed based on the conventional model with normalized prices of regional components (M1).
d. Values are rounded to the nearest first decimal.
e. I assume $\epsilon_r = 6$, $\theta = -0.55$, and $V^0_{ALL} = 3718.4$.
f. In the first stage of estimation, the counterfactual equilibrium results in a benchmark market share of (m^0_r) based on the gross value of imports including duties.

The results are modest across the supply elasticities—increasing the supply elasticity from 6 (7) to 7 (8) raises the NoI level by 3.0% (2.4%). Korea's 2017 benchmark market share in the U.S. LRW market decreases 0.02% when the supply elasticity increases from 6 to 8.

In contrast, the NoI level is more sensitive to a change in supply elasticity under a higher Armington elasticity. Given an Armington elasticity of 30, a change in supply elasticity from 6 (7) to 7 (8) increases the computed NoI by 6.5% (5.2%).

3.6.3 Two-Stage Model with Anti-dumping and Countervailing Duties Applied

The arbitrator in case DS464 separately estimated the NoI level from the anti-dumping and countervailing duties, therefore treating the rate of countervailing duty as zero when investigating NoI level from the WTO-inconsistent anti-dumping duty; and, likewise, assuming the anti-dumping duty rate as zero in the estimation of damage from the WTO-inconsistent countervailing duty. In reality, the United States simultaneously imposed both duties in 2012. Therefore, it is necessary to replicate the level of NoI by employing the duties together.

Given the baseline parameters of case DS464, the gross unit price of regional components is computed as the sum of its ad-valorem duties and shipment prices based on Equation (3.5):

$$\tilde{p}_r = (1 + t_{r,AD})(1 + t_{r,CvD})p_r \approx (1 + t_{r,AD} + t_{r,CvD})p_r \;\forall\, r \tag{3.5}$$

In Table 3.7, the NoI level when accounting for both anti-dumping and countervailing duties is \$81.7 million, which is 3.7% smaller than the NoI level using the separate estimation procedure (\$84.8 million).

Based on the 2017 benchmark from the revised estimation procedure, it is possible to decompose the NoI level into damages from both duties. For example, assuming the countervailing duty rate fixed at the benchmark level in the second step estimation, the damage level from the WTO-inconsistent anti-dumping duty can be computed by applying the WTO-consistent counterfactual anti-dumping rate. Likewise, fixing the anti-dumping duty rate at the WTO-inconsistent level, a change in the countervailing duty rate to the WTO-consistent level in the second step estimation suggests the NoI level associated with the countervailing duty. The third and fourth columns of

Table 3.6: Change in Equilibrium and NoI across Supply Elasticities of Regional Components: Anti-dumping Duty in Case DS464

	Equilibrium	$\epsilon_r = 6$ (Baseline)		$\epsilon_r = 7$		$\epsilon_r = 8$	
		Korea	Others	Korea	Others	Korea	Others
$\sigma = 4$	Benchmark in 2017						
	Price	1	1	1	1	1	1
	Quantity	588.3	3060.4	582.4	3066.9	577.5	3072.4
	Value of Shipment	588.3	3060.4	582.4	3066.9	577.5	3072.4
	Market Share	17.7%	82.3%	17.5%	82.5%	17.4%	82.6%
	Duty	69.8	0	69.1	0	68.5	0
	Counterfactual in 2017						
	Price	1.017	0.997	1.016	0.997	1.014	0.998
	Quantity	651.5	3007.797	648.9	3010.9	646.8	3013.4
	Value of Shipment	662.7	2999.127	659.0	3003.0	656.0	3006.1
	Market Share	19.0%	81.0%	18.9%	81.1%	18.8%	81.2%
	Duty	42.6	0	42.4	0	42.2	0
	NoI (U.S. $million)	74.4		76.6		78.5	
$\sigma = 30$	Benchmark in 2017						
	Price	1	1	1	1	1	1
	Quantity	441.2	3224.8	414.0	3255.0	389.5	3282.7
	Value of Shipment	441.2	3224.8	414.0	3255.0	389.5	3282.7
	Market Share	13.3%	86.7%	12.5%	87.5%	11.7%	88.3%
	Duty	52.3	0	49.1	0	46.2	0
	Counterfactual in 2017						
	Price	1.037	0.995	1.036	0.995	1.035	0.995
	Quantity	547.5	3120.2	529.6	3139.9	513.0	3158.1
	Value of Shipment	567.5	3103.1	548.5	3123.8	531.0	3142.8
	Market Share	16.3%	83.7%	15.7%	84.3%	15.2%	84.8%
	Duty	36.5	0	35.3	0	34.1	0
	NoI (U.S. $million)	126.3		134.6		141.5	

a. Unit quantity: millions; unit value: (U.S.) $million.
b. Table 3.11 describes results for the countervailing duty case.
c. Results are computed based on the conventional model with normalized prices of regional components (M1).
d. Values are rounded to the nearest first decimal.
e. We assume $\theta = -0.55$ and $V^0_{ALL} = 3718.4$.
f. A benchmark market share (m^0_r) is a result from the counterfactual equilibrium at the first stage estimation, and it is based on the gross value of imports including the duties.

Table 3.7: Change in the Equilibrium and NoI when Both Anti-dumping and Countervailing Duties are Incorporated Together

	AD only		CvD only		AD only w/ 2017 Benchmark of (AD + CvD)		CvD only w/ 2017 Benchmark of (AD + CvD)		AD + CvD w/ 2017 Benchmark of (AD + CvD)	
	Korea	Others	Korea	Others	Korea	Others	Korea	Others	Korea	Others
Benchmark in 2017										
Price	1	1	1	1	1	1	1	1	1	1
Quantity	588.3	3060.4	763.7	2950.3	580.8	3065.4	580.8	3065.4	580.8	3065.4
Value of Shipment	588.3	3060.4	763.7	2950.3	580.8	3065.4	580.8	3065.4	580.8	3065.4
Market Share	17.7%	82.3%	20.7%	79.3%	17.6%	82.4%	17.6%	82.4%	17.6%	82.4%
Duty	69.8	0	4.4	0	72.2	0	72.2	0	72.2	0
Counterfactual in 2017										
Price	1.017	0.997	1.002	1	1.017	0.997	1.002	1.000	1.019	0.997
Quantity	651.5	3007.8	772.6	2943.6	642.9	3013.4	587.0	3060.1	650.1	3007.5
Value of Shipment	662.7	2999.1	774.1	2942.4	653.9	3004.8	588.1	3059.2	662.4	2998.0
Market Share	19.0%	81.0%	20.8%	79.2%	18.9%	81.1%	17.7%	82.3%	19.0%	81.0%
Duty	42.6	0	0	0	45.8	0	69.7	0	42.6	0
NoI (US$ million)	74.4		10.4		73.1		7.3		81.7	

a. Unit quantity: millions; unit value: (U.S.) $million.
b. Results are computed based on the conventional model with normalized prices of regional components (M1).
c. Values are rounded to the nearest first decimal.
d. I assume $\sigma = 4$, $\epsilon_r = 6$, $\theta = -0.55$, and $V^0_{ALL} = 3718.4$.
e. The counterfactual equilibrium in the first stage estimation results in a benchmark market share of (m^0_r) based on the gross value of imports including duties.

Table 3.7 show damages from anti-dumping ($73.1 million) and countervailing ($7.3 million) duties under the revised estimation procedure. [13]

In the second-stage estimation, the revised estimation procedure employing both anti-dumping and countervailing duties together offers a unified 2017 benchmark, which is a feasible NoI level when excising both duties and is consistent with the actual context of case DS464.

3.7 Conclusion

In two recent Article 22.6 arbitration cases (DS464 and DS471), the WTO incorporated the Armington model. Interestingly, this has not drawn much attention from economists, despite being an essential topic for firms involved in trade disputes. This investigation suggests two critical issues in the arbitration: (a) case DS464 assumes a lower level of Armington elasticity; and, (b) case DS471 shows an error in reported NoI level. In case DS464, the assumed Armington elasticity of 4 creates a difference between Korea's benchmark 2017 U.S. LRW market share (17.7%) and the actual share (6.5%). Replicating case DS464 with the case DS471 framework shows an error in defining NoI in case DS471. Case DS471 contains a change in the duty payment in the NoI level.

Using a higher Armington elasticity in the sensitivity analysis brings Korea's calibrated 2017 U.S. LRW market share closer to actuality and allows for modest results. Using an Amrington elasticity of 30, Korea's calibrated 2017 U.S. LRW market share at the benchmark is 13.3%, which is closer to the actual market share (6.5%) than the calibrated baseline share ($\sigma = 4$) of 17.7%. Moreover, increasing the Armington elasticity from 28 to 30 raises the NoI level by 0.7%, which is smaller than the 27.9% change using an Armington elasticity ranging from 3 to 5. On the supply side, the level of NoI is modest across various supply elasticities. An increase in the supply elasticities from 6 to 8 raises the level of NoI by 5.5% under the baseline ($\sigma = 4$). Given the parameters of case DS464, the NoI level is $81.7 million under the revised estimation procedure

[13] The $1 million difference in the sum of damages between the anti-dumping duty (Table 3.7 column 3), the countervailing duty (Table 3.7 column 4), and both duties together (Table 3.7 column 5) is the gap associated with non-linear structural estimation and is not an estimation error.

that accounts for both duties simultaneously. This amount of damage is 3.7% smaller than results from the separate estimation procedure incorporated case DS464.

3.8 Appendix A: Detailed Data, Fixed and Calibrated Parameters

Table 3.8: Data - Parameters, Initial Values, Instrument and Calibrated Parameters

Data description	Notation	Value	
		2011 (Previous)	2017 (Reference)
Fixed Parameters			
Aggregate demand elasticity	θ	-0.55	
Substitution elasticity across regional components	σ	4	
Supply elasticity for each component	ϵ_r	$6\ \forall r$	
Instrument			
Benchmark duty rate for Korea's LRWs	t^0_{KOR}	0 (AD) 0 (CvD)	0.119 (AD) 0.006 (CvD)
Counterfactual duty rate for Korea's LRWs	t_{KOR}	0.119 (AD) 0.006 (CvD)	0.065 (AD) 0 (CvD)
Initial Values			
Benchmark the U.S. LRW market size measured by gross value	V^0_{ALL}	2653.6	3718.4
Benchmark gross demand value for Korea's LRWs	V^0_{KOR}	552.7	-
Benchmark gross demand value for U.S.'s LRWs	V^0_{USA}	$V^0_{USA} = V^0_{ALL} - V^0_{KOR}$	
Benchmark net price (Conventional models)	p^0_r	1	1
Benchmark gross price (Conventional models)	$\tilde{p}^0_r$	$1 + t^0_r$	$1 + t^0_r$
Benchmark gross price (Alternative model)	$\hat{p}^0_r$	1	1
Calibrated Parameters			
Korea's LRW gross value share in U.S. market	m_{KOR}	$m_{KOR} = V_{KOR}/V_{ALL}$	
Benchmark quantity of each component (Conventional models)	X^0_r	$X^0_r = V^0_r/\tilde{p}^0_r = V^0_r/\left(1 + t^0_r\right)$	
Benchmark quantity of each component (Alternative models)	$\hat{X}^0_r$	$\hat{X}^0_r = V^0_r/\hat{p}^0_r = V^0_r$	
Calibrated aggregate demand shifting coefficient	κ	$\kappa = V^0_{ALL}$	
Calibrated demand shifting coefficient for each component			
Conventional models (Both net and gross pricing)	ω_r	$\omega_r = \left(X^0_r/V^0_{ALL}\right)^{\frac{1}{\sigma}}\left(1 + t^0_r\right)$	
Alternative normalization gross pricing model	$\hat{\omega}_r$	$\hat{\omega}_r = \left(V^0_r/V^0_{ALL}\right)^{\frac{1}{\sigma}}$	
Calibrated supply shifting coefficient for each component			
Conventional models (Both net and gross pricing)	λ_r	$\lambda_r = X^0_r$	
Alternative normalization gross pricing model	$\hat{\lambda}_r$	$\hat{\lambda}_r = V^0_r\left(1 + t^0_r\right)^{\epsilon_r}$	

a. $r \in \{KOR, OTH\}$
b. AD: Anti-dumping duty, CvD: Countervailing duty
c. Values are rounded to the nearest first decimal.
d. $t^0_{OTH} = t_{OTH} = 0$
e. In conventional pricing models, the value of gross demand of each component, (V_r), should equal to the value of gross supply, consisting of the value of net supply, ($p_r X_r$ *or* $\frac{\tilde{p}_r}{1+t_r} X_r$), and value of duties, ($t_r p_r X_r$ *or* $t_r \frac{\tilde{p}_r}{1+t_r} X_r$).

3.9 Appendix B: Calibration Results - Countervailing Duty

Table 3.9: Data Calibrated from the Estimation Models: Countervailing Duty in Case DS464

	Korea in 2017				Others (incl. the U.S.) in 2017			
	Price	Quantity	Value of Imports	NoI	Price	Quantity	Value of Imports	NoI
Conventional: Net price (M1)								
Benchmark	1	763.7	763.7		1	2950.3	2950.3	
Counterfactual	1.002	772.6	774.1		1.000	2943.6	2942.4	
NoI				10.4				-
NoI+ΔDuties				6.0				-
Conventional: Gross price (M2)								
Benchmark	1.006	763.7	763.7		1	2950.3	2950.3	
Counterfactual	1.002	772.6	774.1		1.000	2943.6	2942.4	
NoI				10.4				-
NoI+ΔDuties				6.0				-
Alternative: Gross price (M3)								
Benchmark	1	768.1	763.7		1	2950.3	2950.3	
Counterfactual	0.996	777.1	774.1		1.000	2943.6	2942.4	
NoI				10.4				-
NoI+ΔDuties				6.0				-
Alternative: Gross price model incorporated in DS471 (M3')								
Benchmark	1	768.1	768.1		1	2950.3	2950.3	
Counterfactual	0.996	777.1	774.1		1.000	2943.6	2942.4	
Reported NoI				6.0				-
ΔDuties				−4.3				-
Corrected NoI				10.4				-

Notes: Above three models, (M1) - (M3), calibrated in this study define the value of imports as the shipment value, while the model incorporated in DS471 (M3') measured the value of imports as the gross value of imports, including the amount of duty.

3.10 Appendix C: Sensitivity Analysis - Countervailing Duty

Table 3.10: Change in Equilibrium and NoI across Armington Elasticities: Countervailing Duty in Case DS464

	$\sigma = 4$ (Baseline)		$\sigma = 10$		$\sigma = 20$		$\sigma = 30$	
	Korea	Others	Korea	Others	Korea	Others	Korea	Others
Benchmark in 2017								
Price	1	1	1	1	1	1	1	1
Quantity	763.7	2950.3	758.2	2955.8	754.7	2959.3	753.1	2960.9
Value of Shipment	763.7	2950.3	758.2	2955.8	754.7	2959.3	753.1	2960.9
Market Share	20.7%	79.3%	20.5%	79.5%	20.4%	79.6%	20.4%	79.6%
Implied Duty	4.4	0	4.4	0	4.4	0	4.4	0
Counterfactual in 2017								
Price	1.002	1.000	1.003	0.999	1.004	0.999	1.004	0.999
Quantity	772.6	2943.6	771.8	2944.3	771.3	2944.9	771.1	2945.1
Value of Shipment	774.1	2942.4	774.1	2942.4	774.1	2942.4	774.1	2942.5
Market Share	20.8%	79.2%	20.8%	79.2%	20.8%	79.2%	20.8%	79.2%
Implied Duty	0	0	0	0	0	0	0	0
NoI (US$ million)	10.4		15.9		19.4		21.0	

a. Unit quantity: millions; unit value: (U.S.) $million.
b. Results are computed based on the conventional model with normalized prices of regional components (M1).
c. Values are rounded to the nearest first decimal.
d. I assume $\epsilon_r = 6$, $\theta = -0.55$, and $V^0_{ALL} = 3718.4$.
e. In the first stage of estimation, the counterfactual equilibrium results in a benchmark market share of (m^0_r) based on the gross value of imports including duties.

Table 3.11: Change in Equilibrium and NoI across Supply Elasticities of Regional Components: Countervailing Duty in Case DS464

	Equilibrium	$\epsilon_r = 6$ (Baseline)		$\epsilon_r = 7$		$\epsilon_r = 8$	
		Korea	Others	Korea	Others	Korea	Others
$\sigma = 4$	Benchmark in 2017						
	Price	1	1	1	1	1	1
	Quantity	763.7	2950.3	763.3	2950.6	763.0	2951.0
	Value of Shipment	763.7	2950.3	763.3	2950.6	763.0	2951.0
	Market Share	20.7%	79.3%	20.6%	79.4%	20.6%	79.4%
	Duty	4.4	0	4.4	0	4.4	0
	Counterfactual in 2017						
	Price	1.002	1.000	1.002	1.000	1.002	1.000
	Quantity	772.6	2943.6	772.8	2943.4	772.9	2943.4
	Value of Shipment	774.1	2942.4	774.1	2942.4	774.1	2942.4
	Market Share	20.8%	79.2%	20.8%	79.2%	20.8%	79.2%
	Duty	0	0	0	0	0	0
	NoI (US$ Million)	10.4		10.8		11.1	
$\sigma = 30$	Benchmark in 2017						
	Price	1	1	1	1	1	1
	Quantity	753.1	2960.9	750.874	2963.171	748.735	2965.322
	Value of Shipment	753.1	2960.9	750.874	2963.171	748.735	2965.322
	Market Share	20.4%	79.6%	20.3%	79.7%	20.3%	79.7%
	Duty	4.4	0	4.355	0	4.343	0
	Counterfactual in 2017						
	Price	1.004	0.999	1.004	0.999	1.004	0.999
	Quantity	771.1	2945.1	771.2	2945.0	771.3	2945.0
	Value of Shipment	774.1	2942.5	774.1	2942.4	774.1	2942.0
	Market Share	20.8%	79.2%	20.8%	79.2%	20.8%	79.2%
	Duty	0	0	0	0	0	0
	NoI (US$ Million)	21.0		23.2		25.4	

a. Unit quantity: millions; unit value: (U.S.) $million.
b. Results are computed based on the conventional model with normalized prices of regional components (M1).
c. Values are rounded to the nearest first decimal.
d. I assume $\theta = -0.55$ and $V^0_{ALL} = 3718.4$.
e. In the first stage of estimation, the counterfactual equilibrium results in a benchmark market share of (m^0_r) based on the gross value of imports including duties.

3.11 Appendix D: GAMS and Stata Codes for Estimating NoI - Anti-dumping Duty Case

3.11.1 GAMS Codes

```
$title Korea's LRWs Case (DS471) with Various Calibration Models


*   Gyu Hyun Kim, Iowa State University


$Ontext


    Model Description
        - M1: Conventional Model using Net Prices
        - M2: Conventional Model using Gross Prices
        - M3: Alternative Model using Gross Prices


    Conventional Model: Standardizing Net Prices as unity at the benchmarks
    Alternative Model: Standardizing Gross Price as unity at the benchmarks
$Offtext



Set      r            Region                    /oth,kor/
         i            Measure                   /shipped,dutyincluded/
         j            Model                     /M1, M2, M3/;
Alias (r,rr);


Parameter
*Data given
         v(*)         Value of benchmark,
         v1(*)        Value of step 1 benchmark,
         v2(*)        Value of step 2 benchmark,


         q0_1         Benchmark quantity of net supply
```

```
        t0(r)        Duty rate in step 1 benchmark
        t1(r)        Duty rate in step 1 counterfactual and step 2 benchmark
        t2(r)        Duty rate in step 2 counerfactual

        theta        Elasticity of demand                    /-0.55/
        sigma        Elasticity of substitution              /4/
        epsilon      Elasticity of supply                    /6/;


v1("all") = 2653.6;
v1("kor") = 552.718;
v1("oth") = v1("all")-v1("kor");

v2("all") = 3718.4;

t0(r)= 0;

t1("oth") = 0;
t1("kor") = 0.1186;

*In case of CvD
*t1("kor") = 0.0058;

t2("oth") = 0;
t2("kor") = 0.064312;

*In case of CvD
*t2("kor") = 0;


Parameter
*Instrument
        t(r)         Tariff rate
```

```
*Calibration
        kappa         Aggregate demand shifter
        omega(r)      Import demand shifter (Conventional)
        lambda(r)     Supply shifter (Conventional)

        omega_h(r)    Import demand shifter (Alternative)
        lambda_h(r)   Supply shifter (Alternative)

*Outcome variables
        ms_pre1(r)    Market Share measured by gross term
        ms_post1(r)   Market Share measured by gross term

        ms_pre2(r)    Market Share measured by gross term
        ms_post2(r)   Market Share measured by gross term

        ms_pre3(r)    Market Share measured by gross term
        ms_post3(r)   Market Share measured by gross term;

Positive variables
        Q             Aggregate quantity,
        P             Price of aggregate,

        x1(r)         Quantity associated with M1
        x2(r)         Quantity associated with M2
        x3(r)         Quantity associated with M3

        p1(r)         Price of regional component net
        p2(r)         Price of regional component grs
        p3(r)         Price of regional component grs alt quantity normalization;

*Algebraic Models
```

```
Equations
        DEM           Aggregate demand,

        ARM1          Armington technology (dual),
        MKT1(r)       Market clearance for regional components
        SUP1(r)       Supply of regional components

        ARM2          Armington technology (dual),
        MKT2(r)       Market clearance for regional components
        SUP2(r)       Supply of regional components

        ARM3          Armington technology (dual),
        MKT3(r)       Market clearance for regional components
        SUP3(r)       Supply of regional components;

*------- Aggregate demand - Apply to all models
DEM..   Q -
        kappa*P**theta =g= 0;

*------- Net pricing convention (Original GAMS setup)
ARM1..  (sum(r, (omega(r)**sigma)*((1+t(r))*p1(r))**(1-sigma)))**(1/(1-sigma)) -
        P =g= 0;

MKT1(r).. x1(r) -
          Q * (omega(r)**sigma)*(P /((1+t(r))*p1(r)))**sigma =g=0;

SUP1(r).. lambda(r)*p1(r)**epsilon -
          x1(r) =g= 0;

*------- Gross pricing convention
ARM2..  (sum(r, (omega(r)**sigma)*(p2(r)**(1-sigma))))**(1/(1-sigma)) -
        P =g= 0;
```

```
MKT2(r).. x2(r) -
          Q * (omega(r)**sigma)*(P/p2(r))**sigma =g=0;

SUP2(r).. lambda(r)*(p2(r)/(1+t(r)))**epsilon -
          x2(r) =g= 0;

*------- Alternative quantity normalizaton gross pricing
ARM3..  (sum(r, (omega_h(r)**sigma)*(p3(r))**(1-sigma)))**(1/(1-sigma)) -
        P =g= 0;

MKT3(r).. x3(r) -
          Q * (omega_h(r)**sigma)*(P/(p3(r)))**sigma =g= 0;

SUP3(r).. lambda_h(r)*(p3(r)/(1+t(r)))**epsilon -
          x3(r) =g= 0;

Model M1    /DEM.P,
             ARM1.Q,
             MKT1.p1,
             SUP1.x1/;

Model M2    /DEM.P,
             ARM2.Q,
             MKT2.p2,
             SUP2.x2/;

Model M3    /DEM.P,
             ARM3.Q,
             MKT3.p3,
             SUP3.x3/;

*---------------------------------------
*---------------------------------------
```

```
***       Step 1 - Benchmark         ***
*---------------------------------------
*---------------------------------------


v("all") = v1("all");
v(r) = v1(r);

t(r) = t0(r);
q0_1(r) = v(r)/(1+t(r));

kappa = v("all");

omega(r) = (1+t(r))**(1-1/sigma)*(v(r)/v("all"))**(1/sigma);
lambda(r) = q0_1(r);

omega_h(r) = (v(r)/v("all"))**(1/sigma);
lambda_h(r) = v(r)*(1+t(r))**epsilon;


*       Calibration with net price normalized to one
Q.l=v("all");
P.l=1;
x1.l(r)=q0_1(r);
p1.l(r)=1;

*       Alternative calibration with gross price (normalized to (1+t0))
p2.l(r)=(1+t(r));
x2.l(r)=q0_1(r);

*       From Stata program (normalize gross price to one)
p3.l(r)=1;
x3.l(r)=v(r);
```

```
M1.iterlim=0;
Solve M1 using mcp;
Abort$(M1.objval gt 1e-6) "benchmark for model M1 is not replicated";

M2.iterlim=0;
Solve M2 using mcp;
Abort$(M2.objval gt 1e-6) "benchmark for model M2 is not replicated";

M3.iterlim=0;
Solve M3 using mcp;
Abort$(M3.objval gt 1e-6) "benchmark for model M3 is not replicated";

ms_pre1(r)     = p1.l(r)*x1.l(r)*(1+t(r))/(sum(rr, p1.l(rr)*x1.l(rr)*(1+t(rr))));
ms_pre2(r)     = p2.l(r)*x2.l(r)/(sum(rr, p2.l(rr)*x2.l(rr)));
ms_pre3(r)     = p3.l(r)*x3.l(r)/(sum(rr, p3.l(rr)*x3.l(rr)));

Parameter report_p0_PY(r,j)       Benchmark pricing in previous year;
report_p0_PY(r,"M1") = p1.l(r);
report_p0_PY(r,"M2") = p2.l(r);
report_p0_PY(r,"M3") = p3.l(r);

Parameter report_q0_PY(r,j)       Benchmark quantity in previous year;
report_q0_PY(r,"M1") = x1.l(r);
report_q0_PY(r,"M2") = x2.l(r);
report_q0_PY(r,"M3") = x3.l(r);

Parameter gross_pq0_PY(r,j)       Benchmark p*q (gross measure) in previous year;
gross_pq0_PY(r,"M1") = p1.l(r)*x1.l(r)*(1+t(r));
gross_pq0_PY(r,"M2") = p2.l(r)*x2.l(r);
gross_pq0_PY(r,"M3") = p3.l(r)*x3.l(r);

Parameter net_pq0_PY(r,j)         Benchmark p*q (net measure) in previous year;
```

```
net_pq0_PY(r,"M1") = p1.l(r)*x1.l(r);
net_pq0_PY(r,"M2") = p2.l(r)*x2.l(r)/(1+t(r));
net_pq0_PY(r,"M3") = p3.l(r)*x3.l(r)/(1+t(r));

*---------------------------------------
*---------------------------------------
***       Step 1 - Counterfactual    ***
*---------------------------------------
*---------------------------------------

t(r) = t1(r);

M1.iterlim=1000;
Solve M1 using mcp;

M2.iterlim=1000;
Solve M2 using mcp;

M3.iterlim=1000;
Solve M3 using mcp;

ms_post1(r)     = p1.l(r)*x1.l(r)*(1+t(r))/(sum(rr, p1.l(rr)*x1.l(rr)*(1+t(rr))));
ms_post2(r)     = p2.l(r)*x2.l(r)/(sum(rr, p2.l(rr)*x2.l(rr)));
ms_post3(r)     = p3.l(r)*x3.l(r)/(sum(rr, p3.l(rr)*x3.l(rr)));

*Check whetehr market share are identical across models
Parameter ms_pre_PY(r,j)      Benchnark grs Mkt share in previous year;
ms_pre_PY(r,"M1") = ms_pre1(r);
ms_pre_PY(r,"M2") = ms_pre2(r);
ms_pre_PY(r,"M3") = ms_pre3(r);

Parameter ms_post_PY(r,j)     Counterfacrual grs Mkt share in previous year;
ms_post_PY(r,"M1") = ms_post1(r);
```

```
ms_post_PY(r,"M2") = ms_post2(r);
ms_post_PY(r,"M3") = ms_post3(r);

Parameter report_p_PY(r,j)    Counterfactual pricing in previous year;
report_p_PY(r,"M1") = p1.l(r);
report_p_PY(r,"M2") = p2.l(r);
report_p_PY(r,"M3") = p3.l(r);

Parameter report_q_PY(r,j)    Counterfactual quantity in previous year;
report_q_PY(r,"M1") = x1.l(r);
report_q_PY(r,"M2") = x2.l(r);
report_q_PY(r,"M3") = x3.l(r);

Parameter gross_pq_PY(r,j)    Counterfactual p*q (gross measure) in previous year;
gross_pq_PY(r,"M1") = p1.l(r)*x1.l(r)*(1+t(r));
gross_pq_PY(r,"M2") = p2.l(r)*x2.l(r);
gross_pq_PY(r,"M3") = p3.l(r)*x3.l(r);

Parameter net_pq_PY(r,j)       Counterfactual p*q (net measure) in previous year;
net_pq_PY(r,"M1") = p1.l(r)*x1.l(r);
net_pq_PY(r,"M2") = p2.l(r)*x2.l(r)/(1+t(r));
net_pq_PY(r,"M3") = p3.l(r)*x3.l(r)/(1+t(r));

*---------------------------------------
*---------------------------------------
***       Step 2 - Benchmark         ***
*---------------------------------------
*---------------------------------------

v("all") = v2("all");
v(r)     = v("all")*ms_post1(r);

t(r) = t1(r);
```

```
q0_1(r) = v(r)/(1+t(r));

kappa = v("all");

omega(r) = (1+t(r))**(1-1/sigma)*(v(r)/v("all"))**(1/sigma);
lambda(r) = q0_1(r);

omega_h(r) = (v(r)/v("all"))**(1/sigma);
lambda_h(r) = v(r)*(1+t(r))**epsilon;

*       Calibration with net price normalized to one
Q.l=v("all");
P.l=1;
x1.l(r)=q0_1(r);
p1.l(r)=1;

*       Alternative calibration with gross price (normalized to (1+t0))
p2.l(r)=(1+t(r));
x2.l(r)=q0_1(r);

*       From Stata program (normalize gross price to one)
p3.l(r)=1;
x3.l(r)=v(r);

M1.iterlim=0;
Solve M1 using mcp;
Abort$(M1.objval gt 1e-6) "benchmark for model M1 is not replicated";

M2.iterlim=0;
Solve M2 using mcp;
Abort$(M2.objval gt 1e-6) "benchmark for model M2 is not replicated";

M3.iterlim=0;
```

```
Solve M3 using mcp;
Abort$(M3.objval gt 1e-6) "benchmark for model M3 is not replicated";

ms_pre1(r)     = p1.l(r)*x1.l(r)*(1+t(r))/(sum(rr, p1.l(rr)*x1.l(rr)*(1+t(rr))));
ms_pre2(r)     = p2.l(r)*x2.l(r)/(sum(rr, p2.l(rr)*x2.l(rr)));
ms_pre3(r)     = p3.l(r)*x3.l(r)/(sum(rr, p3.l(rr)*x3.l(rr)));

Parameter report_p0(r,j)       Benchmark pricing;
report_p0(r,"M1") = p1.l(r);
report_p0(r,"M2") = p2.l(r);
report_p0(r,"M3") = p3.l(r);

Parameter report_q0(r,j)       Benchmark quantity;
report_q0(r,"M1") = x1.l(r);
report_q0(r,"M2") = x2.l(r);
report_q0(r,"M3") = x3.l(r);

Parameter gross_pq0(r,j)       Benchmark p*q (gross measure);
gross_pq0(r,"M1") = p1.l(r)*x1.l(r)*(1+t(r));
gross_pq0(r,"M2") = p2.l(r)*x2.l(r);
gross_pq0(r,"M3") = p3.l(r)*x3.l(r);

Parameter net_pq0(r,j)         Benchmark p*q (net measure);
net_pq0(r,"M1") = p1.l(r)*x1.l(r);
net_pq0(r,"M2") = p2.l(r)*x2.l(r)/(1+t(r));
net_pq0(r,"M3") = p3.l(r)*x3.l(r)/(1+t(r));

Parameter duty0                Benchmark implied duty;
duty0(r,"M1") = gross_pq0(r,"M1")-net_pq0(r,"M1");
duty0(r,"M2") = gross_pq0(r,"M2")-net_pq0(r,"M2");
duty0(r,"M3") = gross_pq0(r,"M3")-net_pq0(r,"M3");
```

```
*---------------------------------------
*---------------------------------------
***       Step 2 - Counterfactual    ***
*---------------------------------------
*---------------------------------------

t(r) = t2(r);

M1.iterlim=1000;
Solve M1 using mcp;

M2.iterlim=1000;
Solve M2 using mcp;

M3.iterlim=1000;
Solve M3 using mcp;

ms_post1(r)     = p1.l(r)*x1.l(r)*(1+t(r))/(sum(rr, p1.l(rr)*x1.l(rr)*(1+t(rr))));
ms_post2(r)     = p2.l(r)*x2.l(r)/(sum(rr, p2.l(rr)*x2.l(rr)));
ms_post3(r)     = p3.l(r)*x3.l(r)/(sum(rr, p3.l(rr)*x3.l(rr)));

Parameter ms_pre_2017(r,j)    Benchmark grs Mkt share;
ms_pre_2017(r,"M1") = ms_pre1(r);
ms_pre_2017(r,"M2") = ms_pre2(r);
ms_pre_2017(r,"M3") = ms_pre3(r);

Parameter ms_post_2017(r,j)   Counterfactual grs Mkt share;
ms_post_2017(r,"M1") = ms_post1(r);
ms_post_2017(r,"M2") = ms_post2(r);
ms_post_2017(r,"M3") = ms_post3(r);

Parameter report_p(r,j)       Counterfactual pricing;
report_p(r,"M1") = p1.l(r);
```

```
report_p(r,"M2") = p2.l(r);
report_p(r,"M3") = p3.l(r);

Parameter report_q(r,j)       Counterfactual quantity;
report_q(r,"M1") = x1.l(r);
report_q(r,"M2") = x2.l(r);
report_q(r,"M3") = x3.l(r);

Parameter gross_pq(r,j)       Counterfactual p*q (gross measure);
gross_pq(r,"M1") = p1.l(r)*x1.l(r)*(1+t(r));
gross_pq(r,"M2") = p2.l(r)*x2.l(r);
gross_pq(r,"M3") = p3.l(r)*x3.l(r);

Parameter net_pq         Counterfactual p*q (net measure);
net_pq(r,"M1") = p1.l(r)*x1.l(r);
net_pq(r,"M2") = p2.l(r)*x2.l(r)/(1+t(r));
net_pq(r,"M3") = p3.l(r)*x3.l(r)/(1+t(r));

Parameter NoI(i,j);
NoI("shipped",j) = net_pq("kor",j) - net_pq0("kor",j);
NoI("dutyincluded",j) = gross_pq("kor",j) - gross_pq0("kor",j);

Parameter ms_post_2017   Counterfacrual grs Mkt share in reference year (2017);
ms_post_2017(r,"M1") = gross_pq(r,"M1")/sum(rr,gross_pq(rr,"M1"));
ms_post_2017(r,"M2") = gross_pq(r,"M2")/sum(rr,gross_pq(rr,"M2"));
ms_post_2017(r,"M3") = gross_pq(r,"M3")/sum(rr,gross_pq(rr,"M3"));

Parameter duty    Counterfactual implied duty;
duty(r,"M1") = gross_pq(r,"M1")-net_pq(r,"M1");
duty(r,"M2") = gross_pq(r,"M2")-net_pq(r,"M2");
duty(r,"M3") = gross_pq(r,"M3")-net_pq(r,"M3");

Parameter d_duty Change in implied duty;
```

```
d_duty(r,"M1") = duty(r,"M1")-duty0(r,"M1");
d_duty(r,"M2") = duty(r,"M2")-duty0(r,"M2");
d_duty(r,"M3") = duty(r,"M3")-duty0(r,"M3");

Display report_p0,
        report_q0,
        net_pq0,
        ms_post_PY,
        duty0
        report_p,
        report_q,
        net_pq,
        ms_post_2017,
        duty,
        d_duty
        NoI;
```

3.11.2 Stata Codes of the DS464 Case Modified from the DS471 Case

I maintain most of the Stata code utilized in case DS471. I rearrange the mathematical symbols to be consistent with the GAMS code in 3.11.1 and remove redundancy by suppressing the initial market shares as zeros. I include the codes showing the exact number of the NoI level, which does not contain a change in the duty amount.

```
clear all
capture program drop all

// Please assign your working directory here before the beginning. For example,
cd "\\IASTATE.EDU\ECON\GRADSTUDENTS\OTHERDATA\gyuhyun\DESKTOP\WTO-Stata"

************************* SOLUTION OF THE ARMINGTON MODEL **********************
program nlArmington
        syntax varlist(min=2 max=2) [if], at(name)
```

```
// Specify name
local RHS: word 1 of `varlist'
local exogenous: word 2 of `varlist'

// Specify the temporary variable names
tempname p_oth p_da1 p_kor p_da2 p_da3 epsilon_oth epsilon_da1 epsilon_kor ///
                epsilon_da2 epsilon_da3 m_oth m_da1 m_kor m_da2 m_da3 kapp theta ///
                sigma t0_da1 t_da1 t0_kor t_kor t0_da2 t_da2 LHS P Q omega_oth omega_da1
                ///
                omega_kor omega_da2 omega_da3 lambda_oth lambda_da1 lambda_kor lambda_da2
                lambda_da3 QS_oth QS_da1 ///
                QS_kor QS_da2 QS_da3 QD_oth QD_da1 QD_kor QD_da2 QD_da3

// Specify the endogenous parameters
scalar `p_oth' = `at'[1, 1] // US and other counturies shipments
scalar `p_da1' = `at'[1, 2] // Deactivated term (The share is suppresed as zero)
scalar `p_kor' = `at'[1, 3] // US imports from Korea subject to WTO-inconsistent rate
scalar `p_da2' = `at'[1, 4] // Deactivated term (The share is suppresed as zero)
scalar `p_da3' = `at'[1, 5] // Deactivated term (The share is suppresed as zero)

// Specify the exogenous parameters (i.e. elasticities, initial market
// shares, initial total expenditure and initial anti-dumping duties)
local i = 1
foreach param in epsilon_oth epsilon_da1 epsilon_kor epsilon_da2 ///
                                epsilon_da3 m_oth m_da1 m_kor m_da2 m_da3 kapp theta sigma
                                ///
                                t0_da1 t_da1 t0_kor t_kor t0_da2 t_da2 {
        levelsof `exogenous' in `i'
        generate double ``param'' = `r(levels)'
        local i = `i' + 1
}
        replace `t0_da1' = 0 if `t0_da1' == .
```

```
// Specify the initial market clearance conditions
        generate double `LHS' = 0

// Compute the index price
        generate double `P' = (`m_oth'/100 * `p_oth' ^(1 - `sigma') + ///
                                                        `m_da1'/100 * `p_da1' ^(1 -
                                                        `sigma') + ///
                                                        `m_kor'/100 * `p_kor' ^(1 -
                                                        `sigma') + ///
                                                        `m_da2'/100 * `p_da2' ^(1 -
                                                        `sigma') + ///
                                                        `m_da3'/100 * `p_da3' ^(1 -
                                                        `sigma') ) ///
                                                        ^(1/(1 - `sigma'))

// Compute the aggregate demand
        generate double `Q' = `kapp' * `P' ^`theta'

local i = 1
foreach x in oth da1 kor da2 da3 {
// Compute the shifting factors
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
                `lambda_`x'' = `kapp' * `m_`x''/100
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
                `lambda_`x'' = `kapp' * `m_`x''/100 * (1 + `t0_`x''/100) ^(`epsilon_`x'')
        generate double `omega_`x'' = exp(ln(`m_`x''/100) / `sigma')
                replace `omega_`x'' = 0 if `m_`x'' == 0 | `m_`x'' == .

// Compute the supply functions
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
                `QS_`x'' = `lambda_`x'' * (`p_`x'') ^`epsilon_`x''
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
                `QS_`x'' = `lambda_`x'' * ((`p_`x'')/(1 + `t_`x''/100)) ^`epsilon_`x''
```

```
        // Compute the demand functions
                generate double `QD_`x'' = `Q' * (`omega_`x''^^`sigma') * ///
                                                                        (`p_`x''/`P')^(-`sigma')

        // Compute the market clearance conditions
                        replace `LHS' = `QD_`x'' - `QS_`x'' in `i'
                        if `i' == 5 replace `LHS' = `QD_`x'' - `QS_`x'' +1 in `i'
                local i = `i' + 1
        }
        // Ensure the market clearance conditions are met
                        replace `RHS' = `LHS'
end

******************** CORRESPONDING PRICES AND QUANTITIES **********************

program define dPQ
        // Specify the input variables:
        * `1': variable with prices
        * `2': variable with exogenous parameters

        // Specify the temporary variable names
        tempname p_oth p_da1 p_kor p_da2 p_da3 epsilon_oth epsilon_da1 epsilon_kor ///
                        epsilon_da2 epsilon_da3 m_oth m_da1 m_kor m_da2 m_da3 kapp theta ///
                        sigma t0_da1 t_da1 t0_kor t_kor t0_da2 t_da2 LHS P Q lambda_oth lambda_da1
                        ///
                        lambda_kor lambda_da2 lambda_da3

        // Specify the parameters
        local i = 1
        foreach param in p_oth p_da1 p_kor p_da2 p_da3 epsilon_oth epsilon_da1 ///
                                        epsilon_kor epsilon_da2 epsilon_da3 m_oth m_da1 m_kor ///
                                        m_da2 m_da3 kapp theta sigma t0_da1 t_da1 t0_kor t_kor ///
```

```
                                t0_da2 t_da2 {
        if `i' <= 5 scalar ``param'' = `1' in `i'
        if `i' > 5 local j = `i' - 5
        if `i' > 5 scalar ``param'' = `2' in `j'
        local i = `i' + 1
}

// Compute the index price
        generate double `P' = (`m_oth'/100 * `p_oth' ^(1 - `sigma') + ///
                                                        `m_da1'/100 * `p_da1' ^(1 -
                                                        `sigma') + ///
                                                        `m_kor'/100 * `p_kor' ^(1 -
                                                        `sigma') + ///
                                                        `m_da2'/100 * `p_da2' ^(1 -
                                                        `sigma') + ///
                                                        `m_da3'/100 * `p_da3' ^(1 -
                                                        `sigma') ) ///
                                                        ^(1/(1 - `sigma'))

// Compute the aggregate demand
        generate double `Q' = `kapp' * `P' ^`theta'

local i = 1
foreach x in oth da1 kor da2 da3 {
// Compute the shifting factors
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
                `lambda_`x'' = `kapp' * `m_`x''/100
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
                `lambda_`x'' = `kapp' * `m_`x''/100 * (1 + `t0_`x''/100) ^(`epsilon_`x'')

// Compute the percent changes in prices
        generate double dp_`x' = (p_`x' - 1) * 100 in 1
```

```
// Compute the initial equilibrium quantities
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
           iniq_`x' = `lambda_`x'' * 1 ^`epsilon_`x'' in 1
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
           iniq_`x' = `lambda_`x'' * (1 / (1 + `t0_`x''/100)) ^`epsilon_`x'' in 1

// Compute the initial duties
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
                inid_`x' = 0 in 1
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
                inid_`x' = (`t0_`x''/100)/(1 + `t0_`x''/100) * iniq_`x' in 1

// Compute the new equilibrium quantities
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
                newq_`x' = `lambda_`x'' * (p_`x') ^`epsilon_`x'' in 1
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
                newq_`x' = `lambda_`x'' * ( p_`x' / (1 + `t_`x''/100)) ^`epsilon_`x'' in 1

// Compute the percent changes in quantities
        generate double dq_`x' = (newq_`x' - iniq_`x')/iniq_`x' * 100 in 1
                if dq_`x' == . replace dq_`x' = 0 in 1

// Compute the new expenditures
        generate double newX_`x' = p_`x' * newq_`x' in 1

// New codes to compute the fixedf duties
        if "`x'" == "oth" | "`x'" == "da3" generate double ///
                newD_`x' = 0 in 1
        if "`x'" == "da1" | "`x'" == "kor" | "`x'" == "da2" generate double ///
                newD_`x' = (`t_`x''/100/(1+`t_`x''/100)) * newX_`x' in 1


// Compute the change in expenditures
```

```
                generate double dX_`x' = (newX_`x' - iniq_`x') in 1

        // New code to calculate change in duties
        // Compute the change in duties
                generate double dD_`x' = (newD_`x' - inid_`x') in 1
        }
end

************************** IMPLEMENTATION OF STEP 1 **************************
* Import data inputs for WTO-inconsistent duties reported in Appendix Table [XX]
* Appendix Table [XX] saved in an Excel file named "Data.xlsx"

        import excel "Data.xlsx", firstrow clear
                rename antidumpingorder Product
                rename Y kapp
                rename Y2017 kapp2017
                drop if Product == ""

* Create additional inputs
                foreach var in da1 kor da2 {
                        generate double epsilon_`var' = epsilon_import
                        generate double t0_`var' = 0
                        rename t_`var' t1_`var'
                }
                rename epsilon_import epsilon_da3
        save "Inputs.dta", replace

* Solve the Armington model for anti-dumping order at issue in the year
* prior to the imposition of the anti-dumping duty rates (2011)
        use "Inputs.dta", clear
                levelsof Product, local(Product)
                foreach product of local Product {
                        use "Inputs.dta", clear
```

```
        keep if Product == "`product'"
        display " "
        display "******************** `product' ********************"
quietly {
* Create constraints and exogenous variables structure
        set obs 19
        generate double MrktEq = 0
                replace MrktEq = 1 in 5
        local i = 1
        generate paramname = ""
        generate double param = .
        foreach param in epsilon_oth epsilon_da1 epsilon_kor ///
                        epsilon_da2 epsilon_da3 m_oth m_da1 m_kor ///
                        m_da2 m_da3 kapp theta sigma t0_da1 t1_da1 ///
                        t0_kor t1_kor t0_da2 t1_da2 {
                levelsof `param' in 1, local(temp)
                replace paramname = "`param'" in `i'
                capture replace param = `temp' in `i'
                replace param = 0 if param == . in `i'
                local i = `i' + 1
        }
}
* Solve the Armington model with imposition of anti-dumping duties
        nl Armington @ MrktEq param, param(p_oth p_da1 p_kor p_da2 p_da3)
        ///
                initial(p_oth 1 p_da1 1 p_kor 1 p_da2 1 p_da3 1) eps(1e-12)
        quietly {
                matrix B = e(b)
                svmat double B
                local i = 1
                foreach x in oth da1 kor da2 da3 {
                        rename B`i' p_`x' // New price
                        local i = `i' + 1
```

```
                                }
                        * Compute new market shares
                                matrix B = B'
                                svmat double B
                        dPQ B param
                        egen double kapp1 = rowtotal(newX_*)
                                foreach x in oth da1 kor da2 da3 {
                                        generate double m1_`x' = newX_`x' / kapp1 * 100
                                }
                        keep in 1
                                drop param*
                        quietly save "`product'_step1.dta", replace
                        drop p_* dp_* iniq_* inid_* newq_* newD_* dq_* newX_* dX_* dD_*
                        MrktEq B1
                        }
                quietly save "`product'.dta", replace
        }
        quietly keep if Product == "?"
        foreach product of local Product {
                append using "`product'.dta"
                erase "`product'.dta"
        }

************************** IMPLEMENTATION OF STEP 2 **************************
* Create additional inputs
        generate double t2_da1 = 0
                * Brackets should be removed before running the code
                * replace t2_da1 = [[***]] if Product == "OCTG" // This is BCI in the DS471
                case
        generate double t2_kor = 6.4312
        generate double t2_da2 = 0
    save "Inputs.dta", replace
```

```
* Solve the Armington model for anti-dumping order at issue in 2017 by using
* the simulated market shares associated with the imposition of the anti-dumping
* duty rates and calculated in step 1
        use "Inputs.dta", clear
                levelsof Product, local(Product)
                foreach product of local Product {
                        use "Inputs.dta", clear
                                keep if Product == "`product'"
                                display " "
                                display "******************** `product' ********************"
                        quietly {
                        * Create constraints and exogenous variables structure
                                set obs 19
                                generate double MrktEq = 0
                                        replace MrktEq = 1 in 5
                                local i = 1
                                generate paramname = ""
                                generate double param = .
                                foreach param in epsilon_oth epsilon_da1 epsilon_kor ///
                                                epsilon_da2 epsilon_da3 m1_oth m1_da1 m1_kor ///
                                                m1_da2 m1_da3 kapp2017 theta sigma t1_da1 t2_da1
                                                ///
                                                t1_kor t2_kor t1_da2 t2_da2 {
                                        levelsof `param' in 1, local(temp)
                                        replace paramname = "`param'" in `i'
                                        capture replace param = `temp' in `i'
                                        replace param = 0 if param == . in `i'
                                        local i = `i' + 1
                                }
                        }
                        * Solve the Armington model for counterfactual anti-dumping duty rates
                                nl Armington @ MrktEq param, param(p_oth p_da1 p_kor p_da2 p_da3)
                                ///
```

```
                initial(p_oth 1 p_da1 1 p_kor 1 p_da2 1 p_da3 1) eps(1e-12)
        quietly {
                matrix B = e(b)
                svmat double B
                local i = 1
                foreach x in oth da1 kor da2 da3 {
                        rename B`i' p_`x' // New price
                                local i = `i' + 1
                }
* Compute the level nullification or impairment
        matrix B = B'
        svmat double B
dPQ B param

* Added: Compute the counterfactual market shares
egen double kapp2 = rowtotal(newX_*)

foreach x in oth da1 kor da2 da3 {
generate double m2_`x' = newX_`x' / kapp2 * 100
}

* Added: Value of the duties
generate double NI = dX_da1 + dX_kor + dX_da2
generate double NI_fixed = dX_da1-dD_da1 + dX_kor-dD_kor + dX_da2-dD_da2

        * Added: In case for investigating detailed value in the
        equilibrium,
        * Please deactivate the following two lines.
        keep Product NI NI_fixed
        keep in 1
        }
quietly save "`product'.dta", replace
quietly save "`product'_step2.dta", replace
```

```
}
quietly keep if Product == "?"
foreach product of local Product {
        append using "`product'.dta"
        erase "`product'.dta"
}
```

3.11.3 Data.xlsx File for Executing Stata Codes

The format of this file is consistent with the excel file employed in case DS471.

Table 3.12: Data.xlsx File for Executing Stata Codes in the Previous Section of 3.11.2

antidumpingorder	theta	epsilon_oth	epsilon_import	sigma	m_oth	m_da1	m_kor	m_da2	m_da3	Y	Y2017	t_da1	t_kor	t_da2
LRWs	-0.55	6	6	4	79.171	0	20.829	0	0	2653.6	3718.4	0	11.86	0

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CHAPTER 4. NON-FUNDAMENTAL HOME BIAS IN INTERNATIONAL EQUITY MARKETS

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4.1 Abstract

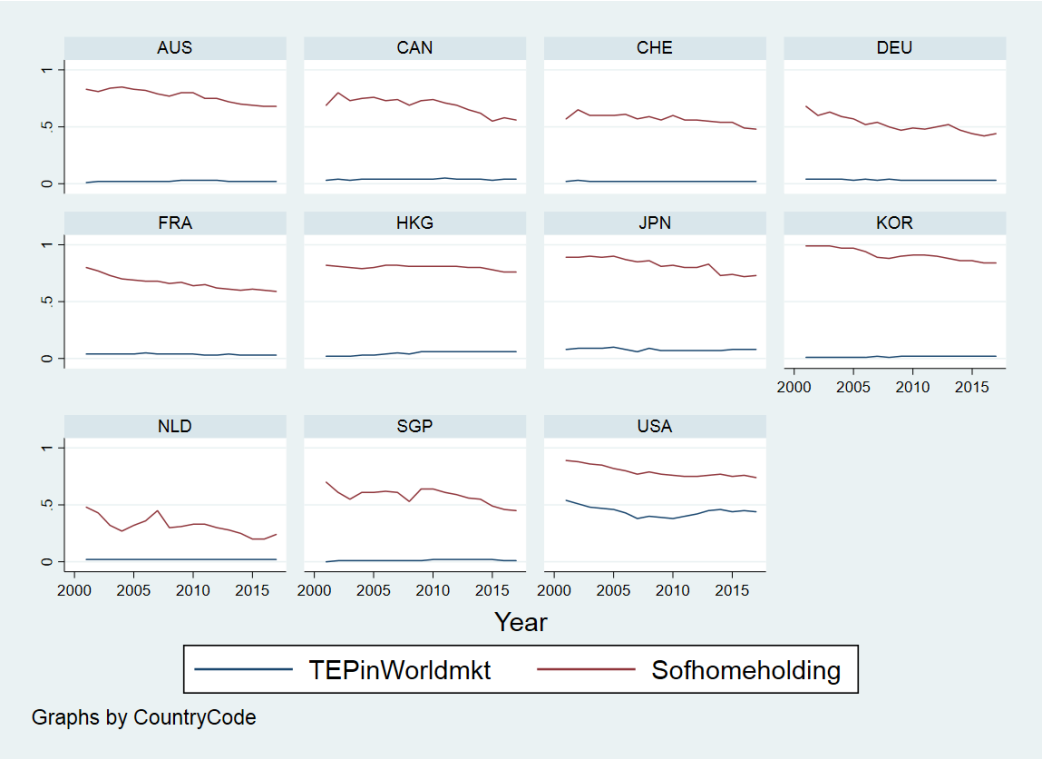
This study investigates the relationship of the equity home bias with 1) the country-level behavioral unfamiliarity, and 2) the home-foreign return correlation. We set the hypotheses that 1) unfamiliarity about foreign equities plays a role in the portfolio set up and 2) the correlation of return on home and foreign equities affects the equity home bias when there is a lack of information about foreign equities. For the empirical analysis, the proportion of respondents to the question "How much do you trust? - People you meet for the first time" is used as a proxy measure for country-specific unfamiliarity. Based on the eleven developed countries for which such data are available, we implement a feasible generalized linear squares (FGLS) method. Empirical results suggest that country-specific unfamiliarity has a significant and positive correlation with the equity home bias. When it comes to the correlation of return between home and foreign equities, we identify that there is a negative correlation with the equity home bias, which is against our hypothesis. Moreover, an excess return on home equities compared to foreign ones is found to have a positive correlation with the equity home bias, which is consistent with the comparative statics when foreign investors have a higher risk aversion than domestic investors. We check the robustness of our empirical analysis by fitting alternative specifications and use a log-transformed measure of the equity home bias, resulting in consistent results with ones with the original measure.

4.2 Introduction

This paper investigates the role of behavioral bias in international equity markets with information frictions. Investors set an optimal portfolio that offers the highest return, which is equivalent to the highest future wealth. When investors have comprehensive information about foreign equities, they consider a combination of sensible economic factors: returns, transaction costs, risks, and market correlations. In this case, the equity home bias is an outcome of transaction costs, such as differences in regulations and operating costs of local offices for financial institutions. Nevertheless, in reality, investors indeed do not have comprehensive information about foreign financial assets. In this case, a behavioral bias such as unfamiliarity can work as part of the noise on the home country's information about returns on foreign equities. For example, under a lack of information about foreign equities, home investors may undervalue foreign equities, though they reflect measurable transaction costs. In this study, we investigate whether non-fundamental familiarity about foreign equities is a significant determinant of the equity home bias.

French and Poterba (1991) first pointed out the equity home bias by observing that domestic equities comprise over 90% of equity wealth in the U.S and Japan. Since the 1990s, the equity home bias has been a widely explored puzzle in international financial markets. Lewis (1999) and van Wincoop and Warnock (2010) approach this puzzle with hedge mechanisms. Cooper et al. (2013) suggest that domestic investors expect lower returns on foreign assets due to international transaction costs. Current research analyzes the equity home bias considering both institutional and behavioral frameworks (Lewis (1999) and Cooper et al. (2013)).

Furthermore, despite the high integration of the current international finance market, equity home biases have been relatively stable over time. It is agreed that integration in the international financial market leads to a drastic reduction of the transaction costs incurred from different languages and legal systems. For example, Werner and Tesar (1997) and Coeurdacier and Rey (2013) point out that this bias has been reduced since the onset of financial market integration. However, as Figure 4.1 shows, the share of domestic equity in the United States and Japan is still over 70%, and its trend is relatively stable, although the global shares of total equity value in each country



Note: Computed from IMF CPIS and World Bank data

Figure 4.1: Share of Total Equity Portfolio in World Market Capitalization (Blue) and Share of Holdings of Domestic Equity in Total Equity Portfolio (Red)

are less than 60%: ranging from 38% to 54% in the U.S. and from 2% to 3% in Japan between 2001 and 2014. [1] .

This study focuses on how two factors - namely, 1) information frictions about foreign equities and 2) the correlation between domestic and foreign return on equities - are related to the equity home bias. Moreover, this work empirically shows that non-fundamental unfamiliarity is a significant determinant of the equity home bias. Based on a two-country model modified from that of Chan et al. (2005) and Foad (2011), the optimal equity shares of both domestic and foreign equity are derived when we employ information frictions on foreign equities. At the optimal share of the portfolio, this study examines how the equity home bias depends on 1) the information frictions on foreign equities and 2) the correlation between domestic and foreign equity returns. For

[1] In 2001 ~2014, the global shares of total equity value in each country are computed by dividing the total equity portfolio by the global total equity portfolio.

the empirical analysis, we assume that there are information frictions about the foreign equities, and implement a feasible generalized linear squares (FGLS) method. In the empirical analysis, the country-level equity home bias is computed using data from the World Bank and Coordinated Portfolio Invest Survey (CPIS). The country-level proportion of respondents to the survey question, "How much you trust: People you meet for the first time?", in the World Value Survey (WVS) is exploited as a measure for the level of non-fundamental unfamiliarity, which is an essential factor for noise from the information frictions on foreign equities. In the last part of this research, we conduct additional empirical analyses using transformed measures of unfamiliarity.

This work is innovative in two senses. Firstly, we use a novel measure of personal behavior based on publicly available data. The question adopted from the WVS data closely represents the country-level unfamiliarity. Using this data, we support the relationship between country-specific unfamiliarity and the equity home bias when home investors have limited information about foreign equities. Previous studies, such as Huberman (2000), Beugelsdijk and Frijns (2010), and Chan et al. (2005), investigate the relationship between familiarity and the equity home bias using proxies, such as languages and distance. Secondly, we investigate behavioral factors and market correlation simultaneously.

Comparative statics hypothesize an increase in the equity home bias under the information frictions. Moreover, a positive correlation between domestic and foreign equities leads to a higher equity home bias, which explains that investors have less incentives to buy foreign assets due to higher substitution. In the empirical analysis, assuming that domestic financial markets have information frictions about foreign equities, we verify that unfamiliarity has a significant and positive correlation with the equity home bias. Regarding the correlation of return between home and foreign equities, we find a negative association with the equity home bias, which is opposite to the result from the comparative statics. Additionally, an excess return on home equities compared to foreign ones is found to have a positive correlation with the equity home bias, which is consistent with the comparative statics when foreign investors have a higher risk aversion than domestic investors. To check the robustness of our empirical analysis, we fit alternative estimation models,

and use a log-transformed measure of the equity home bias, which turns in consistent results with ones with the original measure.

This paper proceeds as follows. In section 4.3, related studies are reviewed. Then, we set the theoretical model and provide analytic solutions in section 4.4. After the theoretical work, in section 4.5, the hypotheses are tested and the empirical results discussed. Finally, in section 4.6, the concluding remarks are provided.

4.3 Related Literature

Traditional studies approach the equity home bias with a transaction cost, such as relevant fees incurred from cross-border financial transactions (Stulz (1981) and Obstfeld and Rogoff (2000)). Beyond transaction costs, there have been numerous studies exploring the determinants of the equity home bias. The ability to hedge domestic or exchange rate risks is considered as one of the most significant determinants of the equity home bias (Cooper and Kaplanis (1986), Cooper and Kaplanis (1994), Mishra (2011), Beck and Fidora (2008) and Coeurdacier and Rey (2013)). Moreover, asymmetric information (Kang and Stulz (1997), Ivković and Weisbenner (2005), Foad (2011)) and corporate governance structures (Gelos and Wei (2005)) are suggested as factors associated with the equity home bias.

The equity home bias is also explained as a result of the interaction between financial markets. Quinn and Voth (2008) and Levy and Levy (2014) argue that if markets' returns move in the same direction, then investors have less incentives to use foreign equities for investment diversification. Comovement of both domestic and foreign returns implies that there is a high substitute relationship between domestic and foreign equities. In this case, foreign equities are not attractive to hedge domestic equity risk. Levy and Levy (2014) show that home bias is proportional to the average correlation between markets, and the proportion is less than 1 [2].

[2]Given costs, Levy and Levy (2014) show that the home bias is proportional to $\frac{\rho}{1-\rho}$, where ρ is the correlation between market returns.

Recently, there has been a consensus that the equity home bias is an outcome of the combination of behavioral and institutional factors. Using panel data from 38 countries between 2001 and 2010, Bose et al. (2015) show that improving financial literacy has a significant impact on reducing the equity home bias, and its impact is amplified in the less financially developed economies. Beugelsdijk and Frijns (2010) suggest that risk aversion and cultural differences relate to unfamiliarity with foreign assets. Huberman (2000) argues that investors overestimate the risk of foreign assets because the foreign assets are less familiar to domestic investors. Most of the familiarity in those works is measured by official languages, the distance between countries or cultural similarities (Grinblatt and Keloharju (2001), Chan et al. (2005) and Berkel (2007)). Morse and Shive (2011) introduce patriotism. Using the World Values Survey (WVS) data, they show that patriotism can explain marginally five percent of the equity home bias. Barberis and Thaler (2003) introduce belief perseverance, which is the investors' reluctance to look for evidence that refutes the beliefs.

This study is in line with previous studies, which suggest that the equity home bias arises from a combination of socio-behavioral features, asymmetric information, and financial markets' interactions. This work is in the context of the results from Huberman (2000), Foad (2010), and Foad (2011) in the sense that investors tend to avoid foreign equities because unfamiliarity plays a role when there is a lack of information about foreign equities. Since this work considers the comovement of domestic-foreign market returns, it is also related to the study by Levy and Levy (2014).

Compared to the previous literature, this work has two distinguishable points. Firstly, it utilizes a novel measure of personal behavior, unfamiliarity, from publicly available data. Secondly, it analyzes both the behavioral factor and market correlation simultaneously.

4.4 Theoretical Framework

Lewis (1999) and Foad (2011) suggest a mean-variance framework to analyze the equity home bias under information frictions on foreign financial markets. While sharing the spirit of the international capital asset pricing model (ICAPM) of Foad (2011), this work sets the model without

inflation and exchange rate. For simplicity, we introduce a mean-variance framework instead of a constant relative risk aversion model (CRRA). Furthermore, to concentrate on the role of unfamiliarity in information frictions about foreign equities, this work does not consider cross-border labor movements such as immigration, which are incorporated in Foad (2011).

Following Ljungqvist and Sargent (2018), we can derive a mean-variance utility from an exponential utility function and a normally distributed return on a portfolio [3].

In Section 4.7, we show how maximizing the expected utility function is equivalent to maximizing the mean-variance utility, which is a linear function of mean and variance of return on a portfolio. Combining the information set, I_h for home country and I_f for foreign country, and the home investor's share of both domestic and foreign equity, w_h^h and $w_h^f = 1 - w_h^h$, we can define the home investor's portfolio expected return and variance as:

$$\begin{aligned} E\left(R_h^P \,|\, I_h\right) &= w_h^h \left[E\left(R^h \,|\, I_h\right) - c_h^h\right] + \left(1 - w_h^h\right)\left[E\left(R^f \,|\, I_h\right) - c_h^f\right] \\ (\sigma_h^P)^2 |\, I_h &= \left(w_h^h\right)^2 var\left(R^h \,|\, I_h\right) + \left(1 - w_h^h\right)^2 var\left(R^f \,|\, I_h\right) + \\ &\quad 2\left(w_h^h\right)\left(1 - w_h^h\right) cov\left(R^h,\, R^f \,|\, I_h\right). \end{aligned} \tag{4.1}$$

When it is assumed that short leverage is not allowed, w_h^h is the non-negative domestic portfolio share of home country's total investment, while w_h^f is the foreign portfolio share of domestic portfolio [4] [5]. Also, R^h and R^f are the expected return of each domestic and foreign equity. c_h^h $\left(c_h^f\right)$ is defined as the cost of home investors holding domestic (foreign) equity. The objective function of the home investor in mean-variance form is:

[3] We can also get a mean-variance utility from a second-order approximation of an expected utility function with respect to the level of future wealth.

[4] A country might have unfamiliarity and information frictions that are differentiated across countries. For example, from the perspective of country A, the degree of unfamiliarity and information frictions about equity of country B are not equal to those of country C. For simplicity, we assume that a foreign asset is a combination of multiple country-specific portfolios, and it is given. By doing so, we can specify unfamiliarity and information frictions, focusing on the local investor's point of view.

[5] Since we view unfamiliarity about foreign equities as a non-fundamental feature on which an investor depends when he/she has information frictions, we do not explicitly incorporate a degree of unfamiliarity into the framework in this study.

$$Max_{w_h^h}\ w_h^h\left[E\left(R^h\,|\,I_h\right)-c_h^h\right]+\left(1-w_h^h\right)\left[E\left(R^f\,|\,I_h\right)-c_h^f\right] \\ -\frac{\lambda_h}{2}\left[(\sigma_h^P)^2|\,I_h\right] \tag{4.2}$$

where λ_h (λ_f) is home (foreign) investor's degree of risk aversion.In order to focus on the issue of our interest, we do not incorporate currency differences which are associated with exchange rate risk. Since the mean-variance utility is equivalent to the expected utility of an investor's future wealth from the portfolio, we can define consumption of a representative investor as the expected future wealth of the portfolio in this framework. Given a positive optimal portfolio share, it implies a positive relationship between domestic equity return and consumption.

From the home investors' perspective, there are information frictions on foreign equities. Likewise, foreign investors do not have complete information on home equities. Especially, according to Foad (2011), given the information set of I_h, home investors consider a degree of uncertainty on foreign equities quantified by η_f. Also, foreign investors with I_f face risk about home equities in the amount η_h. Denoting η_h (η_f) as a variance of return on home (foreign) equity from the perspective of foreign (home) investors with information set I_f (I_h), we can describe the following relationships when we assume u_f (u_h) does not have a correlation with $R^h\,|\,I_f$ ($R^f\,|\,I_h$):

$$R^h\,|\,I_f = R^h\,|\,I_h + u_f\ where\ u_f \sim (0,\,\eta_f)$$
$$E\left[R^h\,|\,I_f\right] = E\left[R^h\,|\,I_h\right] \equiv \mu^h$$
$$var\left(R^h\,|\,I_f\right) = var\left(R^h\,|\,I_h\right) + \eta_f \equiv \left(\sigma^h\right)^2 + \eta_f$$

$$R^f\,|\,I_h = R^f\,|\,I_f + u_h\ where\ u_h \sim (0,\,\eta_h)$$
$$E\left[R^f\,|\,I_h\right] = E\left[R^f\,|\,I_f\right] \equiv \mu^f$$
$$var\left(R^f\,|\,I_h\right) = var\left(R^f\,|\,I_f\right) + \eta_h \equiv \left(\sigma^f\right)^2 + \eta_h$$

where $\left(\sigma^h\right)^2$ and $\left(\sigma^f\right)^2$ are the true variances of domestic and foreign assets, respectively. Both home and foreign investors share the expected rate of return of the home (foreign) equity, μ^h and μ^f, despite the different information sets. Nevertheless, as foreign investors make more precise predictions regarding the rate of return on foreign equities, the home investors face an additional noise about the foreign equities, with the amount of η_h, beyond the actual variance of foreign equity. Likewise, home investors who are familiar with domestic equities can anticipate the expected return on domestic equities, so foreign investors face an additional noise with the amount of η_f beyond the real variance of home equity.

For convenience, we assume that the covariance of domestic-foreign equity return is constant and independent of information sets, i.e. $cov\left(R^h,\, R^f \,|\, I_h\right) = cov\left(R^h,\, R^f \,|\, I_f\right) = \sigma^{hf}$.

From Equation (4.2), assuming an interior solution, the optimal share of domestic and foreign equities for home investors, w_h^h and w_h^f, are [6]

$$
\begin{aligned}
w_h^h &= \frac{1}{\lambda_h}\frac{\left(\mu^h - c_h^h\right) - \left(\mu^f - c_h^f\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h} + \frac{\left(\sigma^f\right)^2 - \sigma^{hf} + \eta_h}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h} \\
w_h^f &= \frac{1}{\lambda_h}\frac{\left(\mu^f - c_h^f\right) - \left(\mu^h - c_h^h\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h} + \frac{\left(\sigma^h\right)^2 - \sigma^{hf}}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h}.
\end{aligned}
\tag{4.3}
$$

The market-clearing condition is required for equilibrium in the international financial markets. Let us denote the proportion of global total equity portfolio owned by a home (foreign) country as Π_h (Π_f). That is, Π_h and Π_f, can be interpreted as the share of world wealth belonging to home and foreign countries. The market clearing condition is,

[6] Analogously, the foreign investors' optimal shares of home and foreign equities are:

$$
\begin{aligned}
w_f^h &= \frac{1}{\lambda_f}\frac{\left(\mu^h - c_f^h\right) - \left(\mu^f - c_f^f\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} + \frac{\left(\sigma^f\right)^2 - \sigma^{hf}}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} \\
w_f^f &= \frac{1}{\lambda_f}\frac{\left(\mu^f - c_f^f\right) - \left(\mu^h - c_f^h\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} + \frac{\left(\sigma^h\right)^2 - \sigma^{hf} + \eta_f}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f}
\end{aligned}
$$

$$\Pi_h w_h^h + \underbrace{(1-\Pi_h)}_{\equiv \Pi_f} w_f^h = w^{h*} =$$

$$\Pi_h \frac{1}{\lambda_h} \frac{\left(\mu^h - c_h^h\right) - \left(\mu^f - c_h^f\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h} + \Pi_h \frac{\left(\sigma^f\right)^2 - \sigma^{hf} + \eta_h}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h}$$
$$+ (1-\Pi_h) \frac{1}{\lambda_f} \frac{\left(\mu^h - c_f^h\right) - \left(\mu^f - c_f^f\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} + (1-\Pi_h) \frac{\left(\sigma^f\right)^2 - \sigma^{hf}}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} \quad (4.4)$$

$$\Pi_h w_h^f + \underbrace{(1-\Pi_h)}_{\equiv \Pi_f} w_f^f = w^{f*} =$$

$$\Pi_h \frac{1}{\lambda_h} \frac{\left(\mu^f - c_h^f\right) - \left(\mu^h - c_h^h\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h} + \Pi_h \frac{\left(\sigma^h\right)^2 - \sigma^{hf}}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h}$$
$$+ (1-\Pi_h) \frac{1}{\lambda_f} \frac{\left(\mu^f - c_f^f\right) - \left(\mu^h - c_f^h\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} + (1-\Pi_h) \frac{\left(\sigma^h\right)^2 - \sigma^{hf} + \eta_f}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f}$$

where w^{h*} $\left(w^{f*}\right)$ is the home's (foreign's) domestic market capitalization share in the international financial market. By combining Equations (4.3) and (4.4), One can derive the difference between w and w^* by combining one can derive the equity home bias from the perspective of a home country, $(w_h^h - w^{h*})$:

$$w_h^h - w^{h*} =$$

$$(1-\Pi_h) \frac{1}{\lambda_h} \frac{\left(\mu^h - c_h^h\right) - \left(\mu^f - c_h^f\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h} + (1-\Pi_h) \frac{\left(\sigma^f\right)^2 - \sigma^{hf} + \eta_h}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_h}$$
$$- (1-\Pi_h) \frac{1}{\lambda_f} \frac{\left(\mu^h - c_f^h\right) - \left(\mu^f - c_f^f\right)}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} - (1-\Pi_h) \frac{\left(\sigma^f\right)^2 - \sigma^{hf}}{\left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf} + \eta_f} . \quad (4.5)$$

Based on the property of the variance of two returns, we can easily verify that $Var(R^h - R^f) = \left(\sigma^h\right)^2 + \left(\sigma^f\right)^2 - 2\sigma^{hf}$ is positive. The first two terms of $\left(w_h^h - w^{h*}\right)$ in Equation (4.5) are related to domestic investors. The first term explains the relationship between the relative net return on

home equity and the equity home bias. It is sensible that home investors tend to increase their share of home equities if the net return on domestic equities is relatively high compared to the one on foreign equities. The second term shows the relationship between the volatility of foreign equity and the equity home bias, given the information frictions of the home country. The latter two terms are associated with foreign investors' behavior. Foreign investors increase the share of home equities if home equities give a relatively high net return compared to foreign equities (the third term). Also, foreign investors tend to avoid the volatility of foreign equities by purchasing home equities (the fourth term) [7].

Moreover, assuming symmetric uncertainty, i.e. $\eta_h = \eta_f$, and transaction cost, i.e. $c_h^h = c_h^f$ and $c_f^h = c_f^f$, we expect that the equity home bias depends on the correlation between investors' consumption and return on domestic equities only when the degree of risk aversion (λ) is heterogeneous across countries. Based on the current framework, consumption is defined as future wealth from investment. Therefore, we can identify that the correlation between consumption and domestic return is non-negative, as the optimal shares of both home and foreign equities are between zero and one. For example, if there is a higher net return on the domestic equity compared to the foreign equities, ($\mu^h > \mu^f$), the equity home bias is increasing in return on domestic equity only when foreign investors have a higher degree of risk aversion than domestic investors ($\lambda_f > \lambda_h$). This implies that domestic investors face a higher correlation between consumption and domestic equity return compared to foreign investors. In such a case, domestic investors tend to increase the domestic equity share when the domestic equities give a relatively higher return. Alternatively, if domestic investors are relatively less sensitive to the portfolio return than foreign investors ($\lambda_f < \lambda_h$), the equity home bias is decreasing in return on domestic equities because foreign investors would increase their domestic equity share more than domestic investors when a domestic return is higher. When both domestic and foreign investors have symmetric sensitivity of their consumption to the return on the portfolio ($\lambda_f = \lambda_h$), the equity home bias is independent of the correlation between

[7] Analogously, a home country increases the share of foreign equity if the net return of foreign equities and the risk of home equities are relatively higher.

consumption and domestic equity return, because the same correlation level between consumption and domestic return gives both investors to set the same share of domestic equity.

To simplify the comparative statics, we can additionally assume that investors in both countries have the same levels of degree of risk aversion, i.e., $\lambda_h = \lambda_f$. Then, the equity home bias described in Equation (4.5) is simplified without the assumption of an identical net return across countries ($\mu^h = \mu^f$), such as Equation (4.6):

$$w_h^h - w^{h*} = (1 - \Pi_h)\left(w_h^h - w_h^f\right) = (1 - \Pi_h)\frac{\eta}{(\sigma^h)^2 + (\sigma^f)^2 - 2\sigma^{hf} + \eta}. \tag{4.6}$$

By taking partial derivatives with respect to either η and σ^{hf}, one can get $\frac{\partial\left(w_h^h - w^{h*}\right)}{\partial\eta} > 0$ and $\frac{\partial\left(w_h^h - w^{h*}\right)}{\partial\sigma_{hf}} > 0$ [8]. Given that η is positive, a higher correlation between home and foreign assets leads to a higher equity home bias, which is consistent with the results of Levy and Levy (2014), in which they argue that higher substitution between home and foreign equities leads to a higher home bias because investors do not have incentives to convert their domestic equities to foreign ones. In the case that the home equity is a substitute for the foreign equity, i.e., a positive σ^{hf}, the existence of information frictions on foreign equity amplifies the equity home bias.

4.5 Empirical Analysis

4.5.1 Measures

As there is no specific data about the equity home bias, this study measures the equity home bias following the procedure in Coeurdacier and Rey (2013). We can define the equity home bias in the home country as the difference between (A) the proportion of domestic equity in the total

[8] Alternatively, we can maintain heterogeneity in noise from the information frictions across countries as in Equation (4.6). Taking the partial derivative with respect to the covariance between home and foreign equities (σ^{hf}), we can get the following form:

$$\frac{\partial\left(w_h^h - w^{h*}\right)}{\partial\sigma^{hf}} = (1 - \Pi_h)\left[\frac{\eta_h}{\left\{(\sigma^h)^2 + (\sigma^f)^2 - 2\sigma^{hf} + \eta_h\right\}^2} + \frac{\eta_f}{\left\{(\sigma^h)^2 + (\sigma^f)^2 - 2\sigma^{hf} + \eta_f\right\}^2}\right]$$
$$+ (1 - \Pi_h)\left\{\left(\sigma^f\right)^2 - \left(\sigma^h\right)^2\right\}\left[\frac{1}{\left\{(\sigma^h)^2 + (\sigma^f)^2 - 2\sigma^{hf} + \eta_h\right\}^2} - \frac{1}{\left\{(\sigma^h)^2 + (\sigma^f)^2 - 2\sigma^{hf} + \eta_f\right\}^2}\right].$$

Assuming the same variance ($\left(\sigma^h\right)^2 = \left(\sigma^f\right)^2$), the equity home bias is increasing in the covariance of return between home and foreign equities.

equity portfolio of a home country and (B) the share of a home country's capitalization in total world equity market capitalization, i.e., (A) - (B). The following equation (4.7) defines the measure of equity home bias in this study:

$$EHB_h = 1 - \frac{\frac{HFE_h}{TEP_h}}{\frac{DMC_h}{World\,Total\,Market\,Cap}} \tag{4.7}$$

where EHB_h is the equity home bias, HFE_h denotes holding of foreign equity by the home country, TEP_h is the total equity portfolio in the home country, and DMC_h represents domestic market capitalization. Also, in order to get the total equity portfolio in the home country (TEP_h) in Equation (4.7), the following relationship should be satisfied:

$$TEP_h = DMC_h + HFE_h - HFE_f \tag{4.8}$$

where HFE_f is the foreign holdings of domestic equity. If the portfolio of the home country is perfectly diversified, EHB_h should be zero based on the international capital asset pricing model (ICAPM) (Coeurdacier and Rey (2013)).

For a measure of unfamiliarity under information frictions about foreign equities, this work utilizes the proportion of respondents who answered the survey question, "How much you trust: People you meet for the first time?" from the World Value Survey (WVS) (WVS (2014)). Although Hofstede's cultural dimensions data set captures several aspects of country-specific differences, this is not precisely consistent with country-specific unfamiliarity about foreign equities. For example, individualism and uncertainty avoidance in Hofstede's data are not sufficient alternatives to unfamiliarity [9].

[9] In Hofstede's model (https://geert-hofstede.com/countries.html), each country's cultural factors are analyzed by 6 dimensions, (1) Power Distance, (2) Individualism, (3) Masculinity, (4) Uncertainty Avoidance, (5) Long-term Orientation, and (6) Indulgence. Beugelsdijk and Frijns (2010) use (2) and (4) for their analysis.

4.5.2 Data

4.5.2.1 Equity Home Bias

Equity home bias can be calculated using domestic market capitalization and total portfolio investment across the border with Equations (4.7) and (4.8). The World Bank (WB) and the World Federation of Exchanges (WFE) provide domestic market capitalization data in terms of market capitalization in equity. This paper exploits the WB data set because it provides country-level information [10]. Also, total portfolio investment across the border by nations can be extracted from the Coordinated Portfolio Investment Survey (CPIS) of the IMF. In CPIS, there are total portfolio investment assets and liabilities in equity for each country, which are equivalent to domestic holdings of foreign equities and foreign holdings of domestic equities.

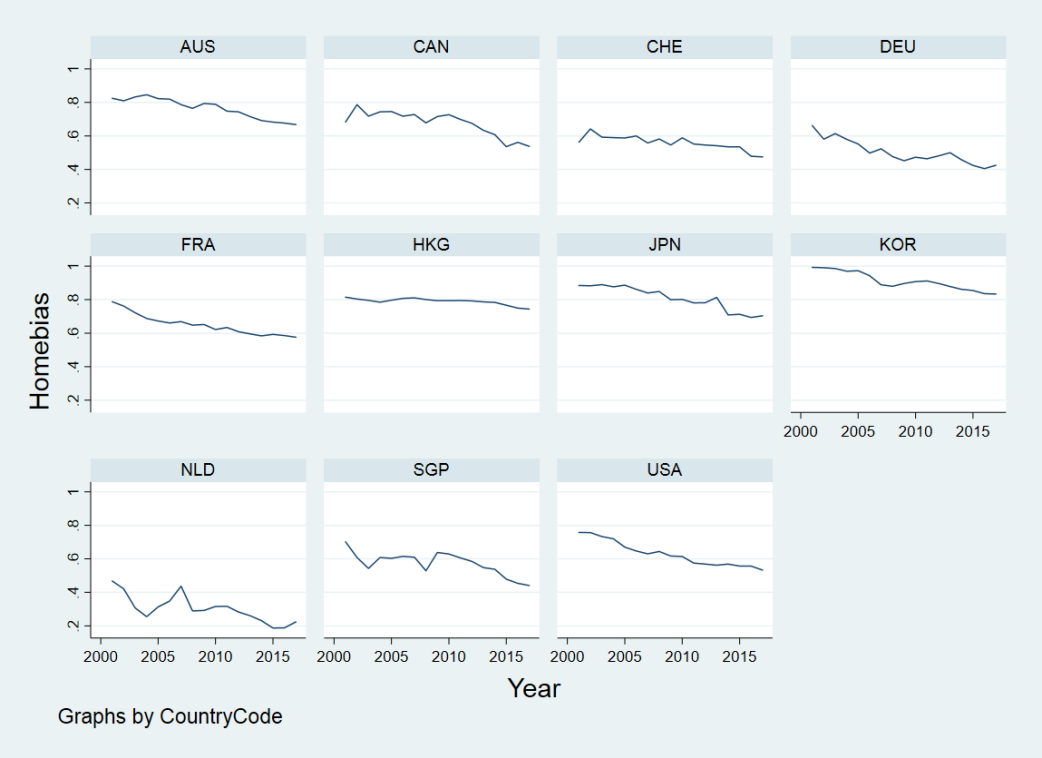
The period for the empirical analysis in this study is 17 years, from 2001 to 2017. Data on market capitalization earlier than 2001 are available. In contrast, the data for the cross-border investment in equity in CPIS has been published only since 2001. Data for 2018 are not employed because of missing values for some countries. To construct a balanced panel data set, the sample comprises 11 countries (Australia, Canada, France, Germany, Hong Kong, Japan, South Korea, the Netherlands, Singapore, Switzerland, and the U.S.) that have reported domestic market capitalization to WB and cross-border portfolios to CPIS without missing values among developed countries with the WVS data.

All of the selected countries have equity home bias, as shown in Figure 4.2. Most of the non-EU countries, for example, Australia, Canada, Hong Kong, Japan, South Korea, and the U.S., show a higher equity home bias compared to the selected EU-countries. For instance, in 2014, the equity home biases in three non-EU countries were 71% (Japan), 57% (U.S.), 53% (Switzerland) and 60% (Canada). Although France has shown temporarily higher home biases than the U.S. and Canada earlier in the 21st century, other selected countries in the EU, for example, Germany and

[10] The WFE data are exchange market based, therefore those data do not always correspond to the country-based data.

the Netherlands, exhibit significantly lower home equity biases. Capital movement freedom may explain this feature within EU countries [11].

As shown in Figure 4.2, the bias of each country was smaller in 2017 compared to 2001, even if there were fluctuations. The simple average of equity home bias in these 11 countries was 74% in 2001, which contrasts with an average home bias of 56% in 2017. Considering those eleven countries are highly developed countries whose financial markets are deeply integrated, the equity home bias puzzle cannot be explained only by the transaction cost, including differences in legal systems and languages.



Note: Computed from IMF CPIS and World Bank data

Figure 4.2: Equity Home Bias in Several Developed Countries

[11] We could not include Italy into our sample for analysis, because there has been no update regarding market capitalization data since 2008.

4.5.2.2 Non-fundamental unfamiliarity

Non-fundamental unfamiliarity is measured from the WVS dataset, survey data regarding cultural features by nations. WVS has conducted six waves since 1990; it has interviewed between 1,000 and 2,000 people in each nation per wave. Given this dataset, this paper considers the proportion of people who respond "Do not trust much" or "Do not trust at all" to the question: *" I 'd like to ask you how much you trust people from various groups. Could you tell me for each whether you trust people from this group completely, somewhat, not very much or not at all? - People you meet for the first time"* in each country [12].

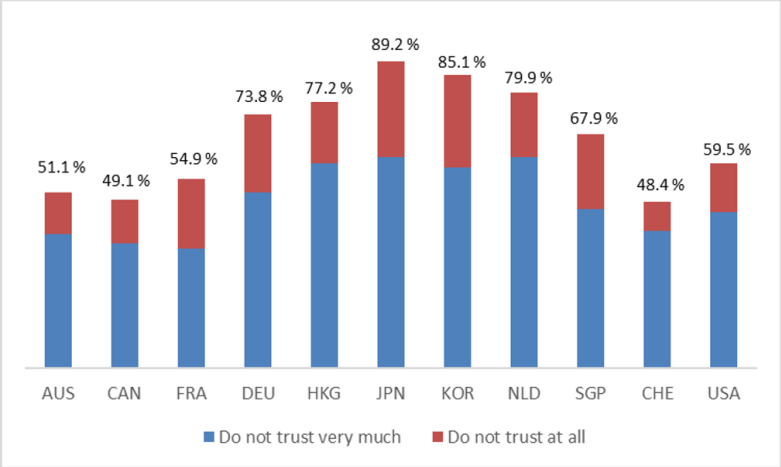
Figure 4.3 shows the individual mistrust from unfamiliarity of others by selected nations. Except for Canada and Switzerland, over half of respondents in selected countries stated that they do not trust strangers. Specifically, over 70% of German, Italian and Japanese respondents showed mistrust toward unfamiliar people.

4.5.3 Empirical Model and Results

In the empirical analysis, a panel analysis is implemented. As country-specific unfamiliarity is time-invariant in this set up, we conduct a feasible generalized linear squared regression (FGLS) method. Moreover, the FGLS method is useful when the error structure across the panels is heteroskedastic and correlated.

Our variables of interest are 1) country-level unfamiliarity, 2) the correlation of return between domestic and foreign equities, and 3) the difference in annual returns between domestic and foreign equities. Regarding country-level unfamiliarity, we use the portion of respondents for "Do not trust much" or "Do not trust at all" to the WVS question: "Do you trust people you meet for the first time?"

[12] This question is provided only in waves 5 (2005 $\sim$ 2009) and 6 (2010 $\sim$ 2014). All of the selected countries, except for Hong Kong, Japan and Singapore, reported in wave 5, while only eight countries (Australia, Germany, Hong Kong, Japan, South Korea, Netherlands, Singapore and the U.S.) reported in wave 6. There are no significant changes in the proportion of our interest in the five countries that reported in both waves (Australia, Germany, South Korea, Netherlands, the U.S.). Therefore, we utilize data in wave 5 for the measure of the unfamiliarity in each country except for Hong Kong, Japan, and Singapore, for which we use wave 6 instead.



Note: Computed from the WVS data

Figure 4.3: The Portion of Respondents for "Do not trust much" or "Do not trust at all" to the Question: *" I 'd like to ask you how much you trust people from various groups. Could you tell me for each whether you trust people from this group completely, somewhat, not very much or not at all? - People you meet for the first time."*

For a measure of the correlation of return between domestic and foreign equities, the rate of return on the Global Dow Jones index is assumed as the return on foreign equity. The benchmark equity index in each nation is treated as the equity of the home country [13].

Based on the daily rate of return on those indexes, we compute the annual correlation of returns between domestic and foreign equities for sample countries. The difference in annual returns between domestic and foreign equities represents the amount of excess return on the local benchmark index compared to the Global Dow Jones index in each country [14].

In terms of control variables, we introduce 1) a Euro currency area dummy, and 2) a city-level market dummy, and 3) the GDP growth rate. The Euro currency area dummy stands for free capital movement among the member countries of the currency union in the European Union (EU). Also, we introduce a dummy variable that represents city-level markets, Hong Kong and Singapore.

[13]Data were extracted from Yahoo finance and the Wall Street Journal online. The country indexes we used are All Ordinaries for Australia, S&P TSX composite index for Canada, CAC 40 for France, DAX for Germany, Hang Seng for Hong Kong, Nikkei 225 for Japan, KOSPI for S. Korea, Amsterdam AEX index for the Netherlands, Strait Times Index for Singapore, SMI for Switzerland, and Dow Jones Industrial Average for the United States. Also, the Global Dow Jones index is used to construct the growth rate of global equity return. A limitation of this paper is that it does not compute the exact covariance of equity return across markets.

[14]The Global Dow Jones index is a stock index consisting of 150 firms from around the world.

Table 4.1: Summary Statistics (Aggregate Level)

Variable	Mean	Standard Deviation	Minimum	Maximum	# of Obs.
Home Bias	0.652	0.173	0.187	0.993	187
Unfamiliarity	0.668	0.144	0.480	0.890	11
Correlation with foreign return	0.582	0.193	0.162	0.869	187
Difference in return between home and foreign equities	-0.012	0.113	-0.312	0.355	187
Hong Kong and Singapore	-	-	0	1	11
GDP growth rate	0.024	0.024	-0.056	0.145	187
Euro currency area	-	-	0	1	11
Year	-	-	2001	2017	17

Those financial markets are highly depend on international financial transactions. Table 4.1 offers summary statistics for the variables used. A country-level summary of statistics is attached in Section 4.9 [15].

Since there is a decreasing trend in equity home bias in each country, we control for the trend in equity home bias by adding year as a control variable. Based on a fixed-effect analysis (FE) by regressing the equity home bias on the year variable, the estimated coefficient for the year variable is -0.11 with a standard error of 0.0005, which is significant at the 1% level.

We construct five estimation models to investigate the relationship of unfamiliarity with the equity home bias. Model 1 is a benchmark model. The equity home bias is treated as the dependent variable. Also, unfamiliarity, GDP growth rate, and the Euro currency area dummy are incorporated as explanatory variables. In model 2, the correlation of returns between home and global equities is included to verify whether a higher substitution between domestic and global equity leads to a higher equity home bias. In model 3, the correlation between local and global equity returns is replaced with the difference in return between domestic and global equities to test whether an excess return on home equities compared to the global equity has a positive relationship with equity home bias. In model 4, both the correlation and the difference with the global returns

[15] It is important to check multicollinearity among independent variables in the sample panel dataset. Using the variance inflation factor (VIF), we determine that there is no multicollinearity since VIF values from independent variables are no more than 2.18, which are much smaller than the often-used threshold of 10.

Table 4.2: Summary of Empirical Results (Original Equity Home Bias across Sample Countries)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Unfamiliarity	0.247***	0.074***	0.239***	0.071***	0.110***
	(0.010)	(0.010)	(0.010)	(0.013)	(0.013)
Correlation with foreign return		-0.305***		-0.302***	-0.313***
		(0.018)		(0.021)	(0.023)
Difference in return			0.090***	0.112***	0.100***
between home and foreign equities			(0.010)	(0.013)	(0.014)
Hong Kong and Singapore					-0.100***
					(0.008)
GDP growth rate	-0.036	-0.305***	0.046	-0.211**	0.163
	(0.039)	(0.090)	(0.068)	(0.103)	(0.102)
Euro currency area	-0.238***	-0.149***	-0.235***	-0.137***	-0.154***
	(0.004)	(0.006)	(0.006)	(0.005)	(0.006)
Year	-0.011***	-0.012***	-0.011***	-0.012***	-0.012***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)
Constant	22.034***	24.242***	22.599***	24.649***	24.413***
	(0.300)	(1.029)	(0.712)	(1.168)	(1.045)
Wald χ^2	37668.14***	3616.48***	9289.05***	1795.88***	2410.58***
(Degree of freedom)	(4)	(5)	(5)	(6)	(7)

a. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$
b. Estimated coefficients (top) and standard errors (bottom, within parenthesis)

are considered for the estimation. Finally, in Model 5, we control for the city-level global financial markets, Hong Kong and Singapore.

Table 4.2 reports the results from the empirical analysis. Among the five estimation models, Model 4 is the preferred specification. Model 4 shows the highest degree of goodness-of-fit in terms of the smallest Wald chi-square statistic, as shown in the last row of Table 4.2. It implies that Model 4 contains significant explanatory variables necessary in the empirical analysis with the least redundancy associated with an insignificant variable. It also suggests that Model 4 is neither under- nor over-specified compared to the other models.

We find a significantly positive relationship of country-level unfamiliarity with the equity home bias. The coefficient estimates from Models 1 and 3 in which the correlation of equity returns between two equities is not included are 0.24. In the case of Models 2 and 4 that incorporate the

correlation of returns, the coefficient estimates are 0.07. In model 5 that controls for Hong Kong and Singapore, the coefficient estimate is 0.1. Even though the point estimates are different across the empirical models, they are all positive at a 1% significance level. In sum, the equity home bias is positively related to country-specific unfamiliarity.

As per the correlation between home and foreign equity returns, the results from the empirical analysis show a negative relationship with the equity home bias. The estimates of coefficients are between -0.31 and -0.30 at a 1% significance level across empirical models. Those results contrast with our hypothesis from the comparative statics in Section 4.4 and the results from Levy and Levy (2014) [16].

The difference in return between home and foreign equities shows a positive relationship with the equity home bias. The estimated coefficient is between 0.09 and 0.12 at a 1% significance level. Those results are opposite to our expectation under the assumption of symmetric degree of risk aversion ($\lambda_f = \lambda_h$) and transaction costs of obtaining equities, as shown in Equations (4.5) and (4.6) of Section 4.4. The empirical results suggest that home investors acquire home equities more than foreign investors when there is an excess return on home equities compared to foreign ones. Those results are consistent with the ones from the theoretical framework under the assumption that foreign investors have a higher degree risk aversion than domestic investors ($\lambda_f > \lambda_h$).

Additionally, we can identify how the equity home bias is associated with other control variables. Firstly, we do not find a consistent result regarding the correlation between the GDP growth rate and the equity home bias. The coefficient is -0.3 ˜-0.2 in Models 2 and 4, while we do not find any significant results from Models 1 and 3.

A city dummy that represents the city-level independent financial markets, Hong Kong and Singapore, has a negative relationship with the equity home bias; the estimate of coefficient is -0.1 at a 1% significance level in Model 5. This result is consistent with the fact that both regions have acted as international financial hubs in Asia. Since most of the financial transactions associated

[16] This counter-intuitive empirical result may be related to several factors, including a difference in the degree of risk aversion ($\lambda_h \neq \lambda_f$). Moreover, the degree of uncertainty on the foreign equity return from the home country (η_h) is not always equal to the degree of uncertainty on the home equity return from the foreign country (η_f), which also may lead to the counter-intuitive results in this empirical analysis.

with Asian countries depend on international finance in those city-level markets, the equity home bias in those regions is at a lower level compared to Korea and Japan.

Furthermore, freedom of capital movement among Euro currency members (Eurozone) has a negative correlation with the equity home bias. The empirical results show a negative relationship between the Euro currency area dummy and the equity home bias with coefficients ranging between -0.24 and -0.14 depending on the models. In sum, this Euro currency area dummy variable can explain a relatively lower level of home equity bias in the three sample countries whose currency is the Euro (France, Germany, and the Netherlands), and we can interpret those results as a lower equity home bias in the Eurozone because of the free capital movement between member countries.

Regarding a trend of the equity home bias, we determine that the equity home bias has decreased over time. The estimate of coefficient is -0.012 $\sim$ -0.011 at a 1% significance level.

4.5.4 Empirical Results with A Transformed Measure of Unfamiliarity

As reported in Tables 4.1 and 4.5 of the previous subsection, the predicted values of the equity home bias are less than 1, which is consistent with the support of the primary measure of equity home bias defined in Equation (4.7) , such as $(-\infty, 1]$.

In this part, we transformed the measure of the equity home bias with a larger support, $(-\infty, +\infty)$, and checked whether the empirical results are consistent with ones from the original data set. Specifically, we defined the latter part in the definition of the equity home bias described in Equation (4.7) as Q_h, such as:

$$Q_h \equiv \frac{\frac{HFE_h}{TEP_h}}{\frac{DMC_h}{World\,Total\,Market\,Cap}} \tag{4.9}$$

where Q_h is the home country's holding portion of foreign equity normalized by the share of its domestic market capitalization share in the world market. As all the values in Equation (4.9) are non-negative, Q_h should be also non-negative, $(Q_h \geq 0)$. Then, we took a log-transformation and defined the measure as g_h by converting this transformed value into negative, as in Equation (4.10):

$$g_h \equiv -ln(Q_h) \tag{4.10}$$

where the support of g_h is ranging from $-\infty$ to $+\infty$. And, the measure g_h is positively associated with the equity home bias.

We maintain the previous five estimation models. Therefore, a benchmark model, Model 1, focuses only on country-level unfamiliarity controlling for GDP growth rate and Euro currency area dummy. We include the correlation of returns between home and global equities in Model 2, while we replace the correlation of equity returns with the difference in return between domestic and global equities in Model 3. In model 4, both correlation and difference of returns between home and global equities are incorporated. Lastly, city-level independent markets are considered in Model 5.

The results from the modified support of the equity home bias are reported in Table 4.3. It can be observed that the results are consistent with ones in the previous part that utilizes the original measure of the equity home bias defined in Equation (4.7). Among the five estimation models, Model 5 shows the best fit for the empirical analysis in the log-transformed measure case: The Wald chi-square statistic shows the lowest value, 974.77.

As per the country-level unfamiliarity, we find that it has a positive correlation with the equity home bias. The coefficients of estimates range from 1.29 to 1.87 at a 1% significance level. The estimated coefficients are higher than 1.7 when the empirical model does not incorporate the correlation of returns between two equities. In contrast, the coefficients are smaller when the correlation of equity returns is included in the model.

In terms of other variables of our interest, we also find that the relationships between the equity home bias and other variables of our interest are empirically consistent with the results obtained by the original equity home bias measure. Regarding the correlation between home and foreign equity returns, the negative estimates of coefficients at a 1% significance level offers consistency with ones from the empirical analysis in the previous part; they are still opposed to the hypothesis from the comparative statics. The estimated coefficients are between -1.13 and -1.04 at a 1% significance level across the empirical models. Moreover, the empirical results also show that an excess return

Table 4.3: Summary of Empirical Results (Transformed Equity Home Bias to the Support between $-\infty$ and $+\infty$, $(-\infty, +\infty)$)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5
Unfamiliarity	1.848***	1.292***	1.742***	1.126***	1.292***
	(0.035)	(0.063)	(0.054)	(0.076)	(0.082)
Corr. with foreign return		-1.044***		-1.113***	-1.125***
		(0.064)		(0.084)	(0.100)
Difference in return b/t home and foreign equities			0.704***	0.767***	0.624***
			(0.071)	(0.079)	(0.089)
Hong Kong and Singapore					-0.491***
					(0.062)
GDP growth rate	0.917***	0.119	1.297***	0.189	2.012***
	(0.244)	(0.260)	(0.367)	(0.382)	(0.508)
Euro currency area	-0.773***	-0.464***	-0.732***	-0.401***	-0.479***
	(0.010)	(0.019)	(0.018)	(0.021)	(0.024)
Year	-0.046***	-0.048***	-0.045***	-0.048***	-0.048***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)
Constant	92.941***	97.643***	90.537***	97.140***	97.389***
	(2.080)	(2.743)	(4.663)	(4.340)	(5.641)
Wald χ^2	18221.04***	3497.20***	2856.06***	1256.26***	974.77***
(Degree of freedom)	(4)	(5)	(5)	(6)	(7)

a. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$
b. Estimated coefficients (top) and standard errors (bottom, within parenthesis)
c. Measure of country-level equity home bias is transformed with the support of $(-\infty, +\infty)$

on domestic equity positively correlates with the equity home bias. The estimates of coefficients are significantly positive at a 1% level, ranging from 0.62 to 0.76.

Consistent with the empirical results in the previous part, the equity home bias has a negative relationship with the currency union, such as the Euro area, and the modified measure of the equity home bias is also decreasing over time.

4.6 Conclusion

Equity home bias is relatively stable over time despite a higher international financial market integration. This study incorporates information frictions about the return on foreign equity as a factor causing the equity home bias. We hypothesize that investors depend on country-specific non-fundamental behavioral factors when there are information frictions on foreign equities, which raises the equity home bias. Furthermore, based on the substitutability of equities across countries, we hypothesize that the correlation of return between home and foreign equities positively relates to the equity home bias.

In the first part of this research, we derive comparative statics describing relationships between the equity home bias and either information frictions or the home-foreign return correlation. Assuming an identical degree of 1) risk aversion and of 2) uncertainty about foreign equity return across countries, an analytical relationship is derived stating that the equity home bias is associated with information frictions about return on foreign equities. Comparative statics also hypothesize that the correlation of return between home and foreign equities raises the equity home bias. In the second part, this work assumes that portfolios may depend on the unfamiliarity about foreign equities. In the empirical analysis, we hypothesize that unfamiliarity positively associates with the equity home bias. Also, to account for the effect of substitution of equities across countries, we hypothesize that correlation of return between home and foreign equities raises the equity home bias.

Based on a panel consisting of eleven developed countries, the empirical analysis tests the hypotheses described above. We introduce the proportion of respondents to the question, "Could

you tell me for each whether you trust people from this group completely, somewhat, not very much or not at all? - People you meet for the first time", as a proxy for the country-specific unfamiliarity from the WVS. For the measure of return correlation return between home and foreign equities, we use an annual correlation of return between the domestic benchmark index and the Global Dow Jones index. We incorporate 1) the difference in return between the domestic benchmark index and Global Dow Jones index, 2) city-level markets such as Hong Kong and Singapore, 3) GDP growth rate, and 4) Euro currency area to the empirical model. We also include time as a regressor because the equity home bias has a decreasing trend.

Setting up five estimation models, we implement an FGLS method allowing heteroskedasticity and correlation across panels. Model 1 considers only country-level unfamiliarity. Model 2 adds the correlation of return between domestic and foreign equities to Model 1. In contrast, Model 3 replaces this return correlation in Model 2 with the excess return on domestic equity. Model 4 employs all the variables of our interest in Model 4. Model 5 adds a dummy representing the city-level markets in Asia to Model 4.

The results from the empirical analysis show a positive relationship between the country-level unfamiliarity and the equity home bias. The coefficient estimates range from 0.07 to 0.24. In contrast to Levy and Levy (2014), the coefficient estimates for the correlation of return between home and foreign equities are negative at a 1% significance level. Besides, an excess return on home equities compared to foreign ones shows a positive correlation with the equity home bias. This positive correlation is consistent with the comparative statics when foreign investors have a higher risk aversion than domestic investors.

To check the robustness of the empirical analysis, we apply a log-transformed measure of the equity home bias to the five estimation models already defined. The empirical results are consistent with the ones using the original measure. Regarding the country-level unfamiliarity, the coefficient estimates are significantly positive, ranging from 1.1 to 1.8. Counter to the hypothesized theoretical relationships, the correlation of return between domestic and foreign equities shows a negative relationship with the equity home bias; the estimates of coefficients are ranging from -1.1 to -1.0.

Moreover, the excess return on domestic equity shows a positive correlation with the equity home bias, which is also opposite to the comparative statics results under the assumption of symmetric degree of risk aversion and transaction costs of purchasing equities.

Both theoretical and empirical results show that country-level unfamiliarity positively relates to the equity home bias. Specifically, in the empirical analysis, the WVS data publicly available is exploited for a measure of unfamiliarity. This work leaves an in-depth exploration with a larger dataset for future research. This work accounts for only countries with a highly integrated equity market. Therefore, most developing markets are not included in the sample of empirical analysis. A dataset with extended time-series is expected to provide additional information about the relationship between the country-specific unfamiliarity and the equity home bias.

4.7 Appendix A: Getting a Mean-variance Utility from an Expected Utility Function (Ljungqvist and Sargent (2018))

Without loss of generality, a home investor plans to invest his initial wealth W_h in domestic and foreign assets. Given R_h^P as the random rate of aggregate return on the home investor's portfolio, we can denote the home investor's future wealth as $\tilde{W}_h = W_h\left(1 + R_h^P\right)$. Given W_h, we can simplify the investor's utility in terms of his future wealth, $U\left(\tilde{W}_h\right)$, as $U\left(R_h^P\right)$ because $\tilde{W}_h$ is fully determined by R_h^P. The utility function is described in Equation (4.11):

$$E\left[U\left(R_h^P\right)\right] = E\left[-e^{-\lambda_h R_h^P}\right]. \tag{4.11}$$

where λ_h is a parameter of exponential utility function. From the property of exponential utility function, we can determine that the parameter in exponential utility function, λ, is the Arrow-Pratt index of absolute risk aversion because:

$$r.a. = -\frac{U''\left(R_h^P\right)}{U'\left(R_h^P\right)} = -\frac{-\lambda_h^2 e^{-\lambda R_h^P}}{\lambda_h e^{-\lambda R_h^P}} = \lambda_h. \tag{4.12}$$

Next, when we suppose that R_h^P is drawn from normal distribution with mean, μ_h^P, and standard deviation, σ_h^P, the probability density function (PDF), $g(R_h^P)$ is given by:

$$g(R_h^P) = \frac{1}{\sigma_h^P\sqrt{2\pi}} e^{-\frac{(R_h^P-\mu_h^P)^2}{2(\sigma_h^P)^2}}. \tag{4.13}$$

Applying this PDF to Equation (4.11), we can expand the expected utility function such as:

$$E\left[U\left(R_h^P\right)\right] = -\frac{1}{\sigma_h^P\sqrt{2\pi}} \int_{-\infty}^{\infty} \left[e^{-\left\{\lambda_h R_h^P + \frac{(R_h^P-\mu_h^P)^2}{2(\sigma_h^P)^2}\right\}} \right]. \tag{4.14}$$

We can rearrange the power term in Equation (4.15) such as:

$$\lambda_h R_h^P + \frac{(R_h^P-\mu_h^P)^2}{2(\sigma_h^P)^2} = \frac{\{R_h^P-\mu_h^P+\lambda_h(\sigma_h^P)^2\}^2}{2(\sigma_h^P)^2} + \lambda_h\left(\mu_h^P - \frac{\lambda_h}{2}(\sigma_h^P)^2\right). \tag{4.15}$$

Then, we can decompose Equation (4.15) as in Equation (4.16):

$$E\left[U\left(R_h^P\right)\right] = -e^{-\lambda_h\left(\mu_h^P-\frac{\lambda_h}{2}(\sigma_h^P)^2\right)} \frac{1}{\sigma_h^P\sqrt{2\pi}} \int_{-\infty}^{\infty} \left[e^{-\left\{\frac{\{R_h^P-\mu_h^P+\lambda_h(\sigma_h^P)^2\}^2}{2(\sigma_h^P)^2}\right\}} \right]. \tag{4.16}$$

where $\frac{1}{\sigma_h^P\sqrt{2\pi}}\int_{-\infty}^{\infty}\left[\exp\left(-\left\{\frac{\{R_h^P-\mu_h^P+\lambda_h(\sigma_h^P)^2\}^2}{2(\sigma_h^P)^2}\right\}\right)\right] = 1$ because it is the area over the entire support when the mean is $\mu_h^P - \lambda_h(\sigma_h^P)^2$ and the standard deviation is σ_h^P. The simplified form of the expected utility function is

$$E\left[U\left(R_h^P\right)\right] = -e^{-\lambda_h\left(\mu_h^P-\frac{\lambda}{2}(\sigma_h^P)^2\right)}. \tag{4.17}$$

Hence, maximization of $E[U\left(\tilde{W}_h\right)]$ is equivalent to maximizing the following quadratic expression:

$$E\left[\hat{U}\left(R_h^P\right)\right] = \mu_h^P - \frac{\lambda_h}{2}(\sigma_h^P)^2 \tag{4.18}$$

where λ_h measures the degree of home investor's risk aversion.

4.8 Appendix B: A Proxy for Country-specific Unfamiliarity

Table 4.4: The Portion of Respondents for "Do not trust much" or "Do not trust at all" to the Question: " I 'd like to ask you how much you trust people from various groups. Could you tell me for each whether you trust people from this group completely, somewhat, not very much or not at all? - People you meet for the first time."

Country	Unfamiliarity		Sum
	Do not trust much	Do not trust at all	
Australia	38.9%	12.2%	51.1%
Canada	36.3%	12.8%	49.1%
France	34.8%	20.1%	54.9%
Germany	51.1%	22.7%	73.8%
Hong Kong	59.5%	17.8%	77.2%
Japan	61.3%	27.9%	89.2%
S. Korea	58.4%	26.7%	85.1%
Netherlands	61.2%	18.7%	79.9%
Singapore	46.2%	21.6%	67.9%
Switzerland	39.8%	8.6%	48.4%
United States	45.5%	14.0%	59.5%

4.9 Appendix C: Country-level Summary of Statistics

Table 4.5: Summary of Statistics (Country Level)

Country	Variable	Mean	Std. Dev.	Minimum	Maximum
Australia	Home Bias	0.766	0.060	0.668	0.846
	Correlation with foreign return	0.348	0.094	0.168	0.507
	Difference in return between home and foreign equities	-0.016	0.092	-0.157	0.181
	GDP growth rate	0.029	0.007	0.019	0.041
Canada	Home Bias	0.676	0.075	0.536	0.787
	Correlation with foreign return	0.648	0.094	0.476	0.769
	Difference in return between home and foreign equities	-0.015	0.086	-0.165	0.159
	GDP growth rate	0.020	0.015	-0.029	0.032
France	Home Bias	0.651	0.062	0.576	0.788
	Correlation with foreign return	0.775	0.055	0.663	0.850
	Difference in return between home and foreign equities	-0.045	0.074	-0.180	0.066
	GDP growth rate	0.012	0.013	-0.029	0.028
Germany	Home Bias	0.504	0.072	0.405	0.662
	Correlation with foreign return	0.769	0.049	0.702	0.867
	Difference in return between home and foreign equities	0.004	0.095	-0.202	0.182
	GDP growth rate	0.013	0.022	-0.056	0.041
Hong Kong	Home Bias	0.790	0.020	0.744	0.815
	Correlation with foreign return	0.424	0.093	0.264	0.573
	Difference in return between home and foreign equities	0.000	0.156	-0.261	0.243
	GDP growth rate	0.037	0.029	-0.025	0.087

Table 4.5 Continued

Country	Variable	Mean	Std. Dev.	Minimum	Maximum
Japan	Home Bias	0.810	0.070	0.694	0.890
	Correlation with foreign return	0.388	0.094	0.184	0.520
	Difference in return between home and foreign equities	-0.008	0.137	-0.275	0.303
	GDP growth rate	0.008	0.020	-0.054	0.042
S. Korea	Home Bias	0.912	0.054	0.834	0.993
	Correlation with foreign return	0.375	0.099	0.162	0.521
	Difference in return between home and foreign equities	0.049	0.142	-0.187	0.355
	GDP growth rate	0.038	0.017	0.007	0.074
Netherlands	Home Bias	0.302	0.081	0.187	0.468
	Correlation with foreign return	0.774	0.054	0.651	0.846
	Difference in return between home and foreign equities	-0.049	0.075	-0.177	0.100
	GDP growth rate	0.013	0.018	-0.037	0.038
Singapore	Home Bias	0.573	0.069	0.441	0.702
	Correlation with foreign return	0.443	0.099	0.255	0.594
	Difference in return between home and foreign equities	-0.018	0.132	-0.205	0.282
	GDP growth rate	0.052	0.038	-0.011	0.145
Switzerland	Home Bias	0.560	0.042	0.475	0.642
	Correlation with foreign return	0.706	0.075	0.503	0.796
	Difference in return between home and foreign equities	-0.040	0.095	-0.198	0.136
	GDP growth rate	0.018	0.015	-0.022	0.041
United States	Home Bias	0.630	0.075	0.533	0.758
	Correlation with foreign return	0.756	0.076	0.609	0.869
	Difference in return between home and foreign equities	-0.001	0.120	-0.312	0.173
	GDP growth rate	0.019	0.015	-0.025	0.038

4.10 References

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CHAPTER 5. GENERAL CONCLUSIONS

In this thesis, I explore three issues in international economics. The first two chapters cover the trade issues, while the last chapter explores the long-lasting puzzle in international finance, the equity home bias.

Chapter 2 demonstrates lowering markups in the short-run equilibrium of international trade when granular firms are heterogeneous and allowed to produce multiple varieties. When it comes to the short-run market environment, I assume the survivors in autarky maintain their productivity in the short-run at the onset of international trade. Since the least productive firms in autarky are expelled from the local market, the survivors in autarky are the entrants in the liberalized market. These assumptions result in head-to-head competition, an essential component of gains from trade. The quantitative results suggest that the pro-competitive market environment and the introduction of foreign productive competitors reduce the firm-level market share, which results in lower markups and prices of varieties. While the optimal range of products is determined by the interaction between the changes in market size and firm-level market share, the aggregate product range is extended, which results in gains from trade.

Chapter 3 explores two recent Article 22.6 arbitration cases (DS464 and DS471) in which the WTO employed the Armington model. Interestingly, this has not drawn much attention from economists, despite being an essential topic for firms involved in trade disputes. This investigation suggests two technical issues in the arbitration: (a) case DS464 assumes a lower level of Armington elasticity; and (b) case DS471 shows an error in reported NoI level. Specifically, Case DS471 contains a change in the duty payment into the NoI level. To address the issue related to the Armington elasticity, using a higher Armington elasticity in the sensitivity analysis brings Korea's calibrated 2017 U.S. LRW market share closer to actuality and allows for modest results.

Chapter 4 investigates the hypotheses for the relationship of the equity home bias with 1) the country-level behavioral unfamiliarity, and 2) the home-foreign return correlation. The empirical analysis tests the hypotheses described above based on the comparative statics derived from a mean-variance framework. This work introduces the proportion of respondents to the question, "Could you tell me for each whether you trust people from this group completely, somewhat, not very much or not at all? - People you meet for the first time", as a proxy for the country-specific unfamiliarity from the WVS. For the measure of return correlation return between home and foreign equities, an annual correlation of return between the domestic benchmark index and the Global Dow Jones index is employed. Based on a panel of eleven developed countries, the empirical results provide a positive relationship between the country-level unfamiliarity and the equity home bias. In contrast, the coefficient estimates for the correlation of return between home and foreign equities are negative, opposite to the outcome from the comparative statics.