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Modeling, Empirics and Policy Implications of Firm Heterogeneity in International Trade

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Head of the Departmental Graduate Program Date

MODELING, EMPIRICS AND POLICY IMPLICATIONS OF FIRM HETEROGENEITY IN INTERNATIONAL TRADE

A Dissertation
Submitted to the Faculty
of
Purdue University
by
Zeynep Akgul

In Partial Fulfillment of the
Requirements for the Degree
of
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To my beloved husband, Altug

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ABSTRACT

Akgul, Zeynep PhD, Purdue University, May 2015. Modeling, Empirics and Policy Implications of Firm Heterogeneity in International Trade. Major Professors: Nelson B. Villoria and Thomas W. Hertel.

Computable General Equilibrium (CGE) models are essential computational tools for trade policy analysis. While traditional CGE models based on the Armington assumption of national product differentiation have been successfully applied to various policy scenarios, they also have significant limitations in explaining the firm-level information prevalent in the recent international trade literature. The pioneering work of Melitz (2003) has provided a firm heterogeneity theory that can help address the shortcomings of Armington-based CGE models by introducing additional productivity mechanisms and extensive margin effects. Incorporation of firm heterogeneity in mainstream CGE models offers great potential to improve computational policy analysis. Even though there have been some efforts to incorporate firm heterogeneity into CGE modeling, a readily accessible Global Trade Analysis Project (GTAP) implementation is currently not available. This dissertation addresses this gap by a combination of theory, calibration, estimation and simulation to develop and implement a firm heterogeneity module executed within the GTAP environment.

Chapter 2 presents the newly developed firm heterogeneity module with a stylized tariff removal scenario and compares the model predictions with those of monopolistic competition and perfect competition frameworks previously established in the standard GTAP model. Chapter 3 proposes a theoretically-consistent way to parameterize the firm heterogeneity module with a focus on the elasticity of substitution across varieties. Results show that the elasticity values that are consistent with the firm heterogeneity theory are considerably lower than Armington elasticities used in the standard GTAP model. Finally, Chapter 4 applies this newly developed module and parameterization to policy analysis in order to investigate the implications of reducing non-tariff measures associated with the beef hormone ban imposed by the European Union on imports from the United States based on the negotiations taking place for the Transatlantic Trade and Investment Partnership (TTIP) Agreement. The firm heterogeneity module predictions of welfare changes in the United States are distinctly different from those predicted by the standard GTAP model. This is explained by the endogenous productivity and variety effects implied by the firm heterogeneity theory. Results also suggest that the choice of policy instrument is an important factor in determining which one of these effects dominates in the final welfare outcome. This dissertation introduces the first implementation of firm heterogeneity into the standard GTAP model which I hope will serve as a powerful tool for policy analysis with improved abilities in tracing out the productivity changes and entry/exit of firms following trade liberalization episodes.

CHAPTER 1. OVERVIEW

As globalization continues to bring countries together, international trade gains momentum and new trade challenges begin to emerge. There is a worldwide convergence of interests on policies that would address those modern trade problems. The Transatlantic Trade and Investment Agreement (TTIP) and the Transpacific Partnership Agreement (TPP) are two major examples of ongoing efforts to design new international trade policies which will have significant implications for global welfare and the global trade architecture (Petri et al., 2012; ECOYRS, 2009; CEPR, 2013). The ability to accurately predict the outcomes of these international trade policies will help improve policy designs and potentially increase worldwide economic gains.

Computable General Equilibrium (CGE) models are essential computational tools used extensively in trade policy analysis (Devarajan S. and Robinson, 2002). They facilitate policy analysis by laying out the main mechanisms that govern trade-induced economic changes in a tractable fashion. The traditional approach in CGE studies is to model trade based on the Armington (1969) assumption of national product differentiation. While this approach has provided many insights into static welfare effects of trade policies as well as other economic outcomes, it also has significant limitations in explaining the firm-level information prevalent in the recent international trade literature.

Stylized facts documented in this literature show that (i) there is significant heterogeneity across firms with respect to their products, productivities, markets they serve, costs they incur etc. (Eaton et al., 2004); and (ii) exporting is a rare event accomplished by only a small subset of firms that are larger and more productive than non-exporters (Bernard and Jensen, 1999; Bernard et al., 2003; Bernard and Jensen, 2004). The pioneering work of Melitz (2003) has provided a modeling framework that can explain those empirical findings by consideration of firm heterogeneity. This novel trade model gives new insights about the underlying mechanisms at play in trade liberalization scenarios where trade improves aggregate productivity by stimulating efficient firms to expand into export markets while simultaneously forcing inefficient firms to exit the industry. This results in a unique productivity channel through which trade affects welfare.

Armington-based CGE models fail to capture these important firm-level mechanisms. As a result, they do not account for trade growth due to changes in the number of varieties traded, i.e. extensive margin, or account for productivity growth due to compositional changes within the industry. Consequently, welfare predictions of Armington-based CGE models can be inaccurate. Incorporating the firm heterogeneity theory into Armington-based CGE models can overcome those shortcomings and strengthen computational policy analysis.

There have recently been some efforts to incorporate Melitz (2003) into CGE modeling (Zhai, 2008; Dixon et al., 2015; Balistreri et al., 2011; Balistreri and Rutherford, 2012; Oyamada, 2013). While each of these studies illustrate the workings of firm heterogeneity in computational policy analysis under stylized models, a readily accessible, policy-oriented CGE model has not been made available yet. The Global Trade Analysis Project (GTAP) provides an Armington-based CGE model often used by policy makers and research institutions. In order to improve its explanatory power and versatility, it is highly desirable to incorporate the firm heterogeneity theory into the GTAP model.

Implementing firm heterogeneity into GTAP is a multi-dimensional task which requires not only a working multi-region, multi-sector CGE model but also a theoretically-consistent parameterization. Pinning down the structural parameters is paramount for policy analysis, as quantitative results heavily depend on parameter values. However previous firm heterogeneity CGE models have often used Armington elasticities that are not appropriate in a firm heterogeneity model (Dixon et al., 2015). The traditional gravity equation that delivers Armington elasticities do not control for the impact of firm self-selection into export markets which is the main micro mechanism for productivity and variety induced gains from trade. In the absence of firm behavior the resulting coefficient estimates confound the demand-side effects with the supply-side effects resulting in inaccurate elasticities. In order to be consistent with the underlying firm heterogeneity theory, there is a need for new elasticity parameters that distinguish between the demand-side and supply-side effects.

This dissertation contributes to the international trade literature by addressing the above issues through the incorporation of firm heterogeneity into the GTAP model, the determination of parameter values consistent with the underlying theory, and an application of the developed module to policy analysis based on a case study in the context of TTIP.

Chapter 2 presents the modeling and implementation of firm heterogeneity theory in the GTAP model. The new mechanisms are illustrated with a stylized scenario in which a tariff removal policy is analyzed. Switches between different model specifications are incorporated to allow for comparisons with the results from a monopolistically competitive model based on Krugman (1980) and a perfectly competitive model based on the Armington (1969) assumption of national product differentiation. The results are contrasted with the monopolistically competitive and perfectly competitive GTAP modules. This comparison shows that incorporation of firm heterogeneity allows for additional economic forces to come into play. In particular, in addition to the traditional allocative efficiency and terms of trade effects of Armington as well as the variety and scale effects of monopolistic competition, the theory of firm heterogeneity incorporates endogenous productivity effects to welfare change.

Chapter 3 explores a host of issues related to the parameterization of the newly proposed firm heterogeneity model. A method to obtain structural parameters that are theoretically consistent with firm heterogeneity models is presented with a focus on the elasticity of substitution across varieties. The intensive and extensive margins of trade are distinguished in a multi-sector, multi-country firm heterogeneity model resulting in two estimating equations. The elasticity of substitution consistent with the theory of firm heterogeneity is obtained based on these equations and the shape parameter estimates of Spearot (2015). Results show that the elasticity values that are consistent with the firm heterogeneity theory are considerably lower than Armington elasticities used in the standard GTAP model.

Chapter 4 mobilizes the model of Chapter 2 and the parameters of Chapter 3 in an applied policy analysis study that focuses on the hormone ban imposed by the European Union (EU) on beef imports from the United States (US) in the context of TTIP negotiations. The ban on hormone-treated beef sales in the EU has become a critical issue in the debate over the rules and regulations concerning agricultural trade policies. Chapter 4 investigates the implications of a possible reduction of this ban by using two alternative policy instruments: fixed export costs and tariff equivalents of the hormone ban. A unique aspect of this study is that it takes firm-level heterogeneity and extensive margin effects prevalent in the monopolistically competitive beef market into account. Important productivity and variety effects are observed under firm heterogeneity which results in different welfare implications of the same policies compared to the Armington-based GTAP model.

CHAPTER 2. INTRODUCING FIRM HETEROGENEITY INTO THE GTAP MODEL

2.1 Introduction

Traditional Computable General Equilibrium models (CGE) rely on the Armington (1969) assumption of national product differentiation (e.g. GTAP) to distinguish preferences between domestic and imported products. Changes in trade flows in these models are conditioned by pre-existing trade shares; therefore, they can only capture the trade adjustments that occur due to changes in export volumes. This is at odds with the empirical trade literature that highlights the contribution of new varieties in export markets to explain the expansion of trade following trade liberalization episodes (Hummels and Klenow, 2005; Chaney, 2008). The firm heterogeneity trade model proposed in the pioneering work of Melitz (2003) combines trade volume changes with expanding varieties as a result of trade liberalization by capturing the self-selection of firms into export markets based on their respective productivity levels. The resulting framework is solidly supported by empirical evidence (Eaton et al., 2004; Bernard et al., 2006). Including firm-level heterogeneity in CGE models can improve their ability to trace out trade and welfare implications of trade policies which were previously unexplored in traditional models.

There have recently been some important efforts to incorporate Melitz (2003) into CGE modeling (Zhai, 2008; Dixon et al., 2015; Balistreri et al., 2011; Balistreri and Rutherford, 2012; Oyamada, 2013). However, a readily accessible GTAP implementation with firm heterogeneity has not yet become available. Our paper addresses this gap by incorporating firm heterogeneity into the GTAP model, calibrating it to the GTAP Data Base V8 (Narayanan et al., 2012) and illustrating this framework with a stylized scenario. A comparison with the Armington-based standard GTAP model, as well as a GTAP-based model of monopolistic competition allows us to shed light on the new elements which the Melitz model brings to bear on trade liberalization impacts.

One of the stylized facts shown by micro-level data is that there is significant variation across firms of the same industry. In particular, firms vary by their productivity, size, profitability, the number of markets served and responses to trade shocks (Bernard et al., 2003; Eaton et al., 2004; Bernard et al., 2007; Balistreri et al., 2011; Melitz and Trefler, 2012). Moreover, only some firms export and they tend to be larger and more productive than non-exporters (Balistreri et al., 2011; Bernard et al., 2003; Bernard and Jensen, 1999). These stylized facts are captured by Melitz (2003) who examines the intra-industry reallocation effects of international trade in the context of a model with monopolistic competition and heterogeneous firms. In his framework, opening the economy to trade or increasing the exposure to trade generates a redistribution of production across firms within the industry based on the productivity differences of firms. In particular, firms with higher productivity levels are induced to enter the export market; firms with lower productivity levels continue to produce for the domestic market and the firms with the lowest productivity levels are forced to exit the industry. These inter-firm reallocations generate a growth in the aggregate industry productivity which increases the welfare gains of trade. This channel is a unique feature of the firm heterogeneity model (Zhai, 2008). The main premise of the Melitz model is that aggregate productivity can change even though there is no change in a countrys production technology. As opposed to the allocative efficiency gains in the firm heterogeneity model, aggregate productivity changes in traditional trade models with homogeneous firms and Armington assumption are brought about by changes in firm-level technology.

Melitz (2003) builds on Krugmans (1980) monopolistic competition framework to model trade; while it draws from Hopenhayn (1992) to model the endogenous self-selection of heterogeneous firms. Likewise, we build on Swaminathan and Hertels (1996) monopolistically competitive GTAP model where variety effects (changes in the number of firms and hence distinct varieties offered) and scale effects (changes in output per firm) are captured. We draw from the work of Zhai (2008) in modeling certain features of firm heterogeneity such as teasing out productivity thresholds for market entry and calibration of fixed export costs, etc. This allows us to endogenize aggregate productivity in the monopolistically competitive sectors of the model, thereby capturing the intra-industry reallocation of resources in the wake of trade liberalization.

In contrast to Zhai (2008) we assume endogenous firm entry and exit. This extension allows tracing out the direct effect of changes in the productivity threshold on entry and survival in export markets. Another simplification in Zhai (2008) is the assumption of no sunk-entry costs of production in the monopolistically competitive industry. In contrast, our model incorporates fixed entry costs following Swaminathan and Hertel (1996), we assume that fixed costs are only comprised of value added inputs which are calibrated using the zero profits condition. An additional contribution of our model is the decomposition of the welfare implications of trade policy. This is an extension of the existing GTAP welfare decomposition (Huff and Hertel, 2000), which now includes, in addition to allocative efficiency and terms of trade effects, scale, variety, and endogenous productivity effects derived from the firm heterogeneity model.

In addition to the firm heterogeneity model, we also explore other model structures to highlight how trade policy impacts differ across various frameworks. These include monopolistically competitive GTAP model motivated by Krugman (1980) and perfectly competitive GTAP model motivated by the standard GTAP model with Armington (1969) assumption. Occasionally, we refer to them as Armington (1969) and Krugman (1980) models. However, the reader should keep in mind that even though these GTAP modules are motivated by Armington (1969) and Krugman (1980), they do not exactly follow the same structure as these seminal works. We bring the main features of these theories into applied work. In addition, we make some changes where necessary since numerical implementation of highly theoretical models requires making additional assumptions and extensions to the original structure.

The rest of the paper is organized as follows: Section 2.2 provides a brief introduction to the theory of firm heterogeneity. Section 2.3 details the implementation of firm heterogeneity theory into the standard GTAP model. Section 2.4 describes the data requirement for the firm heterogeneity model. Alternative closure rules for model switches are discussed in Section 2.5. Section 2.6 illustrates this framework with a stylized trade liberalization scenario. Section 2.7 concludes the paper.

2.2 Main Mechanisms in Firm Heterogeneity Theory

In this framework, we assume that there can be two types of industries: monopolistically competitive industries with heterogeneous firms that produce differentiated varieties and perfectly competitive industries with identical firms that produce homogeneous products which are assumed to be differentiated only at national scale. The characteristics of the standard GTAP model industries are retained in the perfectly competitive industries where a representative firm produces at constant returns to scale technology. The characteristics of firms in the monopolistically competitive industry, on the other hand, are quite different than the standard GTAP model and this warrants a detailed discussion concerning the treatment of production, cost, and especially productivity at the firm level.

The presence of firm heterogeneity in an industry is characterized by a continuum of firms each producing a unique variety that is an imperfect substitute in demand to other varieties. Therefore, in what follows we use firms and varieties interchangeably. While firms are free to enter or exit, entering the market requires covering fixed costs that are associated with expenses made during initial development of the differentiated variety. The existence of fixed costs is a large impediment for start-up firms; however, it also creates potential scale economies in the monopolistically competitive industry. Until each firm makes a commitment to enter the industry and pays these fixed costs, there is no information about their efficiency. Hence firms are assumed to be identical before entering the industry. Once they enter, their productivity levels are revealed and we observe that productivity is heterogeneous across firms within the industry.

In this context, productivity is defined as how much a firm can produce per composite input. It is inversely related to the marginal cost of production; therefore, a high-productivity firm is the one producing a similar variety at a lower marginal cost which follows from the simplification of Melitz (2003). Firm productivity is assumed to be identically and independently distributed with productivities following the Pareto distribution. Each firm draws its productivity out of this distribution and finds out where they stand on the productivity spectrum.

Once they know their productive capabilities, firms are now able to choose whether or not to operate in the market. The decision to produce depends on the potential for making profits given the productivity of the firm and the fixed costs they have already incurred. Firms are assumed to face symmetric fixed costs, while they differ with respect to their productivity. Thus, production is carried out only by firms that are productive enough to afford staying in the market given the fixed costs. High-productivity firms have a better chance of survival since they produce more output and earn higher profits by charging a lower price compared to less productive firms in the market. The competition in the market, therefore, forces low-productivity firms to exit and high-productivity firms to expand their market shares.

Where does trade stand in this framework? Once a firm secures its niche in the domestic market, it has the choice to supply foreign markets as well as satisfying home demand. The decision to export or not has its own challenges. Just as firms incur fixed costs to start producing, they incur fixed costs to start exporting. Fixed export costs are destination specific. They may arise due to expenses associated with distinguishing the firm's variety to make it compatible with regional standards in the destination market. In addition, they may be associated with the expenses of finding local dealerships or doing market research on the rules and regulations of exporting into specific destinations. For example, automobile companies incur the costs of redesigning certain features of their models in order to meet the needs of consumers in the destination market. The battery pack and the number of rows of seating in Prius 2010 differ between the European and Japanese markets. Another example can be the keyboard requirements of personal computers in different regions. A Dell sold in the Japanese market has a different keyboard design than the same Dell sold in the US market because consumers speak different languages.

Independent of their nature, the very existence of fixed export costs is the reason why not all firms export and why firms self-select into export markets based on their respective productivity levels. This mechanism works through the endogenous determination of the productivity threshold to export. Only the firms with productivity levels equal to or higher than this threshold find it profitable to supply that specific market. Hence the distribution of firms is such that while the most productive firms serve in the export markets, firms with lower productivity levels supply only the domestic market, and the lowest-productivity firms do not produce.

Self-selection of firms, first into the domestic market, then into export markets is a unique mechanism in the firm heterogeneity model and offers additional gains from trade due to improvements in industry productivity through inter-firm reallocation of resources. This is a channel that was previously unexplored in trade models. In conventional theory, trade leads to inter-sectoral reallocation of resources with scarce resources shifting towards the more profitable industry. However, in firm heterogeneity, competition for resources also occurs within the industry where high-productivity firms expand their market share and absorb the factors released by low-productivity firms. The expansion of high-productivity firms together with the exit of low-productivity firms in the face of trade liberalization, increases the productivity of the industry on average, generating additional gains from trade.

Everything we have said so far is based on the fact that productivity levels of firms are assumed to be constant. Of course, one could argue that trade also leads to 'learning by exporting' so that firms become more productive as they export. This is plausible and there is a vast literature on the very issue of causality of productivity and exporting, i.e. whether firms self-select into export markets due to their initial productivity levels, or rather firms become more productive as they export. However, as with Melitz (2003), we abstract from endogenous changes in firm productivity levels in this framework.

2.3 Modeling Framework of Firm Heterogeneity in GTAP

This section describes the theoretical structure of firm heterogeneity and its implementation into the standard GTAP model. In this paper, we follow the conventions that were used in previously published work in an effort to facilitate the comparison of our methodology with other Melitz-type CGE models. In addition we explicitly show how to bring the theory into GEMPACK (Harrison and Pearson, 1996) by providing code snippets where applicable. The definition of variables and value flows used in the code is presented in Table A.1.

2.3.1 Production Structure

In this section we offer a brief introduction to the production technology in the firm heterogeneity module of GTAP. Similar to the standard model, production in the monopolistically competitive industry is modeled based on a nested structure which is laid out in Figure 2.1. There are two parts to Figure 2.1: (i) on the left, panel A, we show the modeling of fixed costs and (ii) on the right, panel B, we show the production tree. We should note that not all the branches in this figure represent a nest. Particularly, only the solid lines specify a nest, while the dashed lines specify a market clearing condition. This will become clear as we explore the production structure further below.

The key characteristic that distinguishes production technology in this industry from the perfectly competitive one is the difference between the variable and fixed component of costs. Following Swaminathan and Hertel (1996), we assume that a portion of the value-added inputs of heterogeneous firms are devoted to cover fixed costs and intermediate inputs are not used in this process. These assumptions warrant a brief discussion about the nature of fixed costs explored in this work. As we mentioned before, in order to differentiate their varieties for domestic and export markets, firms invest in research and development as well as market research and advertising. Each of these activities require the employment of labor or capital. Particularly, the equipment used in the research and development lab is considered as capital, while the firm hires labor to advertise their products in foreign markets. A point to note here is that land

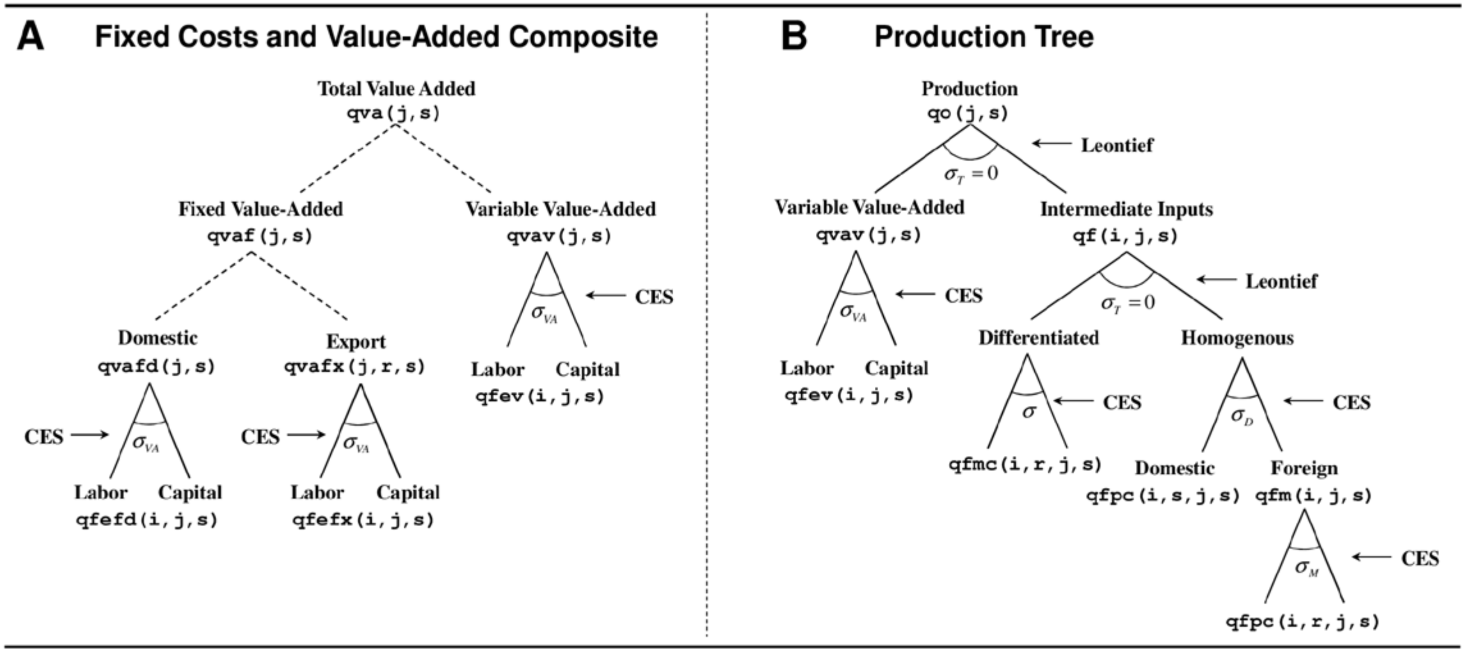

Figure 2.1. Production Structure in the Monopolistically Competitive Industry with Firm-level Heterogeneity where `i` $\in$ `ENDW_COMM` for Endowment Inputs, `i` $\in$ `TRAD_COMM` for Intermediate Inputs, `j` $\in$ `MCOMP_COMM` for Monopolistically Competitive Industry, and `r,s` $\in$ `REG` for Regions.

is not part of the endowment factors that constitute fixed costs merely because land is only used in the production of unprocessed agricultural goods in GTAP and these goods are identical as long as they are not processed.

Due to the distinction between fixed and variable costs, total value-added composite, `qva(j,s)` in Figure 2.1, has two components: variable value-added, `qvav(j,s)`, and fixed value-added, `qvaf(j,s)`[1]. Variable value-added is used in the production of the differentiated variety and therefore is proportional to output. Demand for variable value-added increases as firms expand production. On the other hand, fixed value-added is incurred only once and is invariant to how much the firm produces.

The fixed value-added is further split into domestic and export components based on whether the primary factors are employed to cover fixed domestic costs, `qvafd(j,s)`, or fixed export costs, `qvafx(j,r,s)`. This is shown at the bottom level of the tree in Figure 2.1 where both domestic and export components of fixed value-added are produced by labor and capital according to a CES technology. The same applies to the variable value-added nest in production. An important thing to highlight is that substitution elasticity, σ_{VA} (`ESUBVA(j)` in GTAP), between labor and capital is identical in each of these nests since the labor/capital intensity in fixed and variable value-added composite are assumed to be the same (Swaminathan and Hertel, 1996). This simplifying assumption is largely based on the data availability pertaining to the composition of fixed costs as opposed to variable value-added.

Under certain conditions it can be more appropriate to consider research and development as more capital intensive and marketing as more labor intensive compared to production. In that case it becomes necessary to allow for varying labor/capital intensity across different components of the value-added composite. While this can be achieved in the current model with only minor modifications, it also requires industry-

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[1] Lower-case letters denote percentage change in the upper-case counterparts.

specific information that is currently not available in our data base. Therefore, in this study we restrict ourselves to the assumption of equal intensities.

The domestic and export composites determine the fixed value-added composite based on their respective weights in total fixed costs which then determine the total value-added bundle together with variable value-added composite according to their respective weights in total value-added costs. Note that this aggregation is not based on a production technology. It just adds up the total factor requirements which highlights that total value-added is either used as variable input in production or used as inputs to cover fixed costs of domestic and export markets.

Returning back to Figure 2.1B, we see that output is produced by a combination of the variable value-added and intermediate input composites at the top level of the production tree depending on a constant returns to scale technology. We should emphasize that the assumption of constant returns to scale technology in combining variable inputs does not mean that we abstract from potential scale economies. The existence of fixed costs generate internal increasing returns to scale in sales as firms expand production. Firms take advantage of falling average costs when they operate at a larger scale since each additional input brings about a more than proportional increase in output when fixed costs are present. Hence the economies of scale.

In the lower nest of Figure 2.1B, the intermediate input composite, `qf(i,j,s)`, is composed of differentiated and homogeneous goods. Each firm has the choice to use a differentiated variety, `qfmc(i,r,j,s)`, which is produced in the monopolistically competitive industry or a homogeneous product, `qfpc(i,r,j,s)`, which comes out of the perfectly competitive industry. We assume that there is no substitution between these inputs, i.e. $\sigma_T = 0$. For the homogeneous goods we retain the standard GTAP model assumption of domestic and import distinction where imports are sourced at the border. However, we also use the information on how much of the homogeneous intermediate inputs are actually sourced from particular exporters since the data base is transformed accordingly. A more detailed discussion about data transformation is provided in Appendix A.2. Contrary to homogeneous goods, there is no domestic and imports distinction for differentiated varieties; therefore, there is no additional nest to show their composition. Imported varieties are assumed to compete with domestic varieties at the market based on the corresponding elasticity of substitution, σ.

2.3.1.1 Markup Pricing

Representative firms operate under constant returns to scale in a perfectly competitive industry and set their prices equal to their marginal costs. However, firms in the monopolistically competitive industry are price setters for their particular varieties and can afford to set prices higher than their marginal costs. In particular, the optimal pricing rule for such firms is to charge a constant markup over their marginal costs. Let P_{ir} indicate the supply price of product i in the monopolistically competitive industry in region r, C_{ir} indicate the cost of the input bundle that is used for producing one unit of output in industry i of country r, and let $\widetilde{\varphi}_{ir}$ indicate the average productivity of industry i in region r. Optimal pricing in the monopolistically competitive industry is governed by:

$$P_{ir} = \frac{\sigma_i}{\sigma_i - 1} \frac{C_{ir}}{\widetilde{\varphi}_{ir}}, \tag{2.1}$$

where $\frac{\sigma_i}{\sigma_i - 1}$ gives the markup in industry i which is greater than one as $\sigma_i > 1$. This equation shows that the price set by the representative firm is higher than its marginal cost by the amount of the markup in the industry. Since we assume that the elasticity of substitution across varieties is constant, the markup charged by firms is also a constant. There is a negative relationship between the markup and the elasticity of substitution. As σ_i increases, varieties of the same product become more similar which reduces the power of the firm to charge a higher markup. Hence the markup decreases with the elasticity of substitution.

The second component in equation (2.1) is the marginal cost of the representative firm captured by the fraction $\frac{C_{ir}}{\widetilde{\varphi}_{ir}}$. Unit cost of production is normalized by the average productivity in order to account for the heterogeneity across firms and the resulting endogenous productivity changes in the industry. Equation (2.1) reduces to the familiar pricing rule of $P_{ir} = C_{ir}$ in the perfectly competitive industry since firms have identical productivity levels, i.e.$\widetilde{\varphi}_{ir} = 1$, and, do not have markup power.

Simplifying equation (2.1) and adopting GTAP notation, we obtain:

$$PS_{ir} = MARKUP_{ir} MC_{ir}, \tag{2.2}$$

where PS_{ir} is the supply price (excluding taxes and transportation costs), $MARKUP_{ir}$ is the constant markup which corresponds to $\frac{\sigma_i}{\sigma_i - 1}$, and MC_{ir} is the marginal cost which corresponds to $\frac{C_{ir}}{\widetilde{\varphi}_{ir}}$ in equation (2.1).

Since we assume that production occurs under constant returns to scale technology, average variable cost equals the constant marginal cost of production. Substituting the average variable cost, AVC_{ir} for MC_{ir} in equation (2.2) we obtain:

$$PS_{ir} = MARKUP_{ir} AVC_{ir}. \tag{2.3}$$

Total differentiation of (2.3) yields[2]:

$$ps_{ir} - avc_{ir} = markup_{ir} = 0 \tag{2.4}$$

---

[2] Lowercase letters denote percentage changes in the corresponding uppercase variables.

According to equation (2.4), changes in the producer price is directly proportional to changes in average variable cost at constant markup. We implement this in the code as:

```
Equation MKUPRICE
#markup pricing (with constant markup) in the monop. comp. ind. j in r#
(all,j,MCOMP_COMM)(all,r,REG)
    ps(j,r) = avc(j,r) + mkupslack(j,r) ;
```

where `ps(j,r)` is the price received by the firm in the monopolistically competitive industry j in region r, `avc(j,r)` is the average cost of production in industry j in region r, and `mkupslack(j,r)` is a slack variable which is exogenous in the closure. `Equation MKUPRICE` determines the level of output per firm. The slack variable is included in order to allow for alternative closures for different trade policy applications where firm-level output is not endogenous. For example, if we want to change the industry structure to perfect competition, we need to remove the effect of scale economies and fixed costs. This translates as constant output per firm and no markup. In the absence of fixed costs, $AVC = ATC = P$ which is ensured by zero profits condition. Hence `Equation MKUPRICE` is simply redundant. Therefore, we eliminate it by fixing output per firm and endogenizing `mkupslack(j,r)`. Firm-level output does not change in a competitive model and `mkupslack(j,r)` absorbs the difference between supply price and average variable cost. Since in a competitive model $AVC = ATC = P$, the value of `mkupslack(j,r)` will be close to zero in equilibrium. The use of slack variables is revisited in Section 2.5.

2.3.1.2 Productivity Draw of Firms

Firms are assumed to draw their productivity level, φ, from a Pareto distribution with probability density function, $g(\varphi)$, and the cumulative distribution function, $G(\varphi)$, expressed as:

$$g(\varphi) = \frac{\gamma}{\varphi}\Big(\frac{\varphi_{min}}{\varphi}\Big)^{\gamma}, \tag{2.5}$$

$$G(\varphi) = 1 - \Big(\frac{\varphi_{min}}{\varphi}\Big)^{\gamma}, \tag{2.6}$$

where φ_{min} indicates the lower bound of productivity and γ indicates the shape parameter. We assume that $\varphi \in [1, \infty)$ where the minimum productivity, φ_{min}, is one. The shape parameter, γ, is an inverse measure of the firm heterogeneity. A higher value means that the firms are more homogeneous, i.e. firms have similar cost structures. We assume that the relationship between the shape parameter and elasticity of substitution is such that $\gamma > \sigma - 1$. This condition is enforced to ensure that the size distribution of firms has a finite mean (Zhai, 2008). Let φ^* indicate the productivity threshold of producing in a specific market. In other words, it is the level of productivity required to enter the market. The proportion of firms that have higher productivity levels than the threshold is given by $1 - G(\varphi^*)$ which is governed by

$$1 - G(\varphi^*) = (\varphi^*)^{-\gamma}, \tag{2.7}$$

The firms that pass the threshold are actively participating in the destination-specific market. Hence, we can interpret equation (2.7) as the proportion of successful entry to the destination market, which is given as $\frac{N_{irs}}{N_{ir}}$ where N_{irs} is the number of firms in industry i that export from source r to destination s, and N_{ir} is the total number of firms that produce industry i of region r. We revisit the discussion about productivity threshold and firm entry/exit in the following sections.

2.3.1.3 Firm Profits: Productivity Threshold to Enter Markets

Each firm with productivity φ_{irs} makes the following profit from selling variety i on the $r-s$ market:

$$\pi_{irs}(\varphi) = Q_{irs}(\varphi)\frac{P_{irs}(\varphi)}{T_{irs}} - Q_{irs}(\varphi)\frac{C_{ir}}{\varphi_{irs}} - W_{ir}F_{irs}, \tag{2.8}$$

for all r, s where Q_{irs} is the sale of product i from source r to destination s, P_{irs} is the tax inclusive sale price of product i from r to s, $(P_{irs} = P_{ir}T_{irs})$, T_{irs} is the export tax/subsidy, C_{ir} is the unit price of the composite inputs, W_{ir} is the price associated with fixed costs and F_{irs} is the input demand for covering fixed costs of exporting from r to s. The first component, $Q_{irs}(\varphi)\frac{P_{irs}(\varphi)}{T_{irs}}$, gives the total revenue, the second component, $Q_{irs}(\varphi)\frac{C_{ir}}{\varphi_{irs}}$, gives the variable cost and the third component, $W_{ir}F_{irs}$, gives the fixed cost of exporting from r to s. Substituting the optimal demand and price for each variety, we obtain the maximized profit for each firm as follows:

$$\pi_{irs} = \frac{Q_{irs}P_{irs}^{\sigma_i}}{\sigma_i T_{irs}}\left[\frac{\sigma_i}{\sigma_i - 1}\frac{T_{irs}C_{ir}}{\varphi_{irs}}\right]^{1-\sigma_i} - W_{ir}F_{irs}. \tag{2.9}$$

Firms in industry i of region r export into region s as long as the variable profit they make covers the fixed cost of exporting. The firms with high productivity levels set a lower price with a higher markup, produce more output; thereby, earn positive profits. The only firm that exports on the $r-s$ link and makes zero profits is the marginal firm which has a productivity level equal to the productivity threshold. At that threshold, variable profit only covers the export costs; therefore, the firm makes zero economic profit. The condition that determines the zero-cutoff level of productivity for exporting from region r to s is:

$$\pi_{irs}(\varphi^*_{irs}) = 0. \tag{2.10}$$

Solving equation (2.10) yields the productivity threshold as:

$$\varphi^*_{irs} = \frac{C_{ir}}{\sigma_i - 1}\left[\frac{P_{irs}}{\sigma_i T_{irs}}\right]^{\frac{\sigma_i}{1-\sigma_i}}\left[\frac{W_{ir}F_{irs}}{Q_{irs}}\right]^{\frac{1}{\sigma_i-1}}. \tag{2.11}$$

Any firm that has a productivity level below φ^*_{irs} cannot afford to produce in that market, and therefore exits. On the other hand, any firm that has a productivity level above φ^*_{irs} expands its market share. Total differentiation of equation (2.11) yields:

$$\widehat{\varphi}^*_{irs} = c_{ir} + \frac{\sigma_i}{1-\sigma_i}(p_{irs} - t_{irs}) + \frac{1}{\sigma_i - 1}(w_{ir} + f_{irs} - q_{irs}). \tag{2.12}$$

Equation (2.12) shows that the change in cutoff productivity level depends on the change in unit cost of production, c_{ir} , change in price net of taxes and transportation costs, $p_{irs} - t_{irs}$, and change in fixed cost per sale, $w_{ir} + f_{irs} - q_{irs}$. The same equation is used to determine the productivity threshold for export markets as well as the domestic market with the only difference being the treatment of fixed costs. While fixed domestic costs are used for the domestic productivity threshold, fixed export costs are used to determine the export productivity threshold for export markets.

For the domestic market ($r = s$), equation (2.12) is implemented as:

```
Equation PRODTRESHOLDD
# productivity threshold for the domestic market #
(all,i,MCOMP_COMM)(all,r,REG)
aodt(j,r)
        =  sum{i,TRAD_COMM, SVC(i,j,r) * [pf(i,j,r) − af(i,j,r)]}
        + SVAV(j,r) * [pvav(j,r) − avav(j,r)]
        + [MARKUP(j,r)−1] * [fdc(j,r)−qs(j,r,r)]
        − MARKUP(j,r) * ps(j,r) + dthreshslack(j,r);
```

where `aodt(i,r)` is the productivity threshold for the domestic industry i in region r, `SVC(i,j,r)` is the share of intermediate input i in variable costs of j in r, `pf(i,r)` is the demand price for composite tradeable i by firms in industry j of region r, `af(i,r)` is the intermediate input i augmenting technical change in industry j of region r, `SVAV(j,r)` is the share of variable value-added cost in variable costs of j in r, `pvav(i,r)` is the demand price for composite variable value-added by firms in industry j of region r, `avav(i,r)` is the variable value-added augmenting technical change in industry j of region r, `fdc(i,r)` is the fixed cost of production for the domestic industry i of region r, `qs(i,r,r)` is the domestic sales of product i in region r, `ps(i,r)` is the supply price of product i in region r, and finally `dthreshslack(i,r)` is a slack variable that is exogenous in the closure.

Note that `fdc(i,r)` is a product of price and demand for fixed value-added composite. It is implemented in the code as:

```
Equation FIXEDDC
# fixed domestic costs to enter the monop. comp. industry i in r  #
(all,i,MCOMP_COMM)(all,r,REG)
    fdc(i,r) = pvafd(i,r) + qvafd(i,r);
```

where `pvafd(i,r)` and `qvafd(i,r)` are the composite price and demand that is associated with the domestic component of fixed value-added. As dictated by this equation, domestic fixed costs increase proportionately with associated price and demand for fixed factors.

Similar to the domestic market, the productivity threshold for each export market ($r \neq s$) is determined according to equation (2.12). It is implemented in the code as:

```
Equation PRODTRESHOLDX
# productivity threshold for the export market #
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
aoxt(j,r,s)
= [1 − DELTA(r,s)]
* {sum{i,TRAD_COMM, SVC(i,j,r) * [pf(i,j,r) − af(i,j,r)]}
+ SVAV(j,r) * [pvav(j,r) − avav(j,r)]
+ [MARKUP(j,r)−1] * [fxc(j,r,s)−qs(j,r,s)]
− MARKUP(j,r) * [pfob(j,r,s) + tx(j,r) + txs(j,r,s) + to(j,r)]}
+ xthreshslack(j,r,s);
```

where `DELTA(r,s)` is called the Kronecker delta which is equal to one when $r = s$. It is used in order to calculate the productivity threshold for export markets only.

`aoxt(i,r,s)` is the productivity threshold for exporting product i from the source region r to the destination market s, `SVC(i,j,r)` is the share of intermediate input i in variable costs of j in r, `pf(i,r)` is the demand price for composite tradeable i by firms in industry j of region r, `af(i,r)` is the intermediate input i augmenting technical change in industry j of region r, `SVAV(j,r)` is the share of variable value-added cost in variable costs of j in r, `pvav(i,r)` is the demand price for composite variable value-added by firms in industry j of region r, `avav(i,r)` is the variable value-added augmenting technical change in industry j of region r, `fxc(i,r,s)` is the fixed cost of exporting from r to s, `qs(i,r,s)` is the export sales of product i from region r to s, `pfob(i,r,s)` is the fob price of product i, `tx(i,r)` is the destination generic tax/subsidy, `txs(i,r,s)` is the tax/subsidy associated with exporting from r to s, `to(i,r)` is the output tax/subsidy, and finally `xthreshslack(i,r,s)` is a slack variable that is exogenous in the closure.

Similar to the domestic market, fixed export cost is a product of value added price and fixed value-added inputs. It is implemented in the code as:

```
Equation FIXEDXC
# fixed export costs in industry i to enter the export market s  #
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
    fxc(i,r,s) = pvafx(i,r,s) + qvafx(i,r,s);
```

where `pvafx(i,r,s)` and `qvafx(i,r,s)` are the composite price and demand that is associated with the export component of fixed value-added.

`Equation PRODTRESHOLDD` and `PRODTRESHOLDX` give us productivity thresholds at the firm-level for the domestic and export markets, respectively. There are two factors at play in these equations: (i) competition, and (ii) market access. Competition is a combined effect of the changes in average variable cost and prices. For example, an increase in average variable cost causes the firm to lose competitiveness against more efficient firms and makes it more costly to enter a new market. Hence it raises the productivity threshold for the domestic and export markets. This increase is somewhat reduced by the possibility of scale economies brought about by larger market access. For instance, in trade liberalization scenarios, as markets integrate firms gain access to a larger market. This increases the potential for exports and reduces fixed export costs per sale. As a result, productivity threshold declines.

The competition and market access effects determine the change in the productivity threshold and how different firms respond to this change. For low-productivity firms the competition effect dominates since their costs are too high to take advantage of bigger market access. Hence they exit the market. On the other hand, high-productivity firms benefit from the larger market and are able to expand their production and sales.

2.3.1.4 Average Productivity in the Industry

In equilibrium, only the firms that have productivity levels above the threshold, φ^*_{irs}, afford to supply the destination market s. Since only surviving firms matter for the industry, aggregate productivity is a weighted average of the productivity levels of the firms that make the cut. The distribution of productivity in equilibrium is given by

$$\mu(\varphi) = \begin{cases} \frac{g(\varphi)}{1-G(\varphi^*)} & \text{if } \varphi \geq \varphi^* \\ 0 & \text{otherwise} \end{cases} \tag{2.13}$$

where $g(\varphi)$ is the probability density of the productivity distribution. $\mu(\varphi)$ can be thought of as a conditional distribution of $g(\varphi)$ on $[\varphi^*, \infty)$ which refers to the productivity distribution of firms that are active in the market. This is another way of saying that average productivity of the industry depends only on successful entrants. Using this conditional distribution, average productivity is determined by:

$$\widetilde{\varphi}_{irs}(\varphi^*_{irs}) = \left[\int_{\varphi^*_{irs}}^{\infty} \varphi^{\sigma_i-1}\mu(\varphi)\mathrm{d}(\varphi)\right]^{\frac{1}{\sigma-1}}, \tag{2.14}$$

$$= \left[\frac{1}{1-G(\varphi^*_{irs})}\int_{\varphi^*_{irs}}^{\infty} \varphi^{\sigma_i-1}g(\varphi)\mathrm{d}(\varphi)\right]^{\frac{1}{\sigma_i-1}}, \tag{2.15}$$

where $\widetilde{\varphi}_{irs}$ is a CES weighted average of firm productivity and the weights reflect the relative output shares of firms with different productivity levels. Substituting φ^*_{irs} in and using the probability density of Pareto distribution, the average productivity equation reduces to:

$$\widetilde{\varphi}_{irs}(\varphi^*_{irs}) = \varphi^*_{irs}\left[\frac{\gamma_i}{\gamma_i-\sigma_i+1}\right]^{\frac{1}{\sigma_i-1}}, \tag{2.16}$$

where $\gamma_i > \sigma_i - 1$. Total differentiation of equation (2.16) yields:

$$\widehat{\widetilde{\varphi}}_{irs} = \widehat{\varphi}^*_{irs}, \tag{2.17}$$

where $\widehat{\widetilde{\varphi}}_{irs}$ is the percentage change of average productivity of firms that are active on the $r-s$ market and $\widehat{\varphi}^*_{irs}$ is the percentage change in the threshold for exporting product i from r to s. According to Equation (2.17) there is a one-to-one mapping between the productivity threshold and average productivity in the market. We use Equation (2.17) to determine the average productivity in the domestic market and export markets separately.

For the domestic market ($r = s$):

```
Equation AVEPRODD
# average productivity for the domestic market#
(all,i,MCOMP_COMM)(all,r,REG)
    aod(i,r) = aodt(i,r);
```

where `aod(i,r)` is the average productivity in the domestic market. For the export market ($r \neq s$),

```
Equation AVEPRODX
# average productivity for the export market#
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
    aox(i,r,s) = aoxt(i,r,s);
```

where `aox(i,r,s)` is the average productivity in the export market. Average productivity in each market contributes to the overall industry efficiency depending on their relative importance for the industry sales. Aggregate industry productivity is then simply a weighted average of average productivity in the domestic and export markets. It is implemented in the code as:

```
Equation AOHET
# computes aggregate productivity of the monop. comp. industry with
het. firms #
(all,i,MCOMP_COMM)(all,r,REG)
    ao(i,r) = SHRSMD(i,r,r) * aod(i,r)
            + sum(s,REG, SHRSMD(i,r,s) * aox(i,r,s))
            + prodslack(i,r);
```

where `ao(i,r)` is the percentage change in the aggregate productivity of industry i in region r, `SHRSMD(i,r,r)` is the share of domestic market in total sales, and `SHRSMD(i,r,s)` is the share of each export market in total sales. According to `Equation AOHET`, aggregate productivity rises with an increase in average productivity in the domestic or export markets. Moreover, an increase in the share of domestic or export markets in total sales also boosts aggregate productivity in the industry.

A point to note here is that `ao` in `Equation AOHET` only captures the changes in industry productivity due to changes in the market share of firms. A positive `ao` does not mean that the firms are getting more productive. Rather the expansion in the market share of high-productivity firms improves the efficiency of the industry on average. In other words, it means that more productive firms constitute a larger part of the market than before.

2.3.2 Endogenous Entry and Exit

In this section, we examine the zero profit condition of the industry and the endogenous entry/exit of firms. Each firm in the monopolistically competitive industry produces a differentiated variety that gives them a market power over their unique product. Hence firms have the potential to make positive profits in each market conditional on their productivity levels and the fixed costs they face. This attracts new firms into the industry. As new firms operate in the market, profits of existing firms decline. Firm entry continues until there are profits to make in the market. Therefore, at the industry level, free entry fully exhausts all the potential profits until the zero profit condition in the industry is restored in equilibrium. Hence the total number of firms in the industry is endogenous and is determined by the zero profits condition which is sometimes referred as the ”entry condition”. Conversely, if firms make losses, the movement is out of the industry as firms exit. This continues until all the firms in the industry make zero profits.

2.3.2.1 Industry Profit: Zero Profit Condition

Total industry profit is composed of each active firm’s profit from operating in the domestic market and selling in export markets. The profit of the representative firm in each export market is governed by equation (2.8). Aggregating over all available sales markets, equation (2.8) becomes

$$\sum_s \Pi_{irs} = \sum_s \left[\frac{Q_{irs}P_{irs}}{(1+t_{irs})} - \frac{Q_{irs}C_{ir}}{\widetilde{\varphi}_{irs}} - W_{ir}F_{irs} \right]. \tag{2.18}$$

Expression (2.8) relates export profits to the revenue generated by exporting, $\frac{Q_{irs}P_{irs}}{(1+t_{irs}}$, variable costs of production, $\frac{Q_{irs}C_{ir}}{\widetilde{\varphi}_{irs}}$, and fixed export costs incurred in each export market $W_{ir}F_{irs}$. At the industry level, only the successful entrants contribute to total profits. Therefore, equation (2.18) needs to be adjusted by the number of active firms. However, note that each new firm also incurs sunk entry costs to begin production. These costs need to be included in the calculation of industry profits, as well. Let H_{ir} be the component of value-added composite that is used on fixed domestic costs for each successful entry in industry i and N_{ir} be the total number of firms in the industry. Then industry profit is given by

$$\Pi_{ir} = \sum_{s} N_{irs} \left[\frac{Q_{irs} P_{irs}}{(1 + t_{irs})} - \frac{Q_{irs} C_{ir}}{\widetilde{\varphi}_{irs}} - W_{ir} F_{irs} \right] - N_{ir} W_{ir} H_{ir}. \tag{2.19}$$

Note that in order to obtain the total profit made in each market, we simply multiply the profit of the representative firm with the number of active firms. This ease in aggregation follows from average productivity. As discussed in Melitz (2003), the aggregate outcome of an industry with N representative firms, i.e. firms that have identical productivity levels $\widetilde{\varphi}$, is the same as the aggregate outcome of an industry with N firms of any distribution of productivity levels $\mu(\varphi)$ that yields the same average productivity level $\widetilde{\varphi}$.

There is free entry and exit in the monopolistically competitive industry. Therefore, all the potential profits are exhausted as firms enter the market. Conversely, all the potential losses are recovered as firms exit. Entry/exit continues until the marginal firm in the industry makes zero profits which means that the industry profit is zero in equilibrium. Implementing this condition in equation (2.19), we obtain the zero profit condition for the industry as follows:

$$\sum_{s} \frac{N_{irs} Q_{irs} P_{irs}}{(1 + t_{irs})} = \sum_{s} \frac{N_{irs} Q_{irs} C_{ir}}{\widetilde{\varphi}_{irs}} + \sum_{s} N_{irs} W_{ir} F_{irs} + N_{ir} W_{ir} H_{ir}. \tag{2.20}$$

Equation (2.20) determines the total number of firms in the industry, N_{ir}, as firms enter/exit to satisfy the zero profit condition. We rewrite expression (2.20) using GTAP notation as follows:

$$\begin{aligned} VOA(j,r) = &\sum_{i \in TRAD} VFA(i,j,r) + VAV(j,r) \\ &+ \sum_{s \in REG} VAFX(j,r,s) + VAFD(j,r), \end{aligned} \tag{2.21}$$

where $VOA(j,r)$ is the value of output in industry j of region r, $VFA(i,j,r)$ is the value of purchases of intermediate input i demanded in industry j of region r, $VAV(j,r)$ is the value of purchases of variable value-added composite purchased by industry j in region r, $VAFX(j,r,s)$ is the value of fixed costs associated with exporting product j from source r to destination s, and $VAFD(j,r)$ is the value of fixed costs associated with entering the domestic market j in region r. These value flows correspond to specific components in equation (2.20). For example, $VOA(j,r)$ is the total cost of production and exporting which is equal to total revenue generated by selling in all available markets. Therefore, it corresponds to the components $\sum_s \frac{N_{irs}Q_{irs}P_{irs}}{(1+t_{irs})}$ in equation (2.20). Similarly, j, $\sum_{i \in TRAD} VFA(i,j,r) + VAV(j,r)$ is the total variable cost of production which corresponds to $\sum_s \frac{N_{irs}Q_{irs}C_{ir}}{\widetilde{\varphi}_{irs}}$ in equation (2.20). Finally, $\sum_{s \in REG} VAFX(j,r,s)$ corresponds to fixed export costs aggregated over all markets given by $\sum_s N_{irs}W_{ir}F_{irs}$ and $VAFD(j,r)$ corresponds to total sunk-entry costs in the industry given by $N_{ir}W_{ir}H_{ir}$ in equation (2.20).

Total differentiation of Equation (2.21) and use of the Envelope Theorem yields:

$$\begin{aligned}
VOA(j,r)\,ps(j,r) = &\sum_{i \in TRAD} VFA(i,j,r)\,[pf(i,j,r) - af(i,j,r)] \\
&+ VAV(j,r)\,[pvav(j,r) - avav(j,r)] + VAF(j,r)\,pvaf(j,r) \\
&- VAFD(j,r)\,[qof(j,r) + avafd(j,r)] \\
&- \sum_{s \in REG} VAFX(j,r,s)\,[qox(j,r,s) + avafx(j,r,s)] \\
&- VC(j,r)\,ao(j,r), \qquad (2.22)
\end{aligned}$$

where $VAF(j,r)$ is the total cost of fixed value-added in industry j of region r, $pvaf(j,r)$ is the demand price of fixed value-added in industry j of region r, $VAFD(j,r)$ is the fixed domestic cost of production in industry j of r, $qof(j,r)$ is output per firm in industry j of region r, $avafd(j,r)$ is the fixed value-added augmenting technical change in the domestic industry j of region r, $VAFX(j,r,s)$ is the bilateral fixed cost of exporting product j from source r to destination s, $qox(j,r,s)$ is output per exporting firm in industry j, $avafx(j,r,s)$ is the fixed value-added augmenting technical change in export markets. For details of this derivation we refer the reader to the appendix A.1. Equation (2.22) relates output price to output per firm and factor prices. The important difference between this zero profit condition from that in a perfectly competitive market is the effect of per firm output. Everything else constant, as output per firm increases, the difference between price and average total cost at constant scale declines.

Equation (2.22) is implemented in the code as:

```
Equation ZEROPROFITSMC
# zero pure profits condition for firms in the monopolistically comp
industry #
(all,j,MCOMP_COMM)(all,r,REG)
    VOA(j,r) * ps(j,r)
```

```
= sum{i,TRAD_COMM, VFA(i,j,r) * [pf(i,j,r) - af(i,j,r)]}
+ VA(j,r) * pva(j,r) - VAV(j,r) * avav(j,r)
- VAFD(j,r) * [qof(j,r) + avafd(j,r)]
- sum(s,REG, VAFX(j,r,s) * [qox(j,r,s) + avafx(j,r,s)])
- VC(j,r) * ao(j,r) + VOA(j,r) * profitslackmc(j,r) ;
```

where `profitslackmc(j,r)` is the exogenous slack variable which allows for alternative closures. For instance, if there is no entry/exit in the industry, the number of firms is fixed. In that case, the industry profit may be positive in the short-run. This is captured in the closure by allowing the slack variable to be non-zero, i.e. endogenizing `profitslackmc(j,r)`.

2.3.2.2 Number of Firms in the Domestic and Export Markets

This section focuses on two different free entry conditions: (i) domestic and (ii) export market. As mentioned in section 2.3.2.1, entry/exit of firms in the industry is determined by the zero-profit condition. In fact, the zero-profit condition together with the markup equation dictates the change in output per firm, `qof(j,s)`, which then determines the change in the total number of firms in the industry. This closely follows from Swaminathan and Hertel (1996).

Total output in the industry is a product of output per firm and the number of active firms in the industry given by:

$$Q_{ir} = N_{ir}\tilde{Q}_{ir}, \tag{2.23}$$

where N_{ir} is the total number of firms snd $\tilde{Q}_{ir}$ is the output of the representative firm in the monopolistically competitive industry. We assume that each firm produces the same amount of product. Total differentiation of equation (2.23) yields:

$$q_{ir} = n_{ir} + \tilde{q}_{ir}. \tag{2.24}$$

Equation (2.24) is implemented in the code as:

```
Equation INDOUTPUT
# industry output in the monopolistically competitive industry #
(all,j,MCOMP_COMM)(all,r,REG)
    qo(j,r) = qof(j,r) + n(j,r) ;
```

According to `Equation INDOUTPUT` if output per firm rises less than the industry output, new firms enter the industry to ensure that the zero-profit condition in the industry is restored. On the other hand, if output per firm rises more than the industry output, then some firms must be forced out of the industry.

Entry and exit of firms in the domestic market is based on the interaction between the industry and the representative firm. The export market is a little different. It depends directly on the productivity threshold of the export market. Given the productivity distribution, the number of firms that successfully export is given by:

$$N_{irs} = N_{ir}[1 - G(\varphi^*_{irs})], \tag{2.25}$$

where N_{irs} is the number of firms that export product i from region r to s, and $[1 - G(\varphi^*_{irs})]$ is the proportion of firms that are active in the export market. This representation recognizes that not all firms in industry i are able to export on the particular $r - s$ link. Among all the firms in the industry only the firms that pass the threshold productivity level of exporting are able to enter the export market, given the productivity distribution.

Assuming that the productivity distribution is Pareto, Equation (2.25) becomes:

$$N_{irs} = N_{ir}(\varphi^*_{irs})^{-\gamma_i}. \tag{2.26}$$

Total differentiation yields:

$$n_{irs} = n_{ir} - \gamma_i(\varphi^*_{irs}), \tag{2.27}$$

where γ_i denotes the shape parameter of Pareto distribution. It is implemented in the code as:

```
Equation NXFIRM
# number of active firms in export markets #
(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
    nx(i,r,s) = n(i,r) - SHAPE(i) * aoxt(i,r,s) + entryslack(i,r,s);
```

According to `Equation NXFIRM`, if the productivity threshold for the marginal firm in the export market increases, the firms that do not make the cut are forced to exit the market. This is, of course, based on the heterogeneity of the particular industry which is captured by the shape parameter of Pareto distribution. Recall that γ_i is an inverse measure of heterogeneity. Therefore, as γ_i increases, productivity becomes more uniform and firms become more homogeneous. This means that firms in the same industry now have more similar cost structures. In a more homogeneous industry, more firms must exit the export market given a constant productivity threshold and a constant mass of firms since there are more firms with similar productivity levels.

2.4 Calibration of Fixed Costs

We use GTAP data base V8 (Narayanan et al., 2012) for the illustrative experiments in this paper. There are several changes we made to the standard GTAP data base to make it compatible with the requirements of the firm heterogeneity module. The most fundamental change is the transformation of the data base to account for sourcing of imports by agents which follow from the monopolistically competitive industry structure. In this context, consumers make a decision between many varieties of the same good which are slightly different from each other. Hence the choice is between different brands such as Honda versus Hyundai as opposed to a car sourced in Japan versus one sourced in South Korea. Therefore, in contrast to the import-domestic distinction in the standard data base where composite imports are imperfect substitutes for the domestic commodity, imported varieties compete directly with domestic ones in the firm heterogeneity module. In addition, imports are sourced by the agent in the transformed data base which means that we distinguish between the purchases of imported varieties of private households from that of firms and government. These changes follow from Swaminathan and Hertel (1996) and we outline the details in Appendix A.2.

There is additional information required for the firm heterogeneity model which is not available in the standard GTAP data base. These include elasticity of substitution between varieties, shape parameter of Pareto distribution, and data for fixed costs. Table 2.1 presents the parameters used in this model.

Table 2.1. Parameters of the Firm Heterogeneity Model.

Industry	Model	Elasticity of Substitution across Varieties, $\boldsymbol{\sigma}$	Shape Parameter of Pareto Distribution, $\boldsymbol{\gamma}$
Manufacturing	FH	6.96	7.75
Non-Manufacturing	PC	6.60	6.20

Notes: FH: Firm heterogeneity, PC: Perfect Competition
Source: GTAP Data Base V8 Narayanan et al. (2012) and Zhai (2008).

For the elasticity of substitution, we adopt the values of the Armington elasticity for our particular aggregation in the GTAP data base V8 (Narayanan et al., 2012), i.e. `ESUBM` in GTAP. Note that these have been estimated using cross-section variation in trade costs. For the shape parameter of Pareto distribution, we use the values provided in Zhai (2008) where the shape parameter is calibrated to match the profit ratio in total markup. While the parameter values are taken from the literature, fixed costs are calibrated to the GTAP data base. In this model, we need information for two types of fixed costs: domestic and export. For fixed export costs we follow the calibration in Zhai (2008). In particular, we use a gravity equation which determines the bilateral trade flows. For fixed domestic costs we adopt an indirect approach. First we calibrate total value of fixed costs in the industry following the treatment of Swaminathan and Hertel (1996). Fixed domestic costs are, then, the difference between total fixed costs and fixed export costs aggregated over all markets.

As explained before, value added costs are composed of a fixed, `VAF(i,r)`, and a variable, `VAV(i,r)`, portion. Initial value for the fixed component of value-added is calibrated by using the mark-up pricing rule. It follows that fixed cost is proportional to total cost with a proportionality constant of $\frac{1}{\sigma_i}$:

```
formula (all,i,MCOMP_COMM)(all,r,REG)
VAF(i,r) = VOA(i,r) * [1 / SIGMA(i,r)]};
```

Fixed costs decrease with the elasticity of substitution. As preferences become more homogeneous, i.e. higher σ_i, demand for variety is lower which reduces the need for differentiating the product. Therefore, firms cut down the budget on R & D leading to lower fixed costs. In the extreme case where products are perfect substitutes, i.e. perfect competition with σ_i approaching ∞, fixed costs reduce to zero since all value-added is allocated to production of the identical variety.

The rest of the value-added costs, `VA(i,r)`, are attributed to variable value-added, `VAV(i,r)`, which are used in the production process as follows:

```
formula (all,i,MCOMP_COMM)(all,r,REG)
VAV(i,r) = VA(i,r) − VAF(i,r);
```

Recall that in the firm heterogeneity model, fixed value-added cost, `VAF(i,r)`, is split into two parts: (i) fixed domestic cost, `VAFD(i,r)`, and (ii) fixed export cost, `VAFX(i,r,s)`. The initial value of the fixed export costs is calibrated to the base year bilateral trade flows following Zhai (2008). Fixed costs are proportional to trade flows which is reflected in the calibration as follows:

$$N_{irs} W_{ir} F_{irs} = \frac{P_{irs} Q_{irs}}{T_{irs}} \frac{\gamma_i - \sigma_i + 1}{\sigma_i \gamma_i}. \tag{2.28}$$

The left-hand side in equation (2.28), $N_{irs}W_{ir}F_{irs}$, gives the fixed cost of exporting good i from source r to destination s aggregated over all firms that are active in that market. The right hand side has two components. The first one, $\frac{P_{irs}Q_{irs}}{T_{irs}}$, gives the total revenue of exporting good i from r to s which equals total cost of exporting that particular good to market s. The second component, $\frac{\gamma_i-\sigma_i+1}{\sigma_i\gamma_i}$, is a proportionality constant that depends on preferences and the heterogeneity of the industry. As preferences become more homogeneous, i.e. higher σ_i, firms have little incentive to invest in differentiating their varieties because the markup gets smaller. As a result, fixed export costs decrease with the elasticity of substitution. Similarly, a higher shape parameter, i.e. less heterogeneity across firms, reduces fixed costs of exporting.

This calibration is implemented in the code as:

```
Formula (initial)(all,i,MCOMP_COMM)(all,r,REG)(all,s,REG)
    VAFX(i,r,s) = [1 - DELTA(r,s)]
                * VSMD(i,r,s)
                * [SHAPE(i) - SIGMA(i) + 1] / [SHAPE(i) * SIGMA(i)]} ;
```

where `DELTA(r,s)` is the Kronecker delta which is equal to one when $r = s$. Once fixed export costs are calibrated, fixed domestic cost is obtained as the difference between total fixed costs and fixed export costs aggregated over all markets. It is implemented in the code as follows:

```
Formula (all,i,MCOMP_COMM)(all,r,REG)
    VAFD(i,r) = VAF(i,r) - sum(s,REG, VAFX(i,r,s));
```

2.5 Closure: Differences across Armington, Krugman, and Melitz Specifications

So far we have focused on how to introduce firm heterogeneity theory into the standard GTAP model. In order to discuss the additional insight offered by this framework, we also explore monopolistically competitive GTAP model motivated by Krugman (1980) and perfectly competitive GTAP model motivated by the standard

GTAP model with Armington (1969) assumption. A comparison between Armington (1969), Krugman (1980) and Melitz (2003) in CGE models is warranted since the industry structures they adopt are extremely different. In an applied CGE work, it is important to choose the specification which best matches the industry in question.

The research on this front is still active and there is increasing evidence supporting the relative strengths of each mechanism depending on the industry, initial conditions and the trade policy being explored. Especially, the ongoing work by Dixon et al. (2014) highlights the connections between these three structures and allows for nesting between them. Motivated by this approach, we allow for comparisons across firm heterogeneity, monopolistic competition and perfect competition by using closure swaps. We start with the firm heterogeneity module of GTAP and impose certain restrictions to derive the monopolistically competitive module of GTAP. We should note that, unlike Krugman (1980), we retain the difference between fixed export costs and fixed domestic costs in the monopolistic competition structure. Finally, further restrictions on the model delivers the perfectly competitive module of GTAP.

In order to determine which assumptions need to be imposed on the firm heterogeneity module to retrieve monopolistic competition or perfect competition, we first need to outline the key differences across them. The formulation based on the Krugman (1980) theory assumes the industry to be monopolistically competitive with fixed setup costs where identical firms produce differentiated varieties. Krugman (1980) theory differs from Melitz (2003) on two fronts: (i) there are no fixed costs associated with exporting, (ii) firms are identical with respect to their productivity levels which means that all producing firms are active in all destination markets. In contrast, we observe endogenous productivity changes in the firm heterogeneity module and the number of firms in export markets are a subset of the total firms in the industry. In order to reduce the firm heterogeneity module to the monopolistically competitive one we need to remove the endogenous productivity changes. This is achieved by setting the productivity thresholds as well as the aggregate productivity as exogenous. This also ensures the equality between the number of exporting firms and total firms through equation (2.25).

The slack variables we have in the governing equations in the TABLO code come in handy at this point. Our first objective is to shut down the endogenous productivity thresholds which are determined in Equations `PRODTRESHOLDD` and `PRODTRESHOLDX`. This is achieved by the swap command as follows:

```
swap aoxt(MCOMP_COMM,REG,REG) = xthreshslack(MCOMP_COMM,REG,REG);
swap aodt(MCOMP_COMM,REG) = dthreshslack(MCOMP_COMM,REG);
swap ao(MCOMP_COMM,REG) = prodslack(MCOMP_COMM,REG);
```

This command ensures that the productivity threshold in the domestic market and export markets, `aodt(MCOMP_COMM,REG)` and `aoxt(MCOMP_COMM,REG,REG)` are exogenous, while the slack variables in those markets are endogenous, `xthreshslack(MCOMP_COMM,REG,REG)`, `dthreshslack(MCOMP_COMM,REG)`. With exogenous productivity thresholds the marginal firm no longer makes zero profits from selling in the market. The zero profit condition of the marginal firm is restored by the endogenous slack variables which absorb the accumulating profit of the marginal firm. In addition, this closure rule has further implications for the number of exporting firms. Since there is no change in the productivity threshold of exporting and firms are assumed to have identical productivity, the changes in the number of exporting firms is equal to the changes in the number of total firms in the industry governed by equation (2.25).

As a result of constant productivity thresholds, we do not observe any changes in the average productivity in the domestic market or in export markets according to equation (2.12). Needless to say their contribution to changes in aggregate productivity is also zero based on equation (2.17). Aggregate productivity is automatically exogenous since the components that determine it are exogeneous by the closure. Although it seems redundant to add this as a condition in the closure we retain it in order to allow for alternative closure possibilities.

We impose further restrictions to the monopolistically competitive module to obtain the Armington-based perfect competition module. The formulation based on the Armington assumption entails the standard GTAP model assumptions of perfect competition, and constant returns to scale, where a representative firm produces identical products with identical productivity. Since there is no product differentiation, there are no fixed costs associated with production in this framework. Neither the firm, nor the industry makes positive profits. The key difference between the Krugman and Armington-based trade model is twofold: (i) the products are identical therefore we do not observe the love-of variety in demand, and (ii) there are no fixed costs associated with production in the perfectly competitive industry ; therefore, there are no economies of scale. Hence the two things we need to do in order to reduce the model to the Armington-based perfect competition module is to shut down the love-of-variety effect and the scale economies. This is achieved by imposing the following closure rule:

```
swap vp(MCOMP_COMM,REG,REG) = vpslack(MCOMP_COMM,REG,REG);
swap vg(MCOMP_COMM,REG,REG) = vgslack(MCOMP_COMM,REG,REG);
swap vf(MCOMP_COMM,REG,REG) = vfslack(MCOMP_COMM,REG,REG);
swap qof(MCOMP_COMM,REG) = mkupslack(MCOMP_COMM,REG);
```

The first three swap operators remove the impact of changes in the available varieties in consumer demand by setting the variety indexes as exogenous and the associated slack variables as endogenous. We should highlight that this does not mean that there is no change in the number of firms in the industry. Output variations in the industry is accommodated by the variation in firm numbers. However, these changes no longer create a love-of-variety effect due to the closure rule we imposed.

The last swap operator addresses the issue of increasing returns to scale by removing scale economies. In a perfectly competitive market with no fixed costs, there is no wedge between average total cost and average variable cost which means that $AVC = ATC = P$. As a result, the markup equation becomes redundant and the associated slack variable, `mkupslack`, is set to be endogenous in the closure. Moreover, in a competitive market all output expansion occurs by adding more identical firms at constant costs. Therefore, output per firm remains fixed in the closure.

2.6 Policy Application

In this section, we investigate the behavioral characteristics of the firm heterogeneity module of GTAP and compare it with that of perfect and monopolistic competition modules in the context of a tariff removal scenario. The numerical implementation of these highly theoretical models are carried out by a stylized model which provides a more transparent interpretation of results.

Our model is calibrated to GTAP data base V8 (Narayanan et al., 2012) for 2007. We aggregate the data base to 3 regions: USA, Japan and ROW; and 2 commodities: manufacturing and non-manufacturing. The manufacturing sector is treated as monopolistically competitive with heterogeneous firms, while the non-manufacturing sector retains the perfect competitive structure with Armington assumption. The policy experiment is to eliminate the tariffs levied by Japan on the import of US manufacturing goods, which is a 3.66% decrease in the power of tariffs imposed on US manufactures.

Simulation results for the three models are presented in Table 2.2. In the first three sub-sections, we focus on analyzing the additional insight obtained from the tariff removal scenario in the firm heterogeneity module (FH). Then, we move on to comparing them to that of monopolistic (MC) and perfect (PC) competition modules. We conclude the policy analysis by offering a brief discussion of welfare implications.

2.6.1 Impacts on the US

The direct effect of tariff removal is a reduction in the price of US manufactures in the Japanese market by 3.69% which is accompanied by an increase in sales of US manufactures in Japan by 67.35%. This significant rise in Japanese demand for US manufactures diverts sales from the home and ROW markets (-0.21% and -2.01%, respectively). These results constitute a familiar narrative of the immediate effect of tariff removal in an exporting region.

Additional insights can be gained from examining endogenous firm entry/exit and productivity changes. Regarding the former, Table 2.2 shows that the total number of firms in the US manufacturing industry declines by 0.26%. This loss of variety is due to an increase in output per firm relative to total output. As per firm production increases faster than industry output, there is no need for all firms to continue producing. Therefore, some firms exit the market and the total number of firms in the US manufactures industry decreases. In order to learn more about which firms cease to exist, we need to take a closer look at the marginal firm and the productivity changes in the industry.

Figure 2.2A shows the percentage change in productivity thresholds for each US export destination and percentage change in the number of exporting firms. We observe that the productivity threshold to produce in the US manufacturing industry increases by 0.15%. A higher threshold means that the productivity level of the marginal firm that was able to produce for the home market in the pre-tariff cut US economy, is now too low to make zero profits given the associated variable and fixed costs of production. In fact, US manufacturing firms face a more intense foreign competition in the home

Table 2.2. Simulation Results for the Manufacturing Sector under Armington, Krugman, and Melitz-like Structures where `j` ∈ `MCOMP_COMM` for Monopolistically Competitive Industry, and `r,s` ∈ `REG` for Regions.

Variable	Notation in Code		Model								
			FH			MC			PC		
			USA	JPN	ROW	USA	JPN	ROW	USA	JPN	ROW
Export Sales (%)	`qs(j,r,s)`	USA	-0.211	67.353	-2.007	-0.126	26.899	-0.560	-0.133	26.903	-0.565
		JPN	2.690	-0.549	1.917	1.541	-0.408	1.067	1.517	-0.425	1.047
		ROW	0.954	-5.687	0.010	0.452	-1.537	-0.007	0.449	-1.529	-0.006
Industry Output (%)	`qo(j,r)`		0.091	0.042	-0.011	0.035	-0.054	-0.002	0.028	-0.072	-0.001
Supply Price (%)	`ps(j,r)`		-0.032	-0.479	-0.057	0.065	-0.190	-0.019	0.065	-0.175	-0.019
Average Variable Cost (%)	`avc(j,r)`		-0.032	-0.479	-0.057	0.065	-0.190	-0.019	0.061	-0.181	-0.018
Scale Constant Average Total Cost (%)	`scatc(j,r)`		0.019	-0.362	-0.069	0.069	-0.186	-0.019	0.065	-0.175	-0.019
Number of Varieties (%)	`n(j,r)`		-0.264	-0.776	0.071	0.001	-0.085	-0.001	0.028	-0.072	-0.001
Number of Exporting Firms (%)	`nx(j,r,s)`	USA	-0.264	32.915	-1.781	0.001	0.001	0.001	0.028	0.028	0.028
		JPN	-0.441	-0.776	-0.865	-0.085	-0.085	-0.085	-0.072	-0.072	-0.072
		ROW	0.714	-3.086	0.071	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Output per Firm (%)	`qof(j,r)`		0.356	0.824	-0.081	0.034	0.031	-0.001	0	0	0
Output per Exporting Firm (%)	`qox(j,r,s)`	USA	0.356	-24.696	1.906	0.034	0.034	0.034	0	0	0
		JPN	0.485	0.824	0.915	0.031	0.031	0.031	0	0	0
		ROW	-0.719	3.173	-0.081	-0.001	-0.001	-0.001	0	0	0
Productivity Threshold for the Domestic Market (%)	`aodt(j,r)`		0.150	0.438	-0.033	0	0	0	0	0	0
Productivity Threshold for Export Markets (%)	`aoxt(j,r,s)`	USA	0	-3.638	0.198	0	0	0	0	0	0
		JPN	-0.043	0	0.012	0	0	0	0	0	0
		ROW	-0.083	0.414	0	0	0	0	0	0	0
Aggregate Productivity (%)	`ao(j,r)`		0.115	0.339	-0.031	0	0	0	0	0	0
Terms of Trade (%)	`tot(r)`		0.136	-0.313	0.025	0.103	-0.180	-0.007	0.100	-0.164	-0.011
Welfare Change ($US millions)	`EV(r)`		12159	8390	-12442	2758	-1509	-856	2354	-1191	-739

Note: FH: Firm Heterogeneity, MC: Monopolistic Competition, PC: Perfect Competition market after the tariff cut in Japan. As factors of production become more expensive in the US due to higher foreign demand, domestic firms become less competitive against cheaper imports coming from Japan and the ROW. As a result, US firms lose sales in the home market by 0.21%. This makes production even more costly for the US firms since the fixed domestic costs they face are spread over fewer output. In other words, the sunk entry cost per domestic sale increases by 0.18%. Consequently, low-productivity firms incur negative profits and the productivity threshold for the domestic market increases in the US, forcing them out of the market. Only the firms that are more productive than the new threshold level survive and expand their market share.

This is an example of inter-firm reallocation of resources within the industry as more-productive firms absorb the factors released form the exiting firms while gaining a larger share of the home market. Firm exit continues until the zero profit condition of the industry is satisfied again, which happens when the total number of varieties decline by 0.26%.

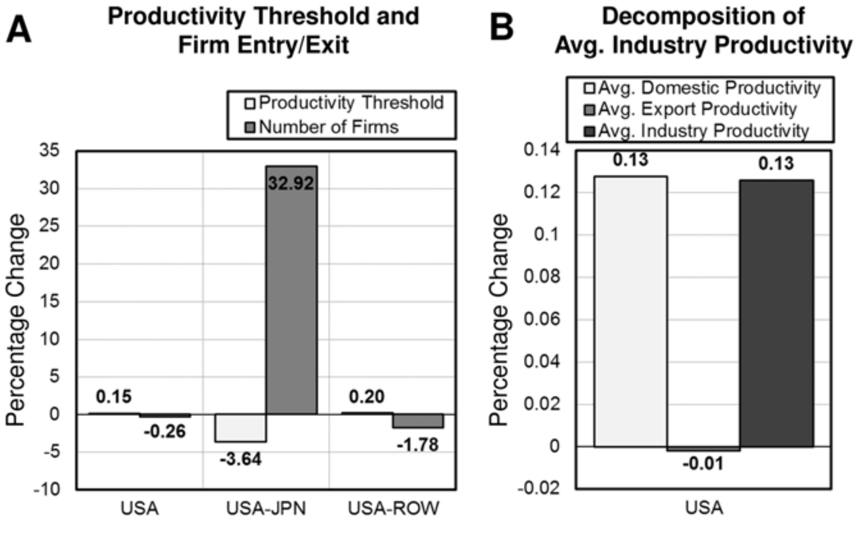

Figure 2.2. Productivity Threshold, Firm Entry/Exit and the Decomposition of Industry Productivity in the US.

Within industry firm reallocation extends to export markets through the shifts in bilateral productivity thresholds. In particular, the tariff cut in Japan lowers the productivity threshold for US manufacturing firms exporting into the Japanese market by 3.64% as depicted in Figure 2.2A. Unlike in the home market case, the marginal firm on the export threshold benefits from this tariff cut since its productivity level is now considered low enough to make positive profits by exporting to Japan. Same applies to the mass of firms that are below the pre-tariff cut threshold, but above the post-tariff cut one.

There are two factors at play for US manufacturing firms exporting into Japan: (i) competitiveness, and (ii) bigger market access. As mentioned above, US manufacturing firms are less competitive in domestic and ROW markets due to higher factor costs. On the other hand, the tariff cut allows US firms to be more competitive in the Japanese market and take advantage of bigger market access. As a result, sales to Japan rise by 67.35% which lowers fixed export cost per sale by 34.13%. This significant drop in fixed cost per exports raises the potential for positive profits and induces a rise in the number of US firms exporting into the Japanese market by 32.92%.

It is appealing to think that higher competitiveness and bigger market access should benefit all US firms by creating positive profits. However, in practice, the impact of the tariff cut on each firm is different depending on the firm's pre-existing cost structure. In the case of low-productivity firms, the impact of higher competition on firm profits dominates since their costs are too high to take advantage of bigger market size. Facing negative profits in the Japanese market, high-cost firms do not export to Japan, but continue to produce for the domestic market. On the other hand, firms with productivity levels above the new threshold are competitive enough to make use of the larger market. Therefore, they start exporting to Japan. Entry into the Japanese market continues until all potential profits from exporting are exhausted.

As a result, even though there are less manufacturing firms in total, more of them export to Japan.

Importantly, even though the new exporters have higher productivity levels compared to non-exporters, they are relatively less productive than the existing exporters. As a result, the lower productivity threshold reduces average productivity in export markets. In order to determine the average exporter productivity, the productivity of exporters to the ROW are also taken into account. As depicted in Figure 2.2A, there is an increase in the productivity threshold for exporting into the ROW market by 0.20%, which in return generates a drop in the number of exporters by 1.78%. Compared to the Japanese market, this is a rather low response rate which is less effective in shaping the average productivity in export markets.

The overall effect on aggregate productivity of the manufacturing industry is shown in Figure 2.2B where the percentage change in the industry productivity is decomposed into average productivity in home and export markets depending on the respective shares of home and export markets in total sales. We observe that the rise in share-weighted domestic productivity by 0.13% dominates the decrease in share-weighted export productivity of 0.01%. This is due to the fact that home market has a much bigger share in sales compared to export markets. Therefore, aggregate productivity in the US manufacturing industry increases by 0.13%. This is purely a gain of inter-firm reallocation within the manufacturing industry.

2.6.2 Impacts on Japan

Impacts of tariff removal on the Japanese economy are presented in Table 2.2 and Figure 2.3. We observe that increasing competition by US firms crowds out Japanese firms from the market and causes a drop in domestic sales by 0.55%.

Although some firms are replaced by US competitors in the home market, surviving Japanese firms benefit from the cheap US manufactures. There is, in fact, a large increase in the demand for intermediate inputs sourced from the US, a 66.62% rise in the manufacturing industry demand and a 67.94% rise in the non-manufacturing industry demand for US manufactures. Lower prices for intermediate inputs reduce the average cost of production in Japan by 0.48%. This is good news for the high-productivity Japanese exporters. In particular, Japanese exports to the US and ROW markets rise by 2.69% and 1.92%, respectively. As Japanese exporters face larger markets, their fixed export cost per sale declines. This together with the declining average variable costs, leads to reductions in productivity threshold of exporting to US as depicted in Figure 2.3A.

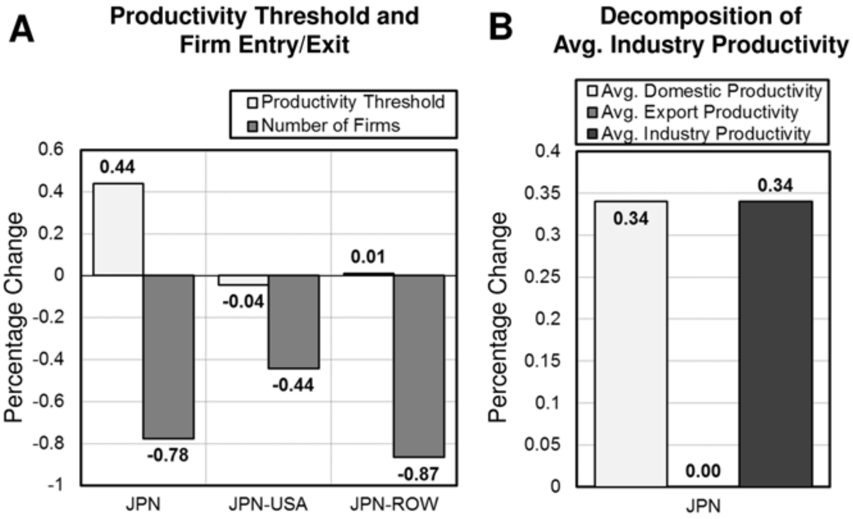

Figure 2.3. Productivity Threshold, Firm Entry/Exit and the Decomposition of Industry Productivity in Japan.

Even though the threshold is now lower, the number of exporters to the US market drops by 0.44% since there are fewer firms in the Japanese manufacturing industry. In fact the total number of manufacturing firms in Japan decreases by 0.77%. On the other hand, the productivity threshold of exporting into the ROW market increases since prices are too low for exporters to profit from higher sales. The higher threshold reduces the number of exporters to the ROW market by 0.87%. Note that despite many Japanese firms exit the export markets, total sales to the US and ROW actually increase. This is merely due to the expansion of high-productivity firms. As less productive exporters exit, high-productivity firms expand and export more to the US and ROW markets.

Similar to the loss of Japanese varieties in export markets, the home market also suffers from the loss of domestic varieties. As is shown in Figure 2.3A, the productivity threshold of producing in the domestic market increases by 0.44%. This change is largely caused by rising fixed costs. Even though firms enjoy lower factor costs, the loss of sales in the domestic market raises fixed cost per domestic sale leading to a decrease in their profits in the face of intensified competition in the home market. In the meantime, the scale of the firms increase by 0.82% which makes the low-productivity firms redundant in the industry given the small increase in manufacturing production. As a result, less productive firms are forced to exit the domestic market, while more productive firms survive and expand.

Like in the US, tariff removal reallocates market share by shifting resources towards more productive firms improving the aggregate productivity in Japan. This is highlighted in the decomposition depicted in Figure 2.3B. Average productivity in the domestic market rises by 0.34% overcompensating for the 0% change in the average productivity of export markets. Consequently, industry productivity rises by 0.34%.

Overall, tariff liberalization improves the industry efficiency not only in the US, but also in Japan. This is a good example of the importance of within industry reallocation of firms in facilitating trade through international supply chains.

2.6.3 Impacts on the ROW

The impact of this tariff cut on the ROW is less pronounced when compared to other regions. Figure 2.4A summarizes the percentage change in productivity thresholds and firm entry/exit in ROW.

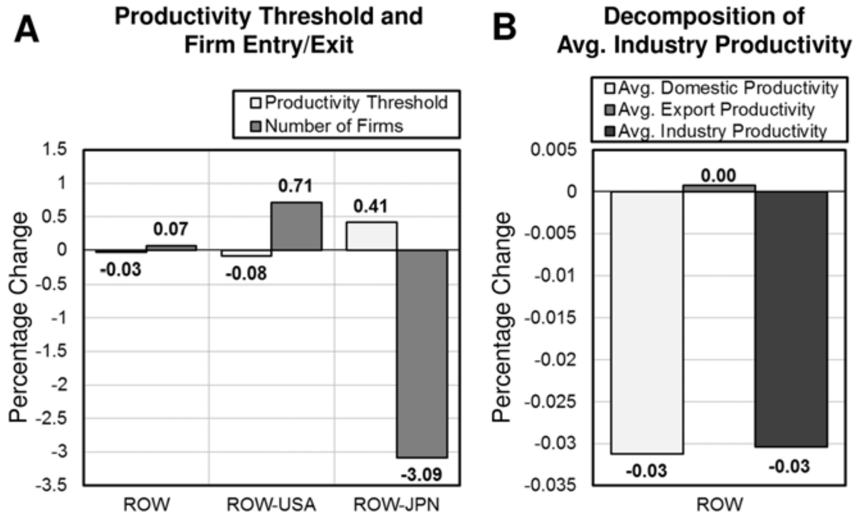

Figure 2.4. Productivity Threshold, Firm Entry/Exit and the Decomposition of Industry Productivity in the ROW.

The most striking change is observed in the trade between ROW and Japan. The productivity threshold for exporting into Japan increases by 0.41% which is largely a result of the US competition. Demand for ROW manufactures in the Japanese market is displaced by US varieties leading to a drop in the number of ROW exporters by 3.09%. While there is some trade diversion in the Japanese market, exports into the US market rises by 0.95%. There is a slight decrease in the productivity threshold by 0.08% which raises the number of ROW exporters into US by 0.71%. Finally, contrary to US and Japan, the ROW market experiences a decline in the domestic productivity threshold by 0.03%. Lower productivity threshold together with declining scale of firms attract less productive firms into the manufacturing industry. The total number of firms increase by 0.07% until all the potential profit is eliminated in the market restoring the zero profit condition.

Figure 2.4B shows the decomposition of aggregate productivity into average productivity in domestic and export markets. Contrary to the previous cases, the decomposition shows that average productivity in the domestic market has a negative contribution to aggregate productivity while that of the export markets has a positive contribution. Since the domestic market has a larger share in overall demand, the contribution of domestic average dominates. Consequently, aggregate productivity in the ROW manufactures sector declines by 0.03%. In practical terms, this is a negligible change and likely indistinguishable from zero. However, its negative sign shows that firm reallocation in the ROW is opposite of the experiences in Japan and US. In particular, the tariff cut leads to a loss of efficiency in the industry where low productivity firms expand their share in the domestic market.

2.6.4 Comparison across different Model Specifications

We start with firm heterogeneity and successively restrict the model to yield simpler forms, such as monopolistic and perfect competition. Then, we explore the same tariff removal scenario between the US and Japan in the context of each model. Table 2.2 reports the findings. A quick look at the results from each model illustrates that the firm heterogeneity model captures the changes that occur in a conventional CGE model with the Armington assumption. Moreover, it includes the effect of changes in varieties as well as economies of scale delivered by the monopolistically competitive structure and still incorporates a unique productivity channel that is linked with factor reallocation across firms within the same industry.

The implications on production, prices, costs and sales are mostly similar across these models. In monopolistic and perfect competition, bilateral trade between US and

Japan rises; the manufacturing sector expands in the US, while it contracts in Japan; the cost of production increases in the US, while it decreases in Japan. Contrary to US and Japan, changes in the ROW are negligible in each model. A striking difference in the firm heterogeneity model is the declining cost of production in the US. This is mainly due to the increase in aggregate industry productivity. As the share of high-productivity firms in the industry increases with the tariff-cut, industry productivity rises which reduces the average variable cost as well as the supply price in the US.

Even though the direction of change in most of the variables is similar across models, the amount of change is magnified in the firm heterogeneity module given the substitution parameter[3]. This is especially true for trade between US and Japan. While US exports to Japan rises by 26.90% in the monopolistically competitive model, it rises by 67.35% in the firm heterogeneity model. This is almost a threefold increase in the trade response. In contrast, when we compare the export changes in the monopolistically competitive model to the perfectly competitive one, we see that they are quite similar in magnitude. This suggests that the contribution of expanding varieties in firm heterogeneity is bigger than that of the monopolistically competitive model. In fact, we observe that while the number of US firms exporting into Japan increases by 0.001% in monopolistic competition, it increases by 32.92% in firm heterogeneity. This striking difference is a consequence of the self-selection of firms into export markets.

The monopolistic competition model dictates that if a firm produces, it also exports into all destination markets. This is reflected in the results reported in Table 2.2. The

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[3] We should note that Melitz (2003) tends to magnify the effects of Armington (1969) for a given value of the trade substitution parameter. This result should not be generalized to the case where the substitution parameters in Armington (1969) and Melitz (2003) are chosen to be different. For example, Dixon et al. (2014) argue that welfare implications are close if the Armington (1969) and Melitz (2003) elasticities are chosen so that the models give the same trade responses.

percentage change in the number of exporters in each market, `nx(j,r,s)`, equals to the percentage change in the number of total varieties `n(j,r)`. However, it does not take the specific circumstances of each firm and each destination into account. Once we factor in the heterogeneity of productivity across firms, we observe that not all firms are able to export into all destinations. In fact, the number of US exporters increase in Japan, while it declines in the ROW in contrast to the monopolistically competitive model which predicts an equal increase in exporters to all destinations.

Another different result in firm heterogeneity is the effect of tariff cut on the number of total varieties in the US. Even though total number of firms in the US increases by 0.001% in monopolistic competition, it decreases by 0.26% in firm heterogeneity. This is due to the relative changes in firm scale compared to industry output. In firm heterogeneity, per firm output increases by 0.36% which exceeds the increase in total industry output and leads to the exit of low-productivity firms. On the other hand, in monopolistic competition, the relative increase of firm scale, 0.034%, is lower than total industry output, 0.035%, which means that new US firms enter the domestic market.

2.6.5 Welfare Effects

There is, currently, no consensus in the literature on the welfare implications of the Melitz model compared to those from traditional models with the Armington assumption. In order to do accurate policy analysis in a CGE setting, we need to understand how these models differ. Are there additional gains from trade that we are not accounting for when we choose one model over the other? If there are, do they matter in the overall welfare response? Do they contribute to aggregate welfare? These questions are getting more attention in the CGE world as traditional models do not provide satisfying explanations for the changes in welfare in the face of trade policies. There is a growing literature that explores these questions in the context of CGE models.

In related work, welfare changes in the Melitz (2003) model are found to be larger than the Armington (1969) benchmark (Balistreri et al., 2011; Kancs, 2010; Zhai, 2008). In fact, incorporating firm heterogeneity into standard CGE models raises the gains from trade liberalization by a multiple of two in Zhai (2008) and by a multiple of four in Balistreri et al. (2011). However, Arkolakis et al. (2008) argue that the impact of trade cost reductions is similar across models once their trade responses are equalized via the calibration of parameters. This argument suggests that the Melitz (2003) model does not offer additional gains from trade conditional on equal trade patterns. A similar finding is discussed by Dixon et al. (2014). Having started from an undistorted initial equilibrium, they observe that gains from productivity and preferences in firm heterogeneity offset each other which results in equal welfare change once the observed trade pattern is fitted with higher substitution elasticities in the Armington formulation.

In this paper, we explore three additional channels through which trade liberalization induces welfare changes in the firm heterogeneity module of GTAP. They can be summarized as: (i) productivity effect, (ii) love-of-variety effect, and (iii) scale effect. The productivity effect is described by Melitz and Trefler (2012) as a new source of gains from trade created by the reallocation of factors of production from less productive firms into more productive ones, thereby generating an improvement in the overall efficiency of the industry. The love-of-variety effect is the ability of the model to capture the trade growth due to expanding varieties and to link it with consumer utility. As new firms enter the market, more varieties are available to consumers contributing to the overall welfare. Kancs (2010) states that even though there are lost domestic varieties, the empirical findings in the literature show that consumers usually benefit from the trade policy. However, if we account for the preference bias, we see that the loss of domestic varieties are more highly valued since consumers like domestic varieties more than imported varieties. The scale effect is associated with increasing returns to scale technology. As the gap between average total costs and average variable costs widens, the scale of the firm expands generating additional gains from trade.

Table 2.3 provides a summary of regional welfare changes and decomposition in each model. From a quick look at the results, we observe that the tariff removal in Japan improves the welfare in the US, while it causes a welfare loss in Japan and the ROW in the monopolistic and perfect competition models. On the other hand, firm heterogeneity results show that not only the US, but also Japan gains from trade. Moreover, the welfare gain in US is much higher in firm heterogeneity. Digging deeper into the decomposition, we observe a quite different picture across model structures. While the perfectly competitive GTAP model only provides information about the classical terms of trade[4] and allocative efficiency effects, the firm heterogeneity model captures the additional information on variety, scale and productivity which have significant effects on the magnitude of the welfare change.

Exploring the welfare implications in the US, we observe that improvements in the efficiency of the manufacturing industry contributes positively to the welfare in US, \$6172 million. This is accompanied by the positive scale effect of \$2345 million. Scale effect in the firm heterogeneity model is determined by a combined effect of output per firm and output per exporting firm. We observe that lower export thresholds in the US leads to an increased number of exporters. However, they operate on a smaller scale which is welfare reducing. On the other hand, the domestic market is supplied by fewer US firms which operate on a larger scale increasing welfare. Since

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[4] The contribution of terms of trade is the combined effect of changes related to the terms of trade and the investment-saving balance.

Table 2.3. Welfare Decomposition of Tariff Removal under Armington, Krugman, and Melitz-like Structures: Equivalent Variation in millions of US$.

Model	**Region**	**Aggregate Welfare Effect**	**Allocative Efficiency Effects**	**Terms of Trade Effects***	**Variety Effects**	**Scale Effects**	**Productivity Effects**
FH	USA	12159	1014	3371	-742	2345	6172
	JPN	8390	880	-2636	-1396	3339	8202
	ROW	-12442	-1350	-737	-804	-2714	-6837
	Total	8107	544	-2	-2942	2970	7537
MC	USA	2758	287	2184	-16	303	0
	JPN	-1509	44	-1338	-341	125	0
	ROW	-856	150	-848	-123	-35	0
	Total	393	481	-2	-479	393	0
PC	USA	2354	254	2100	0	0	0
	JPN	-1191	25	-1217	0	0	0
	ROW	-739	146	-885	0	0	0
	Total	423	425	-2	0	0	0

Note: FH: Firm Heterogeneity, MC: Monopolistic Competition, PC: Perfect Competition

* Terms of trade effect includes the changes in investment-saving balance.

the drop in export scale is far below the rise in domestic scale. the overall impact is a welfare enhancing scale effect in the US. In contrast, the variety effect is negative, $742 million, as consumers suffer from a loss in domestic varieties. Even though US enjoys a wider selection of ROW varieties, the decreasing number of US varieties more than offsets this positive contribution. This confirms the home bias as loss in domestic varieties is more dominant in the final variety effect.

Contrary to monopolistic and perfect competition, Japan gains from this tariff removal scenario in the firm heterogeneity model. Similar to the US results, we see that the productivity effect derives the welfare change. Despite the negative terms of trade (-$2636 million) and variety effects (-$1396 million), the positive productivity ($8202 million) and scale effects ($3339 million) increase the welfare in Japan. Even though Japan benefits from expanding US varieties, the loss of domestic varieties as well as the ROW varieties dominate the variety effect.

The welfare loss in the ROW is much bigger compared to the Krugman and Armington cases. This is mostly due to the bigger negative impact of productivity. There is a small decline in the aggregate productivity of the manufacturing industry in the ROW which reduces the overall welfare ($6837 million). Contrary to the US and Japan, the scale effect is negative in the ROW ($2714 million) due to the smaller scale of firms in the domestic market as opposed to the bigger scale of exporters. The variety effect in the ROW is also negative ($804 million). It is largely driven by the declining varieties sourced from the US. Even though the number of domestic varieties increases, the drop in US varieties accompanied by the loss in Japanese varieties dominates the variety effect. This is mostly dictated by the loss of intermediate inputs used by ROW firms. Even though 95% of the intermediate input demand of ROW firms is met by domestic suppliers, the increase in the number of domestic varieties is no match for the decline in US and Japanese varieties supplied to the ROW. Hence the negative variety effect.

2.7 Concluding Remarks

In this paper we discuss how to implement monopolistic competition with firm heterogeneity into the GTAP model. Different from the standard GTAP model with Armington specification, the firm heterogeneity module includes the effect of new varieties in markets (extensive margin), the effect of scale economies, and the effect of endogenous productivity. We build on Zhai (2008) for firm heterogeneity; however, compared to his approach we incorporate endogenous firm entry/exit, and we distinguish between sunk-entry costs, and fixed export costs.

The model is calibrated to GTAP data base V8 (Narayanan et al., 2012). There are three pieces of information not contained in the GTAP data base V8 (Narayanan et al., 2012) that are needed in firm heterogeneity approach: (i) the elasticity of substitution between varieties, (ii) the shape parameter of the Pareto productivity distributions, and (iii) the magnitude of fixed costs. We use the Armington elasticity values in the GTAP data base for the elasticity of substitution across varieties, while we use the values provided in Zhai (2008) for the shape parameter. In order to calibrate fixed export costs, we adopt Zhai's (2008) approach of using a gravity model of trade based on bilateral trade flows. In order to calibrate total fixed costs we use the markup equation following Swaminathan and Hertel (1996). Model results in firm heterogeneity module depends on the choice of substitution elasticity and shape parameter. For future work, we aim to combine econometric work on model parameters with policy analysis to obtain more robust results.

To illustrate the behavioral characteristics of the model, we analyze the effects of eliminating Japanese tariffs on the import of US manufacturing goods under a three region - two sector aggregation. This is a highly stylized FTA scenario in TPP with the aim of laying out the mechanics of this Melitz-type GTAP model. We observe that productivity threshold for the US-Japan export market reduces mostly due to the reduction in fixed export costs per sale. This scale effect is the dominant factor in threshold reduction and a subsequent increase in the number of US manufacturing firms exporting in Japanese markets. This firm reallocation in US-Japan link is in favor of lower-productivity firms. On the other hand, the within firm reallocation in the domestic market is such that low-productivity firms are forced to exit due to higher average variable costs. As a result of exit of firms in the domestic market, the productivity of US manufacturing sector rises.

By incorporating monopolistic competition and firm heterogeneity, we are able to capture and analyze the previously unobserved effects of trade agreements. The question to ask at this point is whether these effects matter for trade policy implications. An initial comparison of model responses to tariff elimination across GTAP models with Armington, Krugman, and Melitz specifications show that the firm heterogeneity module capture additional gains from trade that result in more pronounced welfare responses.

The main premise of new trade negotiations, such as the Trans-Pacific Partnership Agreement (TPP), is to develop comprehensive, high-quality rules in trade that harmonize standards and thereby reduce barriers to trade. The variation in trade standards across regions force firms to incur significant fixed export costs. Reduction in these costs are expected to generate huge gains for the member countries. As a future work we aim to analyze a more comprehensive trade liberalization scenario with fixed export costs as the policy instrument. The GTAP model with firm heterogeneity responds to fixed export cost reductions by changing industry productivity as a result of shifts in productivity thresholds.

CHAPTER 3. THEORETICALLY-CONSISTENT PARAMETERIZATION OF A MULTI-SECTOR GLOBAL MODEL WITH HETEROGENEOUS FIRMS

3.1 Introduction

Theoretical and empirical developments in the trade literature show that accounting for firm heterogeneity within an industry improves our understanding of how trade barriers affect trade flows and economic welfare by providing a new margin of adjustment through self-selection of firms into and out of markets. Due to this added explanatory power, firm heterogeneity theory has begun to be incorporated into computable general equilibrium models (CGE) (Akgul et al., 2014; Balistreri et al., 2011; Balistreri and Rutherford, 2012; Dixon et al., 2015; Zhai, 2008).

In Chapter 2 we laid out the firm heterogeneity theory and implemented it into the GTAP model with the objective of making this theory accessible for practical policy analysis. However, the remaining obstacle to achieving this goal is the lack of an appropriate set of estimates for the key parameters of the model at the disaggregated industry level. Particularly, the information that is key to the firm heterogeneity model such as the shape of the productivity distribution, which determines productivity heterogeneity across firms, and the degree of markups, which is a function of the elasticity of substitution across varieties, are not available in the GTAP data base. What is available instead are Armington elasticities which may not be appropriate in a firm heterogeneity setting as the estimates incorporate both the demand-side and the supply-side heterogeneity. Due to this lack of information, we search for parameters which are consistent with the firm heterogeneity model and which we can put into use for practical policy analysis within this framework. Therefore, our objective in this paper is to discuss the challenges in the parameterization of a multi-region global CGE model with heterogeneous firms with an empirical illustration.

Parameterization of a firm heterogeneity model is a complicated problem which has been addressed in numerous studies. However, it has not yet been satisfactorily solved in the literature because of the difficulty in identification of the key parameters of the model. The main issue with estimating the key parameters of firm heterogeneity is that there is not enough information in country-level data to disentangle parameters. For example, as trade costs are not observed in the data it is not possible to separate distance elasticities from substitution elasticities because small trade flows can be the result of either large trade barriers and small elasticities or small trade barriers and large elasticities (Simonovska and Waugh, 2014). Therefore, we need reliable measures of trade barriers independent of trade flows to disentangle parameters. Eaton and Kortum (2002) and Simonovska and Waugh (2014) among many others address this issue by using price gaps in product-level data and estimate productivity parameters.

Even with firm-level data, identification is not a straightforward task. For example, Arkolakis et al. (2013) uses firm-level data and tariff variation across locations of firms to estimate the parameters of the firm heterogeneity model. However, they, too, rely on existing information to separate parameter values. In particular, they use markup ratios provided in previous studies (Martins et al., 1996; Domowitz et al., 1988) to obtain elasticities. Since there is not sufficient information in firm-level data to separate parameters one needs to run additional regressions Crozet and Koenig (2010). Due to these challenges parameterization of firm heterogeneity models has remained to be an outstanding issue.

Chaney (2008) extends the seminal work of Melitz (2003) and demonstrates that in models with heterogeneous firms changes in trade barriers affect both the volume of sales by existing exporters (i.e., the intensive margin of trade) as well as the number of firms in the export market (i.e., the extensive margin of trade) due to productivity differences across firms. An important finding in the literature is that the extensive margin is quantitatively very important in governing growth in international trade flows (Hummels and Klenow, 2005; Yi, 2003). As a result, estimates of the elasticity of substitution by models that ignore changes in the extensive margin are biased (Chaney, 2008; Helpman et al., 2008). This finding contrasts with the traditional Armington (1969) view of the world, whereby changes in trade barriers only affect the intensive margin of trade, which is governed by the elasticity of substitution across varieties, σ (Hillberry and Hummels, 2013). However, in firm heterogeneity models there is an additional parameter of interest, namely the shape parameter of Pareto distribution, γ. The shape parameter is an inverse measure of heterogeneity in productivity across firms within an industry and it governs the supply-side effects of trade policies. In fact, the distribution of firm productivity significantly affects aggregate trade response to reduced trade costs as demonstrated in Chaney (2008), Bernard et al. (2003) and di Giovanni and Levchenko (2013). Therefore, to work with a firm heterogeneity model, we need to have estimates of the shape parameter as well as the elasticity of substitution amongst varieties.

Empirical studies of international trade flows rely on gravity equations in order to estimate the structural parameters of trade models. Gravity models relate the volume of bilateral trade to distance and other determinants of trade. In a gravity model, the marginal effect of distance on trade volumes is given by $-\delta\,(\sigma-1)$, where δ is the distance elasticity of trade. Identification of $-\delta\,(\sigma-1)$ requires knowledge on either δ or σ. However, bringing in an additional parameter to reflect firm heterogeneity, i.e. γ, introduces further complexities in identifying the elasticity of substitution. Crozet and Koenig (2010) show that, in the firm-heterogeneity setting of Chaney (2008), the marginal effect of distance on the *probability of a bilateral trade flow taking place* is given by $-\delta\gamma$. Therefore, there are three parameters to estimate, i.e. δ, σ and γ, which implies that an exogenous source of information is needed to identify all of them.

di Giovanni and Levchenko (2013) and Eaton et al. (2011) circumvent this difficulty by imposing the prior values of σ on the model in order to calibrate the values of γ. This method has two drawbacks: (i) Often, estimates for σ are obtained from Armington-type models which are fundamentally inconsistent with firm heterogeneity theory. (ii) The resulting values for γ typically are not sector and region-specific and therefore do not capture the significant variation of heterogeneity along these dimensions. For example, the shape parameter estimates in Spearot (2015) show that electrical machinery is a more heterogeneous industry where productivity differences across firms is more pronounced, while petroleum refining is a much more homogeneous industry. Moreover, according to his estimates, even though electrical machinery is heterogeneous in the US, it is much more homogeneous in Chile. Not accounting for these drawbacks is likely to lead to biased estimates of parameters in the calibrated model.

A theory-consistent approach to estimating the shape parameter is offered by Crozet and Koenig (2010) and Spearot (2015). Both studies present estimates of γ at the product level in a firm heterogeneity model. The model in Crozet and Koenig (2010) is based on Chaney (2008), while the model in Spearot (2015) is based on Melitz and Ottaviano (2008). Even though Spearot (2015) provides values for γ by industry and by region, he does not estimate elasticities that are consistent with γ. Only Crozet and Koenig (2010) have a rich enough dataset to identify both parameters. Interestingly, their estimates of the elasticity of substitution are lower when compared to the traditional Armington elasticity estimates in the GTAP model

(Hertel et al., 2003). Unfortunately, their estimates are of limited use for a global general equilibrium model because they are based only on French firms and cover a limited number of industries. Against this backdrop, our objective in this paper is to solve for a set of elasticities of substitution that are theoretically consistent with trade models considering firm heterogeneity.

To accomplish this, we extend the seminal work of Melitz (2003) to a multi-sector, multi-country model and build on Chaney (2008) to distinguish the intensive and extensive margins of trade. For our gravity estimations, we use bilateral trade data at the country level from GTAP Version 8.1 (Narayanan et al., 2012) which covers the years 1995-2009. This makes sense, since our ultimate goal is to incorporate these parameters in a model based on the GTAP data set. In addition, we use the GeoDist and Gravity databases of CEPII (Mayer and Zignago, 2011) which include bilateral data on several relevant variables such as distance, language, colonial link among others determinant of bilateral trade. The resulting dataset covers 113 countries over 1995-2006. This makes sense, since our ultimate goal is to incorporate these parameters in a model based on the GTAP data set. In this paper, we focus on the motor vehicles and parts industry (MVH) of GTAP which, according to Spearot (2015)s parameters, has one of the highest productivity dispersions across firms among manufacturing industries. Future research will extend this work to all of the GTAP sectors and regions.

Our estimation strategy merges the approach adopted by Helpman et al. (2008) with the extensive margin specification used in Crozet and Koenig (2010). We distinguish between the intensive and extensive margins of trade which results in two estimating equations. The first equation estimates the probability of a bilateral trade taking place, while the second equation estimates the value of bilateral trade conditional on the choice to export. We refer to the first equation as the export participation equation and refer to the second equation as the gravity equation[1]. Following Crozet and Koenig (2010) in both equations we focus on the coefficient of distance. In the export participation equation the distance coefficient is a combination of the distance and substitution elasticities. On the other hand, in the gravity equation, the distance coefficient is a combination of the shape parameter and substitution elasticity. This gives us two equations in three unknowns, whereupon we use the shape parameter estimates provided in Spearot (2015) to solve for the theoretically consistent estimates of substitution elasticities.

Our estimation results show that the elasticity estimate consistent with firm heterogeneity for the motor vehicles and parts industry is considerably lower than the GTAP Armington elasticity (Hertel et al., 2003). This implies that elasticities estimated in that traditional way were in fact picking up additional effects accruing from the supply-side heterogeneity in this framework. In summary, Armington elasticities are high when employed in the context of a firm heterogeneity model because they confound demand-side effects with the supply-side effects. This finding underlines the argument in Dixon et al. (2015) about the observational equivalence between Armington and Melitz models. In particular, they argue that welfare implications of trade policies are similar in magnitude between these models if the Armington and Melitz elasticities are chosen such that trade responses are equal across model specifications. In such a scenario, Armington-based elasticities are higher than Melitz elasticities. This implies that using Armington elasticities in a firm heterogeneity model might lead to overestimated trade volumes and welfare effects.

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[1] In principle, both equations are gravity equations. However, we adopt this convention to distinguish the new margin of adjustment due to firm entry/exit from the traditional gravity equation that determines trade flows.

3.2 Background on Structural Parameters of the Firm Heterogeneity Model

Although Melitz (2003) does not impose any restrictions on productivity, the common approach in the firm heterogeneity literature is to assume that firms draw their productivity levels from a Pareto distribution. There are two main reasons for choosing the Pareto distribution. First, the Pareto distribution is analytically tractable. As Chaney (2008) argues, an important property of Pareto distribution is its stability to truncation from below. As a result of this property, exporters, which are more productive and therefore at the upper tail of the distribution, are also Pareto distributed. Moreover, the same shape parameter that governs the distribution of domestic firms also governs that of exporters[2].

The second reason for favoring the Pareto distribution over alternatives is empirical. The Pareto distribution is a power law and provides a good fit for the observed size distribution of firms[3]. Empirical support for this distribution is found for US firms (Axtell, 2001) and French firms (Eaton et al., 2011) among many others[4]. The Pareto assumption for firm sales is equivalent to assume that firm productivity is Pareto, though with a different shape parameter. Furthermore, the Pareto distribution predicts a linear relationship between the log of rank and the log of firm size (Crozet and Koenig, 2010). An ever-expanding body of empirical studies uses this property to consistently estimate shape parameters based on firm sales data. In particular, they

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[2] There are new empirical findings that might challenge this proposition. di Giovanni et al. (2011) argue that the shape parameter of firm size distribution is systematically different between exporters and non-exporters. Firm size distribution of exporters is more fat-tailed and has a lower shape parameter than non-exporters because they are more productive. This in turn implies that the Pareto shape parameter of productivity distribution is different between exporters and non-exporters given a constant elasticity of substitution for firm varieties.

[3] In developed countries, Pareto seems to provide a better fit for the distribution of manufacturing firms that are medium-sized (Axtell, 2001; Crozet and Koenig, 2010). Moreover, there is a minimum size threshold for power laws to provide a good fit for the data (Axtell, 2001; Luttmer, 2007). As a result, di Giovanni et al. (2011) argue that the size distribution of small firms may not be well-described by a power law.

[4] Size distribution of firms also follows a power law in the case of Japan (Fujiwara, 2004; Okuyama et al., 1999). See Gabaix (2008) for a full survey on power laws.

estimate the Power Law exponent of firm sales given by $\gamma/(\sigma - 1)$ to pin down γ and σ. However, since this expression is a combination of γ and σ, it is not possible to separately identify the structural parameters in these studies.

A key restriction on these parameter values in this context is the condition $\gamma > \sigma - 1$. This is described in Melitz (2003) and Chaney (2008) as the condition that ensures the firm size distribution has a finite mean. This is equivalent to saying

$$\frac{\gamma}{\sigma - 1} > 1$$

. Therefore, the relative values of γ and σ become critical for quantitative outcomes such as export sales. The value of the shape parameter determines price differences across firms in the industry. A small shape parameter implies a large dispersion of productivity among firms with low-productivity firms capturing a small share of the market. In this case new entrants charge higher prices compared to the existing exporters. On the other hand, in an industry with a large shape parameter, there is a big mass of low-productivity firms that represent a larger share of industry output. In this case, prices charged by new entrants are similar to the existing exporters. This supply-side heterogeneity is translated into export sales based on the demand-side heterogeneity.

A small elasticity of substitution means that consumers are willing to pay a premium for differentiated varieties which makes low productivity less of a disadvantage. Therefore, new entrants can capture a larger share of the market. However, a large elasticity of substitution increases the competition in the market and makes low productivity a bigger disadvantage. As a result, marginal firms capture a small share in the market. This discussion suggests that export sales by new entrants are largest when there is supply-side homogeneity (high γ) and demand-side heterogeneity (low σ) (Hillberry and Hummels, 2013).

An opposite case is where $\frac{\gamma}{\sigma-1} = 1$ which is known as the Zipfs Law. This yields a fat-tailed distribution of firm size where the infra-marginal firms in the industry are large and have a disproportionate share of overall sales compared to the small marginal firms. In that case, the welfare impact of trade is driven by infra-marginal firms rather than the marginal ones. Therefore, the contribution of the extensive margin to trade is found to be negligible (di Giovanni and Levchenko, 2013)[5]. An implication of this finding is that quantitative results of trade cost reductions on trade flows and welfare are very sensitive to the firm size distribution and, by extension, very sensitive to the structural parameters of firm heterogeneity. This raises the stakes when it comes to obtaining reliable estimates of the Pareto parameters.

Even though there is a growing body of empirical work aimed at estimating structural parameters, there is still substantial uncertainty about the appropriate parameter values to use in the firm heterogeneity model. This is particularly true because of the challenges associated with the identification of two parameters using only one estimating equation, as mentioned above. A brief overview of parameter values used in the firm heterogeneity literature is provided in Table 3.2[6]. There are three key points that we can draw from this table.

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[5] This can be linked back to the discussion in Dixon et al. (2015) about the offsetting effects of extensive margin and productivity on welfare in a tariff increase scenario.

[6] This table is by no means a full review of the literature. The aim of this table is to present only a sample of the most relevant work to explore the mainstream approach in obtaining parameter estimates and to compare the values of key parameters used in these studies.

Table 3.1. Overview of Structural Parameter Values in the Firm Heterogeneity Literature.

Author (Year)	Country (Period)	Sectors	Model	Dist.	Power Law Exponent, $\gamma/(\sigma-1)$	Shape parameter, γ	Substitution elasticity, σ
Axtell (2001)	US firm-level data (1997)	-	-	Zipf	1.06 (estimated)		
Eaton and Kortum (2002)	Cross-section data of 19 OECD Countries (1990)	Manufacturing	Ricardian model	Fréchet	-	8.28 , 12.86 (based on prices) 3.6 (based on wages)	-
Bernard et al. (2003), BEJK	US plant-level data (1992) for 47 importers	Manufacturing	Eaton and Kortum (2002)	Fréchet	-	3.6 (calibrated)	3.79 (calibrated)
Arkolakis et al. (2008)	Costa Rican imports from 111 exporters (1986-1992)	-	-	Pareto	-	5.3 (calibrated)	6.0
Zhai (2008)	Cross-section data	11 aggregate sectors	Melitz (2003)	Pareto	-	5.17 , 6.20, 7.75 (calibrated)	4.3, 5.0, 6.0 (calibrated)
Crozet and Koenig (2010)	France, panel data at the firm-level (1986-1992)	34 manufacturing sectors	Chaney (2008)	Pareto	-	[1.65-7.31] (estimated) mean: 3.09	[1.15-6.01] (estimated) mean: 2.25
Balistreri et al. (2011)	Cross-section (2001)	7 aggregate sectors	Melitz (2003)	Pareto	-	3.924, 4.582, 5.171 (estimated)	3.8 Bernard et al. (2003)
Eaton et al. (2011)	French firm-level data for 113 importers (1986)	Manufacturing	Melitz (2003)	Pareto	2.46 (estimated)	4.87 (implied)	2.98 (method in Bernard et al. (2003))
di Giovanni et al. (2011)	Fench firm-level data (2006)	25 tradeable sectors	Melitz (2003)	Pareto	[0.362 - 1.011] (exporters) [0.470 -1.663] (non-exporters) 1.06 (domestic sales)	-	-
di Giovanni and Levchenko (2013)	Cross-section data of 50 largest economies	-	Melitz (2003) Eaton et al. (2011)	Pareto	1.06 (di Giovanni et al. (2011))	5.3 (implied)	6 (Anderson and van Wincoop (2004)
Melitz and Redding (2013)	US	-	Melitz (2003)	Pareto	1.42 (empirical evidence)	4.25 (implied)	4 (Bernard et al. (2003))
Spearot (2015)	Cross-section	39 sectors	Melitz and Ottaviano (2008)	Pareto	-	[1.76-6.29] (estimated)	-

Notes: This table is ordered based on each paper's publish date. Empirical methods followed in these studies include: Axtell (2001) uses a Power Law specification for firm sizes to estimate the Power Law exponent; Eaton and Kortum (2002) uses the Method of Moments Estimator to estimate the shape parameter of Fréchet distribution based on trade and prices as well as based on trade and wages; Bernard et al. (2003) calculates the parameter values by matching the productivity and size advantage of exporters in the simulated data with that of the empirical data; Arkolakis et al. (2008) uses the Feenstra (1994) Ratio to adjust the standard import price index for changing varieties and calibrates the shape parameter; in Zhai (2008) the shape parameter is calibrated to profit ratio in total markup, while the elasticity is calibrated to the markup ratio; Crozet and Koenig (2010) use a structural estimation method to estimate both parameters; Balistreri et al. (2011) uses a structural estimation method where they fit trade flows subject to equilibrium conditions in the model; Eaton et al. (2011) uses a Simulated Method of Moments estimator to estimate the Power Law exponent; di Giovanni et al. (2011) estimate the Power Law exponent by using log rank-log size regression; di Giovanni and Levchenko (2013) use the Power Law exponent in di Giovanni et al. (2011) with the elasticity in Anderson and van Wincoop (2004) to infer the shape parameter; Melitz and Redding (2013) calibrate the shape parameter to match the Power Law exponent for firm revenue; Spearot (2015) estimates a structural trade growth equation using Maximum Likelihood to find the shape parameter.

First, empirical studies confirm that the value of the Power Law exponent of firm size distribution is around 1 (Axtell, 2001; di Giovanni et al., 2011) and it is used in various studies to infer shape parameter values by relying on external sources for elasticities (di Giovanni and Levchenko, 2013; Melitz and Redding, 2013). Second, the shape parameter values that are calibrated using the Power Law exponent (di Giovanni and Levchenko, 2013; Eaton et al., 2011; Melitz and Redding, 2013) or by other methods (Arkolakis et al., 2008; Zhai, 2008) are higher compared to the directly estimated values (Crozet and Koenig, 2010; Spearot, 2015). Using calibrated values of shape parameters would attribute lower productivity dispersion to the industry, while there could, in fact, be much higher productivity heterogeneity across firms. Therefore, we prefer to use the information contained in the shape parameter estimates instead of those from the calibration exercises.

Third, aggregation has a significant effect on parameter values. Estimates based on higher levels of aggregation are found to be higher than the ones based on lower levels of aggregation. This is because when we work with aggregated products, we fail to capture the variation across sectors and we settle on one parameter value to describe the entire industry. For example, in the two cases where the parameter values are estimated at a disaggregate level, for more than 30 sectors, the shape parameter estimates are found to show substantial variation in the range of 1.65-7.31 in Crozet and Koenig (2010) and 1.76-6.29 in Spearot (2015). On the other hand, estimates/calibrations that are at an aggregate industry level provide few values that are in the range of 3-7, on average (Arkolakis et al., 2008; Balistreri et al., 2011; Bernard et al., 2003; Eaton and Kortum, 2002; Eaton et al., 2011; Zhai, 2008). Similarly, the difference in aggregation is important for the elasticity values, as well. Elasticity estimates in Crozet and Koenig (2010) are in the range of 1.15-6.01, reflecting a wide range of demand-side heterogeneity compared to the more aggregated studies. In order to account for the variation across sectors, we prefer to work at a disaggregated level of the manufacturing industry, focusing initially on the motor vehicles and parts.

Aggregation is extremely important in analyzing the extensive and intensive margin effects of trade flows, as well. Hillberry and Hummels (2013) argue that the extensive margin plays a larger role when one works with aggregated product lines. On the other hand, the impact of the intensive margin is more pronounced when we work with disaggregated product lines. Making this distinction is paramount in interpreting the results of any policy experiment.

3.3 Theoretical Model

We present a model of international trade with heterogeneous firms building on the theoretical model in Helpman et al. (2008) and Crozet and Koenig (2010). We consider the world to be composed of R countries, where we index exporters by $r = 1, 2, , R$ and importers by $s = 1, 2, , R$. Every country produces and consumes differentiated as well as homogeneous products. For the homogeneous goods industry, we retain the traditional assumption of national product differentiation (Armington, 1969) and the industry is characterized by perfect competition with constant returns to scale technology. On the other hand, we follow Melitz (2003) and assume that there are H differentiated industries indexed by $h = 1, 2, , H$. Each industry is composed of a continuum of firms where each firm produces a unique variety indexed by ω. Moreover, firms differ in their productivity levels and operate under monopolistic competition.

3.3.1 Consumers

We adopt a Dixit-Stiglitz treatment in the demand-side. In this setting, consumers are characterized by love-of-variety where they perceive each variety as a unique product and derive utility from that uniqueness. The utility function for the differentiated good h in country s, U_{hs} , is given by

$$U_{hs} = \left[\sum_{r} \int_{\omega_{hrs} \in \Omega_{hr}} q_{hrs}(\omega_{hrs})^{\frac{\sigma_h - 1}{\sigma_h}} d\omega_{hrs} \right]^{\frac{\sigma_h}{\sigma_h - 1}}, \tag{3.1}$$

where ω_{hrs} indexes the variety of good h imported by country s from the source country r, Ω_{hr} is the set of all varieties of good h available in country r, $q_{hrs}\left(\omega_{hrs}\right)$ is the quantity demanded by a representative consumer in country s of variety ω_{hrs} of good h imported from country r and $\sigma_h > 1$ is the elasticity of substitution between the varieties of good h.

Let P_{hs} be the price index of good h in country s, i.e. the dual price index of the Dixit-Stiglitz composite of demand in equation (3.1), which is given by

$$P_{hs} = \left[\sum_{r} \int_{\omega_{hrs} \in \Omega_{hr}} p_{hrs}(\omega_{hrs})^{1-\sigma_h} d\omega_{hrs} \right]^{\frac{1}{1-\sigma_h}}, \tag{3.2}$$

where $p_{hrs}\left(\omega_{hrs}\right)$ is the price in country s of variety ω_{hrs} of good h imported from country r (gross of trade costs). Based on these demand and price aggregates, we can find the demand for each variety of good h shipped from country r to s to be as follows:

$$q_{hrs}\left(\omega_{hrs}\right) = \frac{p_{hrs}(\omega_{hrs})^{-\sigma_h}}{P_{hs}^{1-\sigma_h}} Y_{hs}, \tag{3.3}$$

where Y_{hs} is the total expenditure in country s on industry h (equal to income in the relevant industry in country s)[7].

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[7] Please note that

$$Y_{hs} = P_{hs} U_{hs} = \int_{\omega_{hrs} \in \Omega_{hs}} p_{hrs}\left(\omega_{hrs}\right) q_{hrs}\left(\omega_{hrs}\right) d\omega_{hrs}$$

3.3.2 Producers

Producer behavior is based on Melitz (2003). In this setting, there are N_{hr} varieties of the differentiated good h produced in the exporting country r. A corollary to this is that there are N_{hr} active firms in the monopolistically competitive industry h in country r. Each firm produces a unique variety, ω, with different productivity, φ. In addition, varieties produced by firms in the exporting country r are distinct from the varieties produced by firms in the importing country s. Each country exports only a subset of its unique varieties because only some firms find it profitable to export into a given market. As a result, exports from country r to s includes only $N_{hrs} < N_{hr}$ varieties being shipped on the r-s trade route. This means that the total number of varieties of good h available to consumers in country s is N_{hs} domestic varieties plus $\sum\limits_{r} N_{hrs}$ imported varieties.

Firms in industry h incur variable and fixed costs of production and of exporting. There are two types of fixed costs: sunk-entry costs to produce in the domestic market and fixed export costs to enter export markets. Fixed export costs are source-destination specific and are assumed to be identical across firms on the same bilateral trade route. There are two types of variable costs: marginal cost of production and transportation costs for export shipments. We adopt the standard assumption of iceberg transportation costs, in which $\tau_{hrs} > 1$ units of good h must be shipped from country r in order for one unit of good h to arrive in country s.

The only type of cost that is firm-specific in this setting is the marginal cost of production which equals c_{hr}/φ_{hr} for an active firm in industry h of country r. Here, c_{hr} is the cost of the input bundle that is used for producing one unit of output in industry h of country r and φ_{hr} is the productivity of an active firm in industry h of country r which measures the amount of output produced by one bundle of input. Given the input bundle cost, let f_{hrs} measure the number of bundles that is used by firms in industry h to cover the fixed costs of exporting from country r to country s. Then, the fixed export costs on this particular bilateral trade route equals $c_{hr}f_{hrs}$.

The profit-maximizing price in a monopolistically competitive industry is a constant markup over marginal cost. Hence the delivered price in country s of the variety produced by a firm in country r with productivity φ is given by

$$p_{hrs}(\varphi) = \frac{\sigma_h}{\sigma_h - 1}\frac{\tau_{hrs}c_{hr}}{\varphi_{hrs}} \tag{3.4}$$

where $\frac{\sigma_h}{\sigma_h-1}$ is the markup that decreases with a larger elasticity of demand. If preferences are more homogeneous (large σ_h), the industry becomes more competitive and firms have to charge a lower markup for their respective varieties. Using the profit maximizing prices in equation (3.4) and utility maximizing level of sales in equation (3.3), the profit from exporting $q_{hrs}(\varphi)$ units of good h into country s is found to be

$$\pi_{hrs}(\varphi) = \frac{p_{hrs}(\varphi)\,q_{hrs}(\varphi)}{\sigma_h} - c_{hr}f_{hrs} = \left[\frac{\sigma_h}{\sigma_h - 1}\frac{\tau_{hrs}c_{hr}}{\varphi_{hrs}P_{hs}}\right]^{1-\sigma_h} Y_{hs} - c_{hr}f_{hrs}. \tag{3.5}$$

Firm export participation is determined by the potential profit to be made in each bilateral market based on equation (3.5). Firm profit increases with market size in the destination country (Y_{hs}), lower marginal costs (c_{hr}/φ_{hr}), and lower barriers to trade (τ_{hrs} and f_{hrs}). Productivity level of the firm plays a key role in determining the potential profit to be made on a particular trade route based on fixed costs associated with exporting. Particularly, destination-specific fixed export costs limit the number of exporters from source country r since only the firms with high productivity levels can cover fixed export costs and make positive profits in the export market. The cutoff productivity level of exporting is destination-specific and is determined by the zero profit condition on each bilateral trade route. The revenue made by the marginal exporting firm is just enough to cover total costs of exporting and determines the productivity threshold. Let the productivity threshold for firms in industry h to export from country r to s be φ^*_{hrs}, which is governed by the following equation

$$\varphi^*_{hrs} = \frac{\sigma_h}{\sigma_h - 1} \frac{\tau_{hrs} c_{hr}}{P_{hs}} \left[\frac{c_{hr} f_{hrs}}{Y_{hs}} \right]^{\frac{1}{\sigma_h - 1}}. \tag{3.6}$$

Firms that have a higher productivity level than φ^*_{hrs} will successfully export on the r-s route, while the rest of the firms, which have lower productivity levels than φ^*_{hrs}, will only supply the domestic market. This self-selection mechanism determines the number of firms in export markets which can differ across destinations. As mentioned above only a subset N_{hrs} firms out of the total N_{hr} firms are able to export into country s and the mass of firms in this subset depends on the productivity distribution in the industry.

We assume that firm productivity follows the Pareto distribution with support $[\varphi_{\min}, \infty)$ and shape parameter γ_h that satisfies the condition $\gamma_h > \sigma_h - 1$. The associated density function, $g(\varphi)$, and cumulative distribution function, $G(\varphi)$, are then as follows:

$$g(\varphi) = \gamma \frac{\varphi^{\gamma}_{\min}}{\varphi^{\gamma+1}}, G(\varphi) = 1 - (\varphi_{\min}/\varphi)^{\gamma} \tag{3.7}$$

where $\varphi_{\min} \in [1, \infty)$ is assumed in this paper.[8] Given the productivity distribution, $1 - G(\varphi^*_{hrs})$ measures the proportion of firms that have productivity levels higher than the threshold φ^*_{hrs}. Therefore, the fraction of active exporters to all firms in the industry N_{hrs}/N_{hr} equals $1 - G(\varphi^*_{hrs})$.[9]

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[8] Helpman et al. (2008) uses a truncated Pareto distribution by imposing upper and lower bounds to productivity. The reason for these bounds is to construct a model that can explain zero trade flows in the country level data with firm behavior. But, using a truncated Pareto distribution brings about nonlinearities into the model which we do not attempt to solve in this paper. For analytical tractability purposes we choose to impose only a lower bound for productivity. An implication of this assumption is that because there is a continuum of firms in the industry, there is a positive mass of exporters for all country pairs as noted in Head and Mayer (2014).

[9] This follows from $N_{hrs} = \int_{\varphi^*_{hrs}}^{\infty} N_{hr} g(\varphi) d\varphi$

3.3.3 Aggregate Trade Flows

The value of aggregate trade flows is the product of number of firms that sell in the destination market and the average revenue along the bilateral trade route. Let M_{hrs} be the total value of demand in destination country s for good h sourced in country r which is given by

$$M_{hrs} = \int_{\varphi^*_{hrs}}^{\infty} N_{hrs} p_{hrs}\left(\varphi\right) q_{hrs}\left(\varphi\right) \mu\left(\varphi\right) d\varphi \tag{3.8}$$

where $\mu\left(\varphi\right)$ is the productivity distribution of successful firms in equilibrium, i.e. conditional distribution of $g\left(\varphi\right)$ on support $[\varphi^*_{hrs}, \infty)$ as in Melitz (2003):

$$\mu\left(\varphi\right) = \begin{cases} \frac{g(\varphi)}{1-G(\varphi^*)} \text{if} \varphi \geq \varphi^* \\ 0 \text{otherwise} \end{cases} \tag{3.9}$$

We simplify (3.8) by using optimal demand and price for good h given by equations (3.3) and (3.4). The simplified representation of bilateral trade flows is then given by

$$M_{hrs} = \begin{cases} \left[\frac{\sigma_h}{\sigma_h - 1} \frac{\tau_{hrs} c_{hr}}{P_{hs}}\right]^{1-\sigma_h} Y_{hs} N_{hr} V_{hrs} \text{if} \varphi \geq \varphi^* \\ 0 \text{otherwise,} \end{cases} \tag{3.10}$$

where V_{hrs} is defined as in Helpman et al. (2008)[10]:

$$V_{hrs} = \int_{\varphi^*_{hrs}}^{\infty} \varphi^{\sigma_h - 1} g\left(\varphi\right) d\varphi. \tag{3.11}$$

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[10] V_{hrs} corresponds to the average productivity in the industry. In Melitz (2003), average productivity is defined as $\tilde{\varphi}_{hrs}\left(\varphi^*_{hrs}\right) = \left[\int_{\varphi^*_{hrs}}^{\infty} \varphi^{\sigma_h - 1} \mu\left(\varphi\right) d\varphi\right]^{\frac{1}{\sigma_h - 1}}$. Based on this definition, we have $V_{hrs} = \tilde{\varphi}_{hrs}^{\sigma_h - 1}\left[1 - G\left(\varphi^*_{hrs}\right)\right]$. Please note that since we define V_{hrs} as $V_{hrs} = \int_{\varphi^*_{hrs}}^{\infty} \varphi^{\sigma_h - 1} g\left(\varphi\right) d\varphi$, we can express M_{hrs} in terms of N_{hr} instead of the bilateral N_{hrs}.

Equation (3.10) can be thought of as a measure of the intensive margin because it takes export sales of all exporters into account in determining aggregate export sales on a particular trade route. Equation (3.10) also shows that bilateral trade flows increase with market size of the importer s (Y_{hs}), the mass of firms in the industry (N_{hr}), competition in the importing market (P_{hs}), reductions in barriers to trade (τ_{hrs}) and reductions in factor costs (c_{hr}). A quick look at equation (3.10) would suggest that the elasticity of trade with respect to reduced trade costs is $1 - \sigma_h$. This corresponds to the trade-cost elasticity in the Dixit-Stiglitz-Krugman monopolistic competition model. However, this is only part of the story. In fact, $1 - \sigma_h$ only represents the demand side effects of reduced trade barriers in a firm heterogeneity model. There are additional effects of trade cost reductions embedded in V_{hrs} which work through the supply side. In particular, V_{hrs} represents how self-selection of firms into export markets stimulate average productivity and thereby increase trade flows in the case of lower trade barriers. This mechanism introduces the supply side effects of trade cost changes into equation (3.10).

The combined effect of demand and supply side effects reveals that the trade-cost elasticity of trade flows in a firm heterogeneity model is different from that of a model with homogeneous firms. In fact, Chaney (2008) shows analytically that trade-cost elasticity[11] is equal to the supply side parameter $-\gamma_h$ in a multi-country Melitz (2003) framework. This finding paved the way for subsequent empirical work that changed the interpretation of parameter estimates in gravity equations in the presence of heterogeneous firms.

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[11] Elasticity is defined as $\frac{\partial M_{hrs}}{\partial \tau_{hrs}} \frac{\tau_{hrs}}{M_{hrs}}$.

3.3.4 Extensive, Intensive and Compositional Trade Margins

Many empirical studies in the gravity literature distinguish between two margins of adjustment to trade shocks: intensive and extensive margins. As trade costs fall, not only does the volume of sales from each exporter increase, i.e. intensive margin, but the set of exporters changes as well, i.e. extensive margin. As opposed to this two-way decomposition, Head et al. (2014) offer a three-way decomposition by arguing that an implicit margin is embedded in the conventional interpretation. Since new entrants are less productive than the existing exporters, sales of new entrants are lower than the average shipment prior to trade cost reductions. The margin of adjustment as a result of this difference in sales is referred to as the compositional margin by Head et al. (2014). The compositional margin is a part of the extensive margin in Chaney (2008) and Crozet and Koenig (2010), while it is included in the intensive margin in Bernard et al. (2007) and Hillberry and Hummels (2008). Needless to say, depending on how the compositional effects are assigned the relative contribution of the intensive and extensive margins of trade will vary across otherwise identical studies. Therefore, it is appealing to break out this compositional effect.

Here we explicitly show the three-way decomposition of trade-cost elasticity. Trade flows in equation (3.8) can be written as the product of the number of exporters and average sales per exporter, $M_{hrs} = N_{hrs} m\left(\tilde{\varphi}_{hrs}\right)$ where average sales is defined as $m\left(\tilde{\varphi}_{hrs}\right) = \int_{\varphi^*_{hrs}}^{\infty} m\left(\varphi\right)\mu\left(\varphi\right) d\varphi$. Using the Leibniz rule, as in Chaney (2008), we obtain a decomposition of the trade-cost elasticity similar to the one in Head et al. (2014) as follows:

$$\begin{aligned} \tfrac{\partial \ln M_{hrs}}{\partial \ln \tau_{hrs}} &= \underbrace{\frac{1}{m\left(\tilde{\varphi}_{hrs}\right)} \int_{\varphi^*_{hrs}}^{\infty} \frac{\partial \ln m\left(\varphi\right)}{\partial \ln \tau_{hrs}} m\left(\varphi\right)\mu\left(\varphi\right) d\varphi}_{\text{intensive margin}} \\ &+ \underbrace{\frac{\partial \ln N_{hrs}}{\partial \ln \tau_{hrs}}}_{\text{extensive margin}} + \underbrace{\left[\frac{m\left(\varphi^*_{hrs}\right)}{m\left(\tilde{\varphi}_{hrs}\right)} - 1\right] \frac{\partial \ln\left[1 - G\left(\varphi^*_{hrs}\right)\right]}{\partial \ln \varphi^*_{hrs}} \frac{\partial \ln \varphi^*_{hrs}}{\partial \ln \tau_{hrs}}}_{\text{compositional margin}} . \end{aligned} \tag{3.12}$$

The first component in equation (3.12) is the intensive margin which gives the adjustment in trade-cost elasticity due to changes in sales of the existing exporters. As mentioned before, the intensive margin effect is the same as in the traditional Armington model. The second component is the extensive margin, due to changes in the set of exporters. The third component is the compositional margin due to lower per firm sales of new entrants. In particular, the term $\left[\frac{m_{hrs}(\varphi^*_{hrs})}{m_{hrs}(\tilde{\varphi}_{hrs})} - 1\right]$ captures the difference between lower sales of new exporters and the average sales of the incumbents in the export market.

We follow Head et al. (2014) in simplifying equation (3.12) by applying the Pareto distribution and using the optimal demand and pricing equations. The resulting trade-cost elasticity of trade flows is identical to Chaney (2008).

$$\frac{\partial \ln M_{hrs}}{\partial \ln \tau_{hrs}} = \underbrace{(1-\sigma_h)}_{\text{intensive margin}} + \underbrace{(-\gamma_h)}_{\text{extensive margin}} + \underbrace{(\sigma_h - 1)}_{\text{compositional margin}} = -\gamma_h \qquad (3.13)$$

According to equation (3.13) the intensive margin depends only on the demand-side parameter σ_h and is equal to the trade-cost elasticity in a Krugman-type model with homogenous firms. Similarly, the compositional margin also depends on the demand-side parameter as sales of new entrants are also governed by the substitution elasticity. An important discussion in Head et al. (2014) is that the intensive and compositional margins exactly offset each other due to the assumed Pareto distribution. This is in line with the discussion in Chaney (2008) even though his definition of the extensive margin includes the compositional part as well. He states that firm-level trade behaves in the same way as aggregate trade behaves in traditional models. As a result, the intensive and compositional margins affect the trade elasticity with the same magnitude, but in opposite direction. On the other hand, the extensive margin introduces supply-side effects through the shape parameter γ_h. In the end, what determines the final trade-cost elasticity of trade flows is the extensive margin in a firm heterogeneity model. An interesting point Chaney (2008) makes is that in firm heterogeneity models, the impact of trade barrier changes on trade flows is larger than that of the representative firm models. This is due to the required condition $\gamma_h > \sigma_h - 1$ which shows that the quantitative importance of the extensive margin on trade flows is higher in a firm heterogeneity setting compared to the intensive margin effect.

In this paper we adopt the convention in Chaney (2008) and include the compositional margin within the extensive margin. Therefore, our definition of the extensive margin captures the combined effect of export sales per new exporter and the change in the set of exporters. Therefore, when we refer to the extensive margin in this paper, we refer to $-\gamma_h + \sigma_h - 1$.

3.4 Data

We use two data sources in this paper. Bilateral trade data comes from the Global Trade Analysis Project (GTAP) Version 8.1 (Narayanan et al., 2012). This version includes 57 GTAP commodities and 134 GTAP regions of which 113 country titles are available. We use the time series bilateral trade data of this version that covers the period 1995 to 2009 with 2007 as the reference year. (Detailed information about data sources and variable definitions can be found in Appendix B.)

In this paper, we focus on the motor vehicles and parts sector, coded as MVH in GTAP. Therefore, we only use the trade data that is related to MVH. This choice is based on the information about the shape parameter estimates reported in Spearot (2015). Motor vehicles and parts is one of the most heterogeneous industries with respect to productivity in Spearot (2015) with a value of 1.79. On the other hand, the Armington elasticity in GTAP for motor vehicles and parts is 5.6 (Hertel et al., 2003). A comparison of these values reveals that the condition for finite size distribution $\gamma > \sigma - 1$ is not satisfied for MVH if we stick to the Armington elasticity $(1.79 < 5.6 - 1)$.

Trade barriers which are modeled as iceberg trade costs are not explicitly observed in the data. Therefore, a common approach in the gravity literature is to assume that iceberg trade cost is a function of many observable variables such as the physical distance between trading partners, sharing a common language, having a colonial relationship etc. We adopt the same approach and use the distance (GeoDist) and gravity (Gravity) databases of Centre d'Etudes Prospectives et dInfiormations Internationales (CEPII) to obtain the information about gravity variables. GeoDist is CEPIIs distance database developed by (Mayer and Zignago, 2005) and it includes country-specific data for 225 countries and bilateral data for 224 country pairs. Further details about this database can be found in Mayer and Zignago (2011). In our paper, data on distance, contiguity, common language, colonial links and landlocked countries are obtained from GeoDist. In addition, we use CEPIIs Gravity database based on Head et al. (2010). This database covers an exhaustive set of variables for 224 countries for the period 1948 to 2006. In our paper, data on common legal origins, common currency, FTA and GATT/WTO membership are obtained from Gravity.

The time period considered in this paper is from 1995 to 2006 to match the time series of bilateral trade from GTAP and the gravity variables from CEPII. In particular, we drop the years 2007-2009 from the GTAP time series data and we drop the years 1948-1994 from the CEPII Gravity data. Our final dataset is obtained by merging GTAP data with CEPII data for motor vehicles and parts industry, 113 country titles and it covers the period from 1995 to 2006. The list of countries included in our dataset is presented in Table B.1.

Table 3.2 provides descriptive statistics for the final sample of our dataset. We also tabulate the frequency of zero trade flows in the dataset by year in Table 3.3.

Table 3.2. Summary Statistics of the Dataset, Motor Vehicles and Parts, 113 Countries, for Years 1995-2006.

Variable	Obs	Mean	Std.Dev.	Min	Max
Exports (millions $US)	151,872	48.35	809.4	0	65206
Distance (km)	151,872	7467	4346	131.8	19781
Contiguity	151,872	0.026	0.158	0	1
Common Language	151,872	0.112	0.315	0	1
Common Colony	151,872	0.062	0.241	0	1
Colonial Link	151,872	0.017	0.128	0	1
FTA/RTA	151,872	0.091	0.287	0	1
Common Legal Origins	151,872	0.299	0.458	0	1
Common Curency	151,872	0.010	0.098	0	1
GATT /WTO Membership (both)	151,872	0.714	0.452	0	1
Landlocked	151,872	0.040	0.196	0	1

Table 3.3. Zeros in the Motor Vehicles and Parts Industry, 113 Countries.

Year	Frequency of Zeros	Fraction of Zeros (%)
1995	10,246	80.96
1996	10,165	80.32
1997	10,094	79.76
1998	10,010	79.09
1999	10,040	79.33
2000	10,028	79.24
2001	9,942	78.56
2002	9,943	78.56
2003	9,458	74.73
2004	9,293	73.43
2005	9,074	71.70
2006	8,996	71.08
Pooled	117,289	77.23

Bilateral trade datasets are known to include large numbers of zeros even at the country level (Helpman et al., 2008). Our dataset is no exception. As reported in Table 3.3, zero trade flows of motor vehicles and parts account for 77 per cent of the observations over the period 1995-2006. Large fraction of zeros in the dataset is known to cause sample selection bias in coefficient estimates in gravity equations where the dependent variable is log of trade flows. Since the logarithm of zero is undefined, zero observations are dropped from the sample in traditional OLS regressions. We follow the approach adopted in Helpman et al. (2008) to control for sample selection.

Table 3.3 also shows that the fraction of zero trade flows diminished across years. While zero trade flows account for almost 81 per cent of the observations in 1995, this fraction reduces to 71 per cent in 2006. This reduction implies that there have been new bilateral trade routes created over the course of 12 years in motor vehicles and parts industry. We can interpret this as the reflection of extensive margin effect in the data resulting from firm entry and exit over the years.

3.5 Empirical Methodology

We follow the common practice of estimating the intensive and extensive margins of trade using a specification based on the gravity equation. Our empirical strategy draws on the work of Helpman et al. (2008) and Crozet and Koenig (2010). The empirical strategy in Helpman et al. (2008) is to develop a two-stage Heckman estimation procedure where they explicitly account for unobserved firm heterogeneity and sample selection bias to consistently estimate the gravity equation in a firm heterogeneity model. Similarly, we consider two equations. The first one is an export participation equation in which we estimate the effect of distance on the probability that a firm exports on the r-s route. The second one is a gravity equation in which we estimate the effect of distance on aggregate trade flows. We diverge from Helpman et al. (2008) on two fronts. First, we estimate these two equations separately, not simultaneously. Second, our latent variable definition for the first equation is different and follows Crozet and Koenig (2010).

Since we focus only on the motor vehicles and parts industry, we suppress the h subscript for industries in the rest of the paper. Moreover, we introduce a time subscript t to the variables that have different values across years.

3.5.1 Export Participation: Probit

The first equation we estimate is the probability of firm participation in export markets which captures entry/exit of firms, i.e. the extensive margin effect. Firm activity is not explicit in our dataset because we only observe trade flows at the country level. Helpman et al. (2008) use a latent variable in order to capture firm behavior in country level observations. Their latent variable is defined as the ratio of variable export profits to fixed export costs. According to this specification, positive trade flows are observed at the country level if and only if the latent variable is greater than one. However, this specification does not use the information implicit in the productivity distribution. As a result, the Pareto shape parameter does not appear in the export selection equation considered in Helpman et al. (2008). In this paper, we want to show the interaction between the shape parameter (γ) and the substitution elasticity (σ) which requires use of the productivity distribution. Therefore, we follow the latent variable definition in Crozet and Koenig (2010) and compare firm productivity with the productivity threshold in the export market. We now turn to the details of this approach.

A firm with productivity φ exports from country r to s if its productivity level passes the threshold level, i.e. $\varphi > \varphi^*_{rs}$. Let T_{rst} be an indicator variable where $T_{rst} = 1$ if the country r exports MVH to country s in year t, and zero otherwise. Then, the probability that a firm exports from r to s in year t is given by $\Pr(T_{rst} = 1) = \Pr(\varphi > \varphi^*_{rst})$.

When we apply the cumulative distribution function of the Pareto distribution we obtain

$$\Pr\left(T_{rst}=1\right)=\Pr\left(\varphi>\varphi_{rst}^{*}\right)=\left(\varphi_{rst}^{*}\right)^{-\gamma} \tag{3.14}$$

Substituting equation (3.6) and (3.14) and rearranging, we obtain the following equation for firm selection into export markets:

$$\Pr\left(T_{rst}=1\right)=\left[\frac{\sigma}{\sigma-1}\frac{\tau_{rst}c_r}{P_s}\left(\frac{c_r f_{rst}}{Y_s}\right)^{\frac{1}{\sigma-1}}\right]^{-\gamma}=\left(\frac{\sigma}{\sigma-1}\right)^{-\gamma}\left(\frac{\tau_{rst}}{P_s}\right)^{-\gamma}\left(\frac{f_{rst}}{Y_s}\right)^{\frac{-\gamma}{\sigma-1}}c_r^{\frac{-\gamma\sigma}{\sigma-1}}. \tag{3.15}$$

We do not have information about the value of variable trade costs and bilateral fixed export costs in our dataset. Hence we follow the convention of imposing additional structure on variable and fixed costs. Variable trade costs are assumed to be a function of distance between countries and several other trade barriers as follows:

$$\tau_{rst}=D_{rs}^{\delta}\exp\left(-k\psi_{rst}-u_{rst}\right), \tag{3.16}$$

where D_{rs} is the distance between country r and s, δ is the distance elasticity of trade which is strictly positive, ψ_{rst} is a vector of trade impeding and trade facilitating variables and $u_{rst}\sim N\left(0,\sigma_u^2\right)$ captures unobserved trade costs that are i.i.d.

We follow Balistreri et al. (2011) and Helpman et al. (2008) and model fixed export costs as a combination of barriers imposed by importers only, by exporters only and by a county-pair specific bilateral cost. Let $f_{rst}\equiv\exp\left(\theta_r+\theta_s+\kappa\theta_{rs}-v_{rst}\right)$, where θ_r are fixed export costs common across destinations incurred by exporting country r, θ_s are the fixed trade barriers imposed by the importing country on all exporters, θ_{rs} are country-pair specific fixed trade barriers, and $v_{rst}\sim N\left(0,\sigma_v^2\right)$ captures unmeasured trade frictions. Helpman et al. (2008) notes that v_{rst} is i.i.d; however, they may be correlated with the unmeasured variable trade costs, u_{rst}.

Incorporating these definitions of variable and fixed export costs into equation (3.15) and taking logarithms of both sides we get the following probit equation:

$$\Pr\left(T_{rst}=1\right)=\alpha_0-\delta\gamma\ln D_{rs}+E_r+E_s+\alpha_4\theta_{rs}+\alpha_5\psi_{rst}+\eta_{rst}, \tag{3.17}$$

where $\alpha_0=-\gamma\ln\frac{\sigma}{\sigma-1}$, $\alpha_4=\frac{\gamma\kappa}{1-\sigma}$, $\alpha_5=k\gamma$, $E_r=\frac{\gamma\sigma}{1-\sigma}\ln c_r+\frac{\gamma}{1-\sigma}\theta_r$, is an exporter fixed effect which controls for the marginal cost (c_r) and fixed cost (θ_r) that are associated with the exporter, $E_s=\gamma\ln P_s+\frac{\gamma}{\sigma-1}\ln Y_s+\frac{\gamma}{1-\sigma}\theta_s$ is an importer fixed effect which controls for market size and fixed costs associated with the importer and $u_{rst}+v_{rst}=\eta_{rst}\sim N\left(0,\sigma_u^2+\sigma_v^2\right)$ is i.i.d.[12] We also add a year dummy that controls for the omitted variables which vary across years but common to all trade flows. The estimating equation, then, becomes

$$\Pr\left(T_{rst}=1\right)=\alpha_0-\delta\gamma\ln D_{rs}+E_r+E_s+E_t+\alpha_4\theta_{rs}+\alpha_5\psi_{rst}+\eta_{rst}, \tag{3.18}$$

where E_t is a year dummy. In our first step regression, we estimate the Probit equation in (3.18) for motor vehicles and parts industry. Since fixed export costs, captured by the variable θ_{rs}, only affect the probability of a bilateral trade taking place, we can use them as exclusion restrictions. We will turn to this again in the results section.

3.5.2 Trade Flows: OLS

The second step in our empirical strategy is to estimate the value of export sales using the gravity equation. We use the aggregate sales of motor vehicles and parts from country r to country s that is governed by equation (3.8). Log linearizing equation

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[12] There is an implicit assumption we impose here. For simplicity, we assume that $\sigma_\eta^2\equiv\sigma_u^2+\sigma_v^2=1$. Helpman et al. (2008) do not impose this restriction which means that all coefficient estimates in their Probit specification is normalized by σ_η.

(3.8) and using variable trade costs defined as (3.16), we obtain the following regression equation:

$$\ln M_{rst} = \lambda_0 - \delta\left(\sigma - 1\right)\ln D_{rs} + E_r + E_s + \lambda_4 \psi_{rst} + \ln \mathrm{V}_{rst} + u_{rst}, \tag{3.19}$$

where $\lambda_0 = \left(1 - \sigma\right)\ln\sigma/(\sigma - 1)$, $[\lambda_4 = k\left(\sigma - 1\right)$, $E_r = \left(1 - \sigma\right)\ln c_r + \ln N_r$ is an exporter fixed effect which controls for the marginal cost (c_r) and new varieties (N_r) that are associated with the exporter, $E_s = \left(\sigma - 1\right)\ln \mathrm{P}_s + \ln \mathrm{Y}_s$ is an importer fixed effect which controls for importer size and prices, and $u_{rst} \sim N\left(0, \sigma_u^2\right)$ is i.i.d.

Consistent estimation of Equation (3.19) requires two corrections as argued in Helpman et al. (2008). The first correction requires adding a control variable into (3.19) for the sample selection bias. Omitting country pairs that have zero trade flows from the dataset might cause a correlation between the unobserved u_{rst} and the explanatory variables. Therefore, we need a consistent estimate for $E\left[u_{rst}|., T_{rst} = 1\right]$. Following Helpman et al. (2008) we define the consistent estimate as $E\left[u_{rst}|., T_{rst} = 1\right] = corr\left(u_{rst}, \eta_{rst}\right)\sigma_u \bar{\eta}_{rst}$ where $\bar{\eta}_{rst} = E\left[\eta_{rst}|., T_{rst} = 1\right]$. In order to be able use this in the gravity equation, we also need a consistent estimate of $\bar{\eta}_{rst}$. As is customary in the Heckman procedure, we obtain this consistent estimate from the inverse Mills ratio $\hat{\bar{\eta}}_{rst} = \frac{\phi(\hat{\rho}_{rst})}{\Phi(\hat{\rho}_{rst})}$, where $\hat{\rho}_{rst}$ be the predicted probability of trade between country r and s based on the estimated Probit equation in (3.18).

The second correction requires adding a control variable into (3.19) for the entry/exit of firms into export markets which is captured by the variable $\ln \mathrm{V}_{rst}$. Since firm productivity is not observed, we need a consistent estimate for $E\left[\ln \mathrm{V}_{rst}|., T_{rst} = 1\right]$. Here, we diverge from Helpman et al. (2008) because our export participation is different from theirs. Instead, we use the relationship between $\ln \mathrm{V}_{rst}$ and $\ln \varphi^*_{rst}$ and apply the cumulative distribution function of firm productivity. The predicted value of our latent variable is $\hat{\rho}_{rst} = \left(\hat{\varphi}^*_{rst}\right)^{-\gamma}$. In log-linear form this is equivalent to $\ln \hat{\varphi}^* = \frac{1}{-\gamma}\ln \hat{\rho}_{rst}$.

Using this condition and the definition in (3.11), a consistent estimate for $\ln V_{rst}$ is given by the following:

$$\ln \hat{V}_{rst} = \ln \frac{\gamma}{\gamma - \sigma + 1} + \frac{\gamma - \sigma + 1}{\gamma} \ln \hat{\rho}_{rst}. \tag{3.20}$$

We use (3.20) to transform our gravity equation in (3.19) which gives

$$\ln M_{rst} = \beta_o - \delta\left(\sigma - 1\right) \ln D_{rs} + E_r + E_s + E_t + \beta_4 \psi_{rst} + \beta_5 \ln \hat{\rho}_{rst} + \beta_6 \hat{\eta}_{rst} + \varepsilon_{rst}, \tag{3.21}$$

where $\beta_o = \lambda_0 + \ln \frac{\gamma}{\gamma - \sigma + 1}$, $\beta_4 = \lambda_4$, $\beta_5 = \frac{\gamma - \sigma + 1}{\gamma}$ and $\beta_6 = corr\left(u_{rst}, \eta_{rst}\right) \sigma_u$. We note that the new error term ε_{rst} satisfies the condition $E\left[\varepsilon_{rst} | ., T_{rst} = 1\right] = 0$. In our second step regression, we estimate the gravity equation in (3.21) for motor vehicles and parts.

Equation (3.17) delivers a combination of the distance elasticity and the shape parameter, $-\delta\gamma$, while equation (3.19) delivers a combination of the distance and demand elasticities, $-\delta\left(\sigma - 1\right)$. However, estimates of $-\delta\gamma$ and $-\delta\left(\sigma - 1\right)$ are not enough to identify three parameters separately.

To circumvent this difficulty Crozet and Koenig (2010) estimate a third equation that governs the relationship between each firms total factor productivity and its production by using firm level data. From this equation they obtain an estimate of $-\gamma + (\sigma - 1)$, which facilitates the identification of three parameters in three equations. With country-level data we cannot determine the relationship between firm sales and their total factor productivity. Instead, we take the ratio of the two coefficients from the Probit and OLS equations which gives estimates of $\gamma/(\sigma - 1)$. Incidentally, this fraction is the Power Law exponent of firm size distribution.

In order to solve for the elasticity of substitution in this fraction, we use the shape parameter estimates provided in Spearot (2015). This method delivers estimates of

σ, which are conditional on γ, and therefore, consistent with the underlying firm heterogeneity theory. This estimate of σ is assumed to capture changes in trade flows coming from substitutability in consumption while γ captures the changes in trade flows taking into account the variation in productivity across industries and regions.

3.6 Results and Discussion

In this section we present and discuss the estimation results. We also note the implications of these results as well as the limitations in the discussed empirical analysis.

3.6.1 Estimation Results

Table 3.4 presents our estimation results. The first two columns give the regression results for a Probit model that determines the probability of firm export participation. Column (1) reports marginal effects evaluated at sample means, while estimates reported in (2) are parameter estimates. Column (3) gives our benchmark model which is a standard gravity equation estimated using ordinary least squares. Column (4) reports estimation results for equation (3.21) where we include the variables $\ln \hat{\rho}$ and $\hat{\eta}$ which correct for sample selection as well as firm heterogeneity. All models in Table 3.4 include country-specific fixed effects as well as year dummies. Standard errors reported in all models are adjusted for clustering on country-pairs.

Our estimation results are in line with the gravity literature in general. In both (1) and (3) distance is found to be statistically significant with an estimated coefficient around -1, which is consistent with the usual coefficient estimates in the gravity literature. Our results show that the rest of the explanatory variables are positive in both regressions. In particular, we find that the probability of exporting as well as the volume of exports increases between country-pairs when countries: (i) are closer to each other, (ii) are adjacent, (iii) are colonized by the same country, (iv) are both

Table 3.4. Gravity Estimation Results for Motor Vehicles and Parts (MVH in GTAP), 113 Countries, for Years 1995-2006.

	Export Participation (Probit)		Export Value (OLS)	
Variables	Marginal Effects (1)	Coefficients (2)	Benchmark (3)	FH-SS (4)
log(Distance)	-0.093***	-0.941***	-0.914***	-1.121***
	(0.003)	(0.031)	(0.038)	(0.056)
Contiguity	0.043***	0.435***	0.548***	0.635***
	(0.011)	(0.116)	(0.105)	(0.118)
Common Colony	0.067***	0.675***	0.767***	0.960***
	(0.009)	(0.087)	(0.140)	(0.237)
Colonial Link	0.058***	0.582***	0.405***	0.581***
	(0.012)	(0.121)	(0.108)	(0.120)
Landlocked	0.015	0.154	0.023	-0.074
	(0.01)	(0.104)	(0.138)	(0.188)
Common Legal Origins	0.023***	0.235***	0.224***	0.323***
	(0.004)	(0.037)	(0.047)	(0.051)
Common Currency	0.018	0.179	0.374***	0.166
	(0.023)	(0.227)	(0.113)	(0.120)
GATT /WTO Membership (both)	0.025***	0.256***	0.383***	0.532***
	(0.004)	(0.045)	(0.056)	(0.066)
FTA/RTA	0.041***	0.410***	0.681***	0.728***
	(0.005)	(0.050)	(0.062)	(0.073)
Common Language	0.021***	0.212***	0.0565	
	(0.006)	(0.059)	(0.077)	
Sample Selection ($\hat{\eta}$)				-0.435*
				(0.227)
Firm Heterogeneity ($ln\hat{p}$)				-0.183***
				(0.033)
Observations	151,872		34,583	28,355
R^2	0.672		0.699	0.721

Notes: Probit reports both the marginal effects at sample means and coefficient estimates, Benchmark is an OLS specification of a traditional gravity equation without any corrections, FH-SS is an OLS specification of a gravity equation with both firm heterogeneity (FH) and sample selection (SS) corrections, SS only corrects for the sample selection bias, and FH only corrects for the firm heterogeneity bias. Each model includes importer, exporter and year fixed effects.R^2 in Probit corresponds to pseudo-R^2. Robust standard errors with country-pair clustering are reported in parantheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

members of GATT/WTO, (v) are both in the same FTA, (vi) share a colonial link, or (vii) share a common legal system.

Our results show that the landlocked indicator is not significant either for export participation or for volume of exports. Moreover, the fact that two countries share the same currency is not significant for export participation, while it increases the volume of exports. To the contrary, the probability that two countries share a common language increases the probability of exporting while it is not significant for how much they trade. We attribute this to the fact that language is akin to a fixed export cost. Once the firm engages in trade, having a common language ceases to be a significant factor for trade volumes as the firm has already invested in the new language for marketing, legal work etc.

As discussed in Helpman et al. (2008) estimating a two-stage model requires using an exclusion restriction that is correlated with the probability of export participation, but not correlated with the residuals in the second-stage gravity equation, as once a decision to export has been made, the exclusion restriction is no longer important for trade volumes. In our model, common language satisfies these requirements for a valid exclusion restriction. This is evident from the regression results in (1) and (3). As mentioned before, common language reduces fixed costs of exporting and thereby it is a significant factor in export participation, while it does not matter for trade volumes. The validity of common language as an excluded variable is also argued by Helpman et al. (2008) who use common language as an alternative exclusion restriction and obtain similar results to the case where religion is used as an excluded variable.

Comparison of (3) with (4) suggests that the coefficients for almost all explanatory variables are underestimated in the benchmark model. These findings substantially differ from Helpman et al. (2008). Their results suggest that the parameters in benchmark model are overestimated because the extensive margin effect and the country pairs that have zero trade flows are excluded in the gravity equation. In particular, they argue that ignoring sample selection introduces a downward bias, while ignoring firm heterogeneity introduces an upward bias. However, according to our results, not only sample selection control, but also firm heterogeneity control corrects for the downward bias. We attribute the difference in our results to the latent variable specification used for the Probit model. Basically, the control for firm heterogeneity captures the movements in productivity thresholds for export markets as trade barriers change. For example, a higher productivity threshold for exporting to a particular country forces low-productivity firms to exit the market which reduces the number of exporters on that bilateral route. Because of having fewer exporters in the market, aggregate trade flows for MVH declines. This is reflected as a significant and negative coefficient on the firm heterogeneity control variable reported in column (4).

While the variable correcting for firm heterogeneity is highly significant, the variable correcting for sample selection is barely significant in column (4). To further explore the effect of each correction in explaining aggregate trade flows in MVH, we estimate two more specifications each focusing on one of the corrections. Results of these regressions are reported in Table 3.5.

In order to facilitate comparison across models we report the estimation results of the benchmark model in column (1) and the estimation results including both corrections in column (2). The results of sample selection correction are given in column (3), while the results of firm heterogeneity correction are given in column (4). We note that the coefficient estimate for sample selection is significant and enters positively contrary to (2). When we look at the firm heterogeneity correction in (4), we see that the coefficient estimates are slightly lower than (3) and similar to (2). Hence we see that firm heterogeneity correction dominates in (2) to the extent that sample selection changes sign and almost becomes insignificant for trade flows in the motor vehicles and parts industry. Overall, the coefficient of distance is robust to

Table 3.5. Corrections in the Gravity Equation for Motor Vehicles and Parts (MVH in GTAP), 113 Countries, for Years 1995-2006.

	Export Value (OLS)			
Variables	Benchmark (1)	FH-SS (2)	SS (3)	FH (4)
log(Distance)	-0.914***	-1.121***	-1.267***	-1.126***
	(0.038)	(0.056)	(0.051)	(0.056)
Contiguity	0.548***	0.635***	0.629***	0.628***
	(0.105)	(0.118)	(0.109)	(0.118)
Common Colony	0.767***	0.960***	1.046***	0.960***
	(0.140)	(0.237)	(0.157)	(0.238)
Colonial Link	0.405***	0.581***	0.696***	0.590***
	(0.108)	(0.120)	(0.117)	(0.120)
Landlocked	0.023	-0.074	0.030	-0.070
	(0.138)	(0.188)	(0.146)	(0.188)
Common Legal Origins	0.224***	0.323***	0.358***	0.325***
	(0.047)	(0.051)	(0.045)	(0.051)
Common Currency	0.374***	0.166	0.110	0.150
	(0.113)	(0.120)	(0.123)	(0.120)
GATT /WTO Membership (both)	0.383***	0.532***	0.504***	0.536***
	(0.056)	(0.066)	(0.053)	(0.066)
FTA/RTA	0.681***	0.728***	0.819***	0.737***
	(0.062)	(0.073)	(0.061)	(0.073)
Common Language	0.0565			
	(0.077)			
Sample Selection ($\hat{\eta}$)		-0.435*	1.375***	
		(0.227)	(0.071)	
Firm Heterogeneity ($ln\hat{\rho}$)		-0.183***		-0.098***
		(0.033)		(0.028)
Observations	34,583	28,355	34,583	28,355
R^2	0.699	0.721	0.729	0.721

Notes: Benchmark is an OLS specification of a traditional gravity equation without any corrections, FH-SS is an OLS specification of a gravity equation with both firm heterogeneity (FH) and sample selection (SS) corrections, SS only corrects for the sample selection bias, and FH only corrects for the firm heterogeneity bias. Each model includes importer, exporter and year fixed effects.R^2 in Probit corresponds to pseudo-R^2. Robust standard errors with country-pair clustering are reported in parantheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

different specifications which is reassuring, as this is what will give us the desired elasticities, to which we now turn[13].

3.6.2 Elasticity of Substitution across Varieties

Up to this point, we have largely followed on the heels of existing work. However, the main interest in this paper lies in obtaining substitution elasticities that are consistent with the underlying firm heterogeneity theory. Given the coefficient estimates reported in Table 3.4, we can now solve for the theoretically-consistent elasticities for use in global trade analysis.

Table 3.6. Elasticities of Substitution between Varieties of Different Sources.

	Models (1)	Probit (2)	Power Law Exponent (3)	Shape Parameter* (4)	Melitz Elasticity (5)	GTAP Armington Elasticity (6)
	$-\delta(\sigma-1)$	$-\delta\gamma$	$\gamma/(\sigma-1)$	γ	σ	ESUBM
Benchmark	-0.91	-0.94	1.03	1.79	2.74	5.60
FH-SS	-1.12	-0.94	0.84	1.79	3.13	5.60

* From Spearot (2015).

Notes: Probit reports coefficient estimates, Benchmark is an OLS specification of a traditional gravity equation without any corrections, FH-SS is an OLS specification of a gravity equation with both firm heterogeneity (FH) and sample selection (SS) corrections.

Table 3.6 reports these elasticities for the motor vehicles and parts industry under the benchmark and FH-SS specifications. A comparison with the associated GTAP Armington elasticity dubbed ESUBM (Hertel et al., 2003) - is also presented in Table 3.6.

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[13] Silva and Tenreyro (2015) argue that the assumption of homoscedastic error terms adopted in Helpman et al. (2008) causes misspecifications in their gravity model and might lead to biased and inconsistent estimators. In order to control for the heteroskedasticity in the data Silva and Tenreyro (2015) suggest using Poisson Pseudo-Maximum Likelihood Estimator (PPML). As a robustness check, we estimate the gravity equation in (3.19) using PPML. Regression results show that the coefficient estimate of distance is -0.71 and is significant at 1 per cent level.

Column (1) reports the coefficient estimate of distance under the benchmark and FH-SS specifications, while column (2) reports the distance coefficient in Probit. The ratio of column (2) to column (1) gives a similar coefficient as the Power Law exponent of firm sizes. Values of this ratio under two specifications are reported in column (3) and found to be around 1. In particular, the ratio is 1.03 for the benchmark model and 0.84 for the FH-SS corrected model. These values are quite close to the Power Law exponent estimates found in the literature summarized in Table 3.2 (Axtell, 2001; di Giovanni and Levchenko, 2013; di Giovanni et al., 2011; Melitz and Redding, 2013). This suggests that empirical evidence about Power Law exponents for firm size is quite robust to the type of data used for estimation, as the value we obtain with country-level data is consistent with that obtained from the firm-level empirical studies.

Armed with empirically supported Power Law exponents, we move on to solve for the theoretically-consistent elasticities of substitution. The shape parameter estimate for motor vehicles and parts industry found in Spearot (2015) is reported in column (4) of Table 3.2. We use this information in the Power Law exponent to solve for our "Melitz substitution elasticities which are reported in column (5). Elasticity values are found to be quite close across our specifications, 2.74 for the benchmark model and 3.13 for the corrected model. Both are substantially lower than the GTAP Armington elasticity of 5.60 and both satisfy the key parameter restriction of the model ($\gamma > \sigma - 1$).

It is important to note that even when the firm heterogeneity and sample selection corrections are not applied, the elasticity implied by the theory is lower than the Armington elasticity used in the GTAP model. This finding is consistent with our arguments and deserves further discussion. Even though the benchmark model does not take sample selection and firm heterogeneity into account, it still gives us a "Melitz elasticity in this framework. This is because we are complementing the estimates found in the benchmark model with the estimates found in the Probit model to infer those elasticities. Although we do not use the Probit predictions in the trade-flow equation, we still use the information about export participation through the Power Law exponent. On the other hand, GTAP Armington elasticities are estimated based only on the trade-flow equation with an Armington structure; thereby, they do not contain any information about firm entry/exit behavior. As a result, we can say that when used with the Probit model, even the benchmark elasticity removes the supply-side effect captured in the GTAP Armington elasticity. In fact, when we compare it with the corrected model, we see that the benchmark case gives a lower elasticity estimate which implies that it removes more than the supply-side effects. That is to say the appropriate elasticity for the firm heterogeneity model lies somewhere between the benchmark elasticity and the GTAP Armington elasticity.

3.6.3 Implications and Limitations

So, what is the economic significance of finding a lower elasticity of substation between varieties for use in global economic analyses? To answer this question we should recall the effect of parameter choice on the extensive margin. Based on the definition in Chaney (2008) the extensive margin captures the contributions to trade flows of both the change in the number of exporters and their respective export volumes. As you may recall this corresponds to the familiar form $\gamma - (\sigma - 1)$. This is where the choice of structural parameters becomes the key to policy implications. The extensive margin is less responsive to trade barriers when the elasticity is high, while the intensive margin is more responsive. Therefore, the choice of structural parameters will determine the trade response as well as the welfare response to policy changes through micro and macro mechanisms in the model. The most relevant mechanisms in this context are changes in average productivity through the self-selection of firms into export markets and changes in consumer utility through the availability of new varieties. Both of these mechanisms primarily depend on the parameter choice.

Finding a lower elasticity means that the demand-side is more heterogeneous in the firm heterogeneity model for motor vehicles and parts than we thought it was based on the Armington elasticity. Since consumer preferences are more heterogeneous there is more room for new exporters in the MVH market to invest in differentiating their varieties. Therefore, marginal firms can markup their prices against large infra-marginal firms in the market. It should be noted that there is also significant supply-side heterogeneity in the MVH market. Spearots shape estimate is 1.79 for MVH is one of the lowest shape parameter values within the aggregate manufacturing industry (Spearot, 2015). This implies that infra-marginal firms have a disproportionate share of the overall activity in this market and marginal firms are much less productive compared to the incumbents. As noted in previous discussions, having a low productivity is less of a disadvantage when preferences are more heterogeneous (low elasticity). Even though marginal firms charge slightly higher prices than the incumbents, consumers are willing to pay a premium for new varieties. However, with a higher elasticity, marginal firms would have lost their market power and would be subsumed by the large and productive infra-marginal firms. So moving from the higher substitution elasticities used previously in GTAP-based studies of firm heterogeneity to the lower values suggested by this study represents an important change.

The take-away from this discussion is that the relative value of the shape parameter and the elasticity of substitution have important consequences for trade and welfare responses in a firm heterogeneity model. In a sense, quantitative outcomes are driven by the Power Law exponent of firm size. For example, as mentioned before, di Giovanni and Levchenko (2013) show that welfare impact of the extensive margin of trade is negligible when the Power Law exponent is 1, i.e. when the firm size distribution converges to Zipfs Law. In fact, they compare welfare gains from reductions in fixed and variable costs when the Power Law exponent is 1 to the case when it equals 2. They show that when the Power Law exponent equals 1, welfare gains from reductions in fixed costs are an order of magnitude lower and welfare gains from reductions in variable costs are an order of magnitude higher compared to the case when the Power Law exponent is 2. Quantitative outcomes are not the only policy implications we are interested in. Parameter choice also matters for analyzing the dominant mechanisms in bringing about the changes in trade flows and welfare.

The objective in this paper is to highlight the need for parameterization of the firm heterogeneity module of GTAP for practical policy analysis. We illustrate the need for using theoretically-consistent parameters with empirical examples in order to have a more informed discussion about the issue. However the work presented here has some limitations. First of all, the use of untruncated Pareto distribution in our theoretical model imposes some restrictions on the theory to explain zero trade flows between countries. The explanatory power of the model can be improved by putting bounds on the productivity distribution similar to Helpman et al. (2008). Secondly, elasticity values presented in this study are conditional on the choice of the shape parameter value as well as the underlying model specification. In particular, some of the variation in our firm heterogeneity elasticities is the result of using Spearot (2015) shape estimates, which are lower than the inferred shape parameters in the mainstream literature. In our view, this issue is an econometric one that requires firm-level data to estimate both parameters simultaneously. Future work should focus on separate identification of key firm heterogeneity parameters and provide confidence intervals to those estimates for systematic sensitivity analysis. While our objective in this paper is to define the problem, the outstanding issue of parameter identification remains to be open for future work.

3.7 Concluding Remarks

In this study we discuss a theoretically-consistent way to parameterize the firm heterogeneity model with a focus on the elasticity of substitution across varieties. The current CGE literature relies on Armington elasticities and infers shape parameters based on these elasticities. However, Armington elasticities are not appropriate in a firm heterogeneity model. In fact, their interpretation and the underlying econometric specification for their estimation are different in a Melitz (2003) framework. Particularly, the traditional gravity equation that delivers Armington elasticities do not control for the impact of firm self-selection into export markets which is the main micro mechanism for productivity and variety induced gains from trade. In the absence of firm behavior the resulting coefficient estimates confound the demand-side effects with the supply-side effects. This indicates overestimated elasticities which pick up part of the supply-side heterogeneity governed by the shape parameter. The resulting parameter set used in the current CGE literature is, then, an overestimated Armington elasticity with an inferred shape parameter that does not capture the substantial variation across industries.

In this study we distinguish between the intensive and extensive margins of trade flows to obtain theoretically-consistent elasticities. In particular, we estimate two equations: an export participation equation and a gravity equation that governs bilateral trade flows. Since we use country level data, we impose further information in order to identify the elasticities. Specifically, we use the shape parameter estimates provided in Spearot (2015) which shows the variation of heterogeneity across industries and regions. Our results show that GTAP Armington elasticities are significantly higher than the elasticity estimates that are theoretically consistent with the Melitz (2003) model.

This study provides an informed discussion about the theoretically-consistent parameterization of firm heterogeneity models in a CGE setting. Since we work with country-level data, separate identification of parameters is not feasible. Therefore, we rely on external shape parameter estimates. Our future research agenda is to identify elasticities and shape parameters separately by utilizing firm-level data. We, then, will be able to test the observational equivalence between an Armington-based model with a Melitz (2003) model in a CGE setting. We believe that combining theory-consistent econometric evidence with the firm heterogeneity model in a CGE framework will lead the way for mainstream application of firm heterogeneity models in the GTAP community.

CHAPTER 4. FIRM HETEROGENEITY, FIXED COSTS AND INTERNATIONAL TRADE AGREEMENTS: THE CASE OF US-EU BEEF TRADE

4.1 Introduction

Regulatory measures and non-tariff barriers are among the key issues discussed in recent trade agreement negotiations between the United States (US) and the European Union (EU). Lowering of protection on several agricultural products has been on the agenda of the Transatlantic Trade and Investment Partnership (TTIP) Agreement where beef trade stands out among many others as it is heavily protected in the EU market. Non-tariff barriers in the EU beef market include sanitary and phystosanitary (SPS) measures such as the hormone ban on beef (Arita et al., 2014). In particular, the use of growth-promoting hormones in beef production was banned in the EU in 1989 which has put a significant restriction on US beef exports into the EU market (FAS, 2014). These measures have been subject to scrutiny by US beef exporters as well as industry stakeholders and are being discussed in recent TTIP negotiations.

In order to ensure that beef exports meet the EU standards, the Agricultural Marketing Service (AMS) of the United States Department of Agriculture (USDA) has been offering the Non-Hormone Treated Cattle (NHTC) Program (FSIS, 2014). Signing up for this program brings additional costs to the firms as it requires them to pay for on-site visits by AMS, prepare the associated documents, adapt the production and packing processes to comply with the hormone-free beef production etc (Arita et al., 2014). These are significant fixed costs which may prevent US beef producers to export into the EU market. Removal of these barriers could yield significant economic gains by reducing fixed costs in export markets and by US improving market access to the EU.

There are a few CGE-based studies of the TTIP that quantify the economic implications of removing NTMs in general (ECOYRS, 2009; CEPR, 2013; EP, 2014) and the beef hormone ban in particular (Arita et al., 2015; Beckman and Arita, 2015). The established approach in this literature is to model trade based on the Armington assumption of national product differentiation. Even though computational policy analysis with Armington-based models shed some light on the implications of NTM removal, it fails to capture (i) important demand-side mechanisms based on product differentiation and (ii) important supply-side mechanisms based on productivity dispersion across firms.

Beef industry is assumed to have a perfectly competitive market structure in these studies (Arita et al., 2015; Beckman and Arita, 2015). However, a more appropriate treatment is to allow for monopolistic competition in the beef industry. Consumers in the EU market differentiate between hormone-free and hormone-treated beef such that they have a higher preference for the hormone-free varieties (Lusk et al., 2003). In fact, studies show that European consumers, on average, indicate a willingness to pay a premium for steaks with a *USDA Choice No Hormones or GMOs* stamp (Tonsor and Shroeder, 2003). A monopolistically competitive industry structure fits better in this case as it captures the effect of availability of different varieties from different source regions.

On the supply-side, the interaction of fixed costs and productivity dispersion across firms provides significant insights into which exporters will sign up for the NHTC program and which will be given the license to export. One of the stylized facts in the empirical literature is that firms substantially vary in their efficiency levels and only the relatively productive ones are able to export (Bernard and Jensen, 1999;

Bernard et al., 2003). This applies to the beef industry as well which implies that the same fixed costs imposed by the NHTC program do not affect each firm in the same way. Productivity dispersion in the beef market dictates which firms will export and which firms will supply the domestic market. Therefore, the costly compliance procedures may prevent inefficient US firms to export beef into the EU market. These mechanisms have significant welfare implications.

In this paper we address these gaps by using the firm heterogeneity module of GTAP developed in Chapter 2 where we explicitly model monopolistic competition with firm-level heterogeneity based on the seminal work of Melitz (2003). A unique aspect of this model is its ability to capture the trade creation and diversion effects at the extensive margin and to tease out productivity changes due to within-industry factor movements. These new mechanisms available in the firm heterogeneity module of GTAP will help better understand the welfare implications of NTMs in general and hormone ban in particular. In addition, we provide values for key parameters of the firm heterogeneity model consistent with the underlying theory based on the insights discussed in Chapter 3.

In this paper we explore the implications of reducing the hormone ban imposed by the EU on US beef imports by using two specific policy instruments: (i) reduction in fixed export costs, (ii) reduction in tariff rates. There are three forms of modeling NTMs in the mainstream CGE literature. These are summarized by Andriamananjara et al. (2003) as tariff-equivalent, export tax equivalent and as efficiency losses. Our treatment for (i) falls broadly under the efficiency loss category, while that of (ii) falls under the tariff-equivalent category.

In the GTAP model NTMs are modeled as efficiency losses by considering their implications on the effective price and demand for imports from a particular exporter (Hertel et al., 2001). This is a demand-side treatment of NTMs which does not trace out the direct effect of fixed costs on firms. However, the fixed costs associated with beef hormone ban accrue directly to producers and exporters before they are reflected in consumer prices. Therefore, we lose important information about firm behavior when NTMs are modeled on the demand-side only. A novelty in our paper is to model NTMs on the supply-side. In particular, we map NTMs to country pair-specific fixed export cost shifters that capture efficiency losses on the use of inputs that cover fixed costs. These shifters are additional policy leverages introduced to the GTAP model in the context of firm heterogeneity.

Finally, we explore the welfare implications of reducing the fixed export costs associated with beef hormone ban. We compare welfare predictions under the firm heterogeneity model to the mainstream models, in this case the standard GTAP model with Armington assumption and perfect competition.

4.2 Data and Empirical Background

Our model is calibrated to GTAP Version 9 Pre-release 1 data base with 2011 as the base year. We aggregate the data base to include eight regions, six tradeable products and three primary factors of production as listed in Table 4.1.

The choice of our regional aggregation is based on major trade partners of US and major beef exporters to the EU. South American countries constitute the biggest

Table 4.1. Data Aggregation: GTAP Version 9.1 Pre-release.

Regions		Sectors	Endowments
European Union (EU)	Canada	Primary Food	Land
United States (USA)	Mexico	Extraction	Labor
Brazil	China	Beef	Capital
Argentina	India	Processed Food	
Uruguay	Rest of the World (ROW)	Manufactures	
Australia		Services	

share in beef import of the EU. In particular, Brazil (40%), Argentina (21%) and Uruguay (17%) account for 78 percent of beef imports in the EU between 2009 and 2013 (Arita et al., 2014) followed by the US as the fourth largest source.

Our sectoral aggregation consists of primary food, extraction products, beef, processed food, manufactures and services. The details of this aggregation are summarized in Appendix C. In the GTAP sectoral definition beef includes *bovine meat products*. Therefore, the beef industry in this study is composed of firms that produce and sell bovine meat products. The rest of the firms which produced other processed food are included in the processed food industry.

We assume a monopolistically competitive market structure in the beef industry with firm-level productivity heterogeneity. The motivation for this treatment is based on consumer preferences. Beef is not just one homogeneous product. There are many varieties within the industry. The most important distinction is between hormone-free and hormone-treated beef. Consumers in the EU have a higher preference for the hormone-free varieties of beef (Lusk et al., 2003) which are sold as premium products.

There is also variation across the varieties of different regions. For example, US beef imports in the EU are grain-fed and are considered as higher value products. In contrast, South American beef is categorized as prepared products such as corned beef and manufacturing-grade product used in ground beef production (Arita et al., 2014).

Similar to beef, we treat processed food and manufacturing industries as monopolistically competitive with heterogeneous firms. The other sectors (Primary Food, Extraction and Services) are assumed as perfectly competitive.

Key to our analysis is how we calibrate the parameters of our aggregation in the firm heterogeneity model. There are two parameters of particular importance in the firm heterogeneity model: (i) the elasticity of substitution across varieties which governs the demand-side heterogeneity and (ii) the shape parameter of productivity distribution (Pareto) which governs the supply-side heterogeneity. As discussed in Chapter 3, parametric assumptions are paramount to computational policy analysis. Interpretation and estimation/calibration of key parameters of the model have to be tailored to the model specification.

These arguments have been addressed in Chapter 3 and we find that the elasticity of substitution is different between the firm heterogeneity model and the Armington-based perfect competition models. As a result, we cannot simply use the Armington elasticities in the GTAP data base in this study. Instead, we use the method proposed in Chapter 3 and obtain the theoretically-consistent elasticities for the firm heterogeneity model conditional on shape parameter estimates of Spearot (2015). We, then, aggregate the new elasticities based on each product's respective share in world trade, while we aggregate the shape parameters based on each industry's respective share in total costs of production. The calculated parameter values are presented in Table 4.2.

Table 4.2. Key Parameters of the Model.

Aggregate Sectors	Market Structure	Shape Parameter γ	Melitz Elasticity σ	GTAP Armington Elasticity ESUBM
Primary Food	PC	-	-	4.97
Extraction	PC	-	-	10.65
Beef	FH	3.78	4.21	7.70
Processed Food	FH	2.71	2.95	4.90
Manufactures	FH	2.59	3.55	7.16
Services	PC	-	-	3.85

Notes: FH: Firm heterogeneity, PC: Perfect Competition (Armington).

Parameters in perfectly competitive industries are calibrated via the usual techniques where GTAP Armington elasticities are used for primary food, extraction and services products. For the monopolistically competitive industries with heterogeneous firms, we find that 'Melitz' elasticities are lower than the GTAP Armington elasticities. The 'Melitz' elasticity for the beef industry is found to be 4.21, while the elasticity is 7.70 if the industry was treated as perfectly competitive. This big difference indicates that the choice of market structure would have important welfare implications.

4.3 Policy Application

In this section we present our policy applications in the firm heterogeneity module of GTAP developed in Chapter 2. Specifically, we examine the implications of reducing EU's hormone ban imposed on US beef imports by using two specific policy instruments: (i) reduction in fixed export costs, (ii) reduction in tariff rates. We, then, compare the effects of each policy under the firm heterogeneity model with that of the perfect competition model.

4.3.1 Treatment of Non-Tariff Measures

Treatment of NTMs in the firm heterogeneity model is quite different than the mainstream approach adopted in the standard GTAP model. To highligt the differences we briefly summarize each approach before detailing the specifics of the shocks.

NTMs are modeled as efficiency losses in the standard GTAP model. They enter as technical coefficients, `AMS(i,r,s)`, and work through the demand-side (Hertel et al., 2001). `AMS(i,r,s)` is defined as the import augmenting technical change of product i from source region r to destination s. Changes in the value of `AMS(i,r,s)` are reflected in the price of imports from a particular exporter as well as the demand for imports from that exporter. Thus, non-tariff measures work its way through the prices. Moreover, since there are no NTM costs in the initial data base, the model needs to be calibrated to add those costs into the data.

Unlike the standard GTAP model, the impact of NTMs work through the supply-side in the firm heterogeneity model. In particular, we map NTMs to country pair-specific fixed export cost shifters that capture efficiency losses on the use of inputs that cover fixed costs. For this purpose, a new policy instrument `AVAFX(i,r,s)` is defined as the technical change in the fixed cost of exporting product i from source region r to destination s. An increase in AVAFX(i,r,s) ensures a fall in the effective quantity of value-added used in covering the fixed export costs in that particular market. In other words, each firm faces lower fixed export costs conditional on exporting. This has repercussions for the effective price of value-added as well. In this model, we assume that firms' price of value-added is the same for fixed and variable portions of value-added in order to ensure market clearing for endowments. Therefore, an improvement in the efficiency of fixed costs reduces the effective price of all value-added independent of whether it is employed in the variable cost coverage or fixed cost coverage.

Initial fixed costs in the model are calibrated based on a gravity equation of trade flows. Chapter 2 explains this in more detail. Here, we modify the calibration slightly to match the share of revenues spent on fixed costs in the export market to that of fixed costs in the domestic market. Our simplifying assumption is that domestic suppliers face similar plant modification costs to segregate the production line for hormone-free and hormone-treated beef. Based on our parameter settings, we find that the average firm in the beef industry devotes 3.6 % of its net revenues from sales in a particular market on the fixed costs to operate in that market.

4.3.2 Shocks on Policy Instruments

The shocks we impose on our policy instruments are based on the gravity estimations obtained in Arita et al. (2015). They use estimates of NTM costs as data in the standard GTAP model as well as in a supply-chain module of GTAP where detailed land-use competition among livestock markets are modeled. The removal of NTM costs is, then, broken out into changes in import taxes (`tms(i,r,s)`), changes in export taxes (`txs(i,r,s)`) and changes in efficiency (`ams(i,r,s)`). They find that if the removal of NTM costs is allocated entirely to the efficiency variable, US beef exports to the EU increases by 274%. If it is allocated entirely to import taxes, US beef exports to the EU increases by 274%, as well. If on the other hand, the removal of NTM costs are broken into three policy variables under a supply-chain model explored by Arita et al. (2015), US beef exports to the EU increases by 306%. These simulation results are in line with the gravity model predictions presented in Arita et al. (2015). According to their gravity model, if the hormone ban were removed, the estimated amount of US beef exports ranges between 210% - 314% across different specifications.

We calibrate the shocks used in our policy scenarios based on the trade volume changes obtained in Arita et al. (2015). We use the percentage change in exports found by using the tariff and efficiency variables only (274%) as opposed to the one found in the supply-chain case (306%). There are two reasons for this preference. First, in the firm heterogeneity model we do not allow for land-use competition among livestock markets as in the supply-chain module in Arita et al. (2015). Second, we explore the effects of policy instruments separately; therefore, isolating the shocks is more appropriate for our purposes.

We fix the percentage change in export sales of beef from the US to EU as 274% in our model and calibrate how much efficiency increase in fixed export costs is required to obtain this trade volume increase. This gives us the shock on our fixed export cost shifter, `avafx(i,r,s)`. We repeat the same procedure for the tariff rate with the same trade volume increase. This gives us the shock on our power of the tariff, `tms(i,r,s)`. These shocks are presented in Table 4.3

We follow the same procedure in calibrating the shocks for the perfect competition model. Note that we use the standard GTAP model as the perfectly competitive model. There are several differences in our policy application under the perfect competition model. First, to calibrate the shock for fixed cost reduction we use the efficiency variable `ams(i,r,s)` as opposed to `avafx(i,r,s)`. Second, in order to be able to compare welfare results in firm heterogeneity with perfect competition we distinguish between Melitz and Armington elasticities in respective model specifications. This is in line with the discussion in Arkolakis et al. (2008) and Dixon et al. (2015). They argue that a meaningful comparison across Melitz and Armington models can be done if the observed trade patterns are equivalent and model-consistent elasticities are used across model specifications. Both of these conditions are satisfied in our policy scenarios. The resulting shocks are summarized in Table 4.3.

Table 4.3. Shocks Imposed on US Beef Imports in the EU under Firm Heterogeneity and Perfect Competition Models where `j` ∈ `MCOMP_COMM` for Monopolistically Competitive Industry, and `r,s` ∈ `REG` for Regions.

Shock Type	Model	Policy Instrument	Shock Value	Original Ad-Volarem	New Ad-Volarem
Tariff Equivalent	FH	`tms(i,r,s)`	−13.42%	65.28%	43.10%
	PC	`tms(i,r,s)`	−16.05%	65.28%	38.75%
Fixed Costs	FH	`avafx(i,r,s)`	207.54%	–	–
	PC	`ams(i,r,s)`	22.01%	–	–

Notes: FH: Firm heterogeneity, PC: Perfect Competition (Armington). `tms(i,r,s)` is the source-specific change in the power of the tax on imports of product i from source r into destination s, `avafx(i,r,s)` is the technical change in the fixed cost of exporting product i from source r into destination s, `ams(i,r,s)` is the import augmenting technical change of product i from source r into destination s.

A comparison of tariff shocks across model specifications show that a higher tariff reduction is required in the perfect competition model (-16.05%) compared to the firm heterogeneity model (-13.42%) to generate the same increase in US beef exports to the EU. Initial ad-volarem tariff rate imposed on beef exports from the US to EU is 65.28 per cent. A -13.42 per cent reduction in the power of tariff brings about an ad-volarem tariff rate of 43.10 per cent. Therefore, it is not a complete removal of tariff, rather a reduction to facilitate imports from the US.

A positive value for the fixed export cost shifter means that, fixed export costs per active firms will be reduced. As per firm fixed export costs are now lower, profitability in the export market increases which attracts new firms into the market. Therefore, the mass of exporters in the US-EU beef market expands. As a result of this firm entry, total fixed costs incurred in the post-shock economy is actually higher than initial fixed costs. This is purely an extensive margin effect. We should note that the fixed export cost shock of 207.54% does not eliminate all fixed costs. It is merely a reduction in fixed costs per firm conditional on observed trade patterns.

We analyze four scenarios that reduce NTMs on US beef imports in the EU:

- Fixed cost reduction of 207.54% under the firm heterogeneity model;
- Tariff reduction of 13.42% under the firm heterogeneity model;
- Fixed cost reduction of 22.01% under the perfect competition (Armington) model;
- Tariff reduction of 16.05% under the perfect competition (Armington) model;

4.3.3 Results under the Firm Heterogeneity Model

One of the major mechanisms captured by the Melitz (2003) model is the self-selection of firms into domestic and export markets. In this theory, firm participation in industries or in export markets is governed by the productivity threshold to enter that market. The productivity threshold is defined as the lowest productivity level for a firm to produce or export in that market. We first focus on the effect of fixed export cost reduction on these key firm heterogeneity mechanisms. Then we compare the results with that of the tariff cut scenario.

Table 4.4 presents the changes in the productivity threshold to enter the EU beef market as well as the changes in the number of exporters that supply this market under the fixed cost reduction scenario. Results show that while export productivity threshold decreases for the US firms, it increases for all other regions. The direct effect of lower fixed export costs per firm is a fall in the demand for value-added inputs used by existing US beef exporters to fulfill the AMS export requirements. As fixed export cost per sale decreases, it becomes more profitable for existing US exporters to supply the EU market. This is especially good news for the marginal exporters of US beef who previously made zero profits in the pre-shock economy. As they start to make positive profits, the cutoff productivity level to export into the EU beef market decreases by 79%.

Table 4.4. Fixed Cost Reduction: Changes in the Export Threshold and Number of Exporters to the EU Beef Market (%).

Regions	Productivity Threshold	Number of Exporters
European Union	0.000	−1.506
United States	−78.582	275.863
Brazil	0.013	−0.048
Argentina	0.013	−0.050
Uruguay	0.014	−0.045
Australia	0.013	−0.035
Canada	0.015	−0.049
Mexico	0.014	−0.050
China	0.018	−0.056
India	0.013	−0.038
Rest of the World	0.013	−0.021

The profitability in the European beef market attracts new exporters which previously could not afford to sign up for the AMS program due to their lower productivity levels relative to the existing exporters. Consequently, the number of US exporters that supply the EU market increases by 276%. This rather large increase is partly because of the rate of productivity dispersion in the beef industry. There is a large pool of low-productivity producers in the beef industry around the margin that can profitably export in the post-shock economy.

While this cost reduction benefits US firms, it diverts trade from other beef exporters. US firms meet almost all the demand in the EU beef market such that they replace sales from all other regions. As potential sales to the EU market drop significantly for the rest of the regions, exporters no longer benefit from scale economies. Therefore, their export productivity thresholds increase as shown in Table 4.4. Marginal exporters lose their market sales and start making negative profits which force them out of the EU market. As a result, the number of exporters to the EU beef market diminish in all regions except for the US.

Table 4.5 presents the results in the tariff cut scenario on productivity threshold and number of exporters into the EU beef market. The tariff cut scenario predicts smaller changes for the threshold and mass of exporters. Reduction in fixed export cost per sale increases the profitability of exporting more than cutting tariffs.

Table 4.5. Tariff Reduction: Changes in the Export Threshold and Number of Exporters to the EU Beef Market (%).

Regions	Productivity Threshold	Number of Exporters
European Union	0.000	−1.228
United States	−53.034	103.756
Brazil	0.011	−0.040
Argentina	0.011	−0.042
Uruguay	0.012	−0.036
Australia	0.011	−0.024
Canada	0.012	−0.027
Mexico	0.016	−0.049
China	0.016	−0.049
India	0.011	−0.031
Rest of the World	0.011	−0.015

It is important to note the difference in the nature of tariffs and fixed costs as policy instruments. By using tariffs as a policy instrument we are allowing for money transfers between exporters and importers. On the other hand by using fixed costs, we are actually improving the efficiency of value-added devoted to cover fixed costs and reduce the factor demand of firms for entering a new market. As a result, the underlying general equilibrium mechanisms are markedly different in each scenario.

Table 4.6 presents the changes in the number of exporters, producers and potential firms in the beef industry of each region under both scenarios. We see that beef exporters increase in all regions except for the EU and Argentina. Beef production in the EU falls as the domestic demand is met by the US imports. As a result, factors of production released from the beef industry are devoted to production in the processed food and manufactures industries in the EU.

Table 4.6. Changes in Varieties in the Beef Market under Fixed Cost Reduction and Tariff Cut Scenarios (%).

Regions	**Exporters**		**All Producers**		**Potential Firms**	
	Fixed Cost Reduction	Tariff Reduction	Fixed Cost Reduction	Tariff Reduction	Fixed Cost Reduction	Tariff Reduction
European Union	−0.071	−0.057	−1.506	−1.228	−1.506	−1.228
United States	0.528	0.182	0.289	−0.170	0.537	0.401
Brazil	0.001	0.001	0.001	0.001	0.001	0.001
Argentina	−0.002	−0.001	−0.001	0.000	−0.001	0.000
Uruguay	0.007	0.011	0.006	0.009	0.006	0.009
Australia	0.021	0.027	0.016	0.019	0.016	0.020
Canada	0.007	0.012	0.007	0.020	0.007	0.020
Mexico	0.007	0.010	0.004	0.011	0.004	0.011
China	0.000	0.000	0.010	0.011	0.010	0.011
India	0.017	0.016	0.011	0.011	0.011	0.011
Rest of the World	0.001	0.001	0.027	0.025	0.027	0.025

We see that the number of all producers increases in most of the regions including the US under the fixed cost reduction scenario (0.289%). The US experience is noteworthy because the domestic productivity threshold increases much more in the US compared to other regions. Interestingly, there is firm entry into the beef industry even though the domestic threshold increases. This can be explained by the effect of trade policies on potential firms.

The pool of potential firms is determined endogenously by the zero profits condition in the model. A potential firm decides to enter the industry if the potential profits from all sales are high enough to cover both domestic and export fixed costs. The US beef industry becomes highly profitable following the fixed export cut as a result of increased sales to the EU market. This attracts many potential firms to make the productivity draw and survive in the beef industry. The increase in the mass of potential firms (0.537%) more than offset the rise in domestic productivity threshold

(0.065%) which eventually leads to an increase in the mass of active firms in the US beef industry (0.289%). The number of potential and total firms are the same in other regions as there is not much of a change in their respective domestic thresholds (only after three decimal places).

The compositional change in domestic and export markets have significant implications for the industry productivity. Table 4.7 presents the changes of average productivity of domestic suppliers, exporters and the whole industry under the two trade policy simulations.

Table 4.7. Productivity Growth in the Beef Industry: Domestic, Export and Industry-Wide Averages under Fixed Cost Reduction and Tariff Cut Scenarios (%).

Regions	**Domestic Suppliers**		**Exporters**		**All Producers**	
	Fixed Cost Reduction	Tariff Reduction	Fixed Cost Reduction	Tariff Reduction	Fixed Cost Reduction	Tariff Reduction
European Union	0.000	0.000	−0.001	−0.001	−0.001	−0.001
United States	0.065	0.151	−0.066	−0.057	−0.084	0.044
Brazil	0.000	0.000	0.000	0.000	0.000	0.000
Argentina	0.000	0.000	0.000	0.000	0.000	0.000
Uruguay	0.000	0.000	−0.001	−0.001	−0.001	−0.001
Australia	0.000	0.000	−0.004	−0.005	−0.004	−0.005
Canada	0.000	0.000	−0.002	−0.003	−0.002	−0.003
Mexico	0.000	0.000	−0.002	−0.002	−0.002	−0.002
China	0.000	0.000	0.000	0.000	0.000	0.000
India	0.000	0.000	−0.003	−0.003	−0.003	−0.003
Rest of the World	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Domestic suppliers report the average productivity growth of firms that only sell in the domestic market. Exporters report the productivity growth of exporters in all export markets weighted by the respective share of each export market in total sales of beef. All producers report the average productivity growth in the industry weighted by the respective share of each market in total sales of beef.

For most regions, average productivity in the domestic market is affected only modestly by these policies. Comparatively, the US experiences a more sizeable change. Average productivity of domestic suppliers increases by 0.065% under the fixed cost reduction scenario while it increases by 0.151% under the tariff cut scenario.

Average productivity of exporters decreases in most of the regions as a result of the expansion of low-productivity firms into export markets. Even though most of the regions suffer from a productivity threshold increase for the EU market, there is a decline in the productivity threshold for other export markets. As a result, they divert their beef sales to regions other than the EU. This allows for low-productivity exporters in the beef market to expand their market shares. Since new exporters are less efficient than the incumbents, their entry into the export markets lowers the overall efficiency in export markets on average.

Industry-wide average productivity is affected by the compositional changes in domestic and export markets. As less efficient firms expand into the beef export market, the industry-wide productivity decreases on average in all regions under both scenarios. The only exception is the US under the tariff cut scenario. In that particular case, domestic market productivity increases more than in the fixed cost scenario because less efficient firms drop out of the industry. The domestic average (0.151%) more than compensates for the reduced export market average (-0.057%). Therefore, tariff cut reallocates market share by shifting resources towards more productive firms improving the aggregate productivity in the US (0.044%).

So far, we have focused on the beef industry. To complete the picture, we briefly turn to other industries. Table 4.8 presents changes in the output of each industry in the EU and US under the two policy scenarios. As expected, production in the primary food industry expands as well as beef in the US. This is not surprising as primary food is the major input used in beef production.

Unlike primary food, production in other industries drops. As beef becomes more profitable, firms in other industries switch to beef production especially the ones in the processed food industry. On the other hand, the EU experiences the opposite such that there is a substantial contraction in the beef industry and a more modest expansion in the manufacturing industry.

Finally, we consider the effects of fixed cost reduction and tariff cut on prices. Table 4.9 presents the supplier prices in each industry for the US and EU across the two scenarios. An interesting finding is that price of beef in the US increases under the fixed cost scenario while it decreases under the tariff scenario. In both cases the expansion in the beef industry bids up factor prices. Although input prices are higher at the industry level, the average efficiency of firms within the industry differs across scenarios.

Table 4.8. Change in the Production of Each Sector under Fixed Cost Reduction and Tariff Reduction Scenarios (%).

Sectors	**Fixed Cost Reduction**		**Tariff Reduction**	
	EU	US	EU	US
Primary Food	−0.063	0.052	−0.051	0.051
Extraction	0.039	−0.026	0.033	−0.025
Beef	−1.497	0.476	−1.221	0.598
Processed Food	−0.001	−0.002	−0.001	−0.002
Manufactures	0.007	−0.010	0.007	−0.009
Services	0.002	0.000	0.001	0.000

Table 4.9. Change in the Supplier Prices of Each Sector under Fixed Cost Reduction and Tariff Reduction Scenarios (%).

Sectors	**Fixed Cost Reduction**		**Tariff Reduction**	
	EU	US	EU	US
Primary Food	−0.014	0.013	−0.012	0.013
Extraction	−0.011	0.007	−0.009	0.007
Beef	−0.007	0.090	−0.006	−0.037
Processed Food	−0.003	0.003	−0.003	0.004
Manufactures	−0.001	0.002	−0.001	0.001
Services	−0.001	0.002	−0.001	0.002

As mentioned before in the tariff cut scenario, the domestic threshold in the beef industry increases and pushes the less efficient firms out of the industry which improves the overall efficiency in the industry. As high-productivity firms constitute a larger share of the industry, the average productivity in the industry falls despite the increase in factor prices. Hence the decline in supplier prices under the tariff-cut scenario. The opposite occurs in the fixed cost scenario due to the rise in domestic average productivity.

4.3.4 Welfare Implications across Model Specifications

Implications of these TTIP scenarios can be better understood by exploring the resulting welfare effects in each region. In this section we provide a detailed analysis on the components of welfare change in firm heterogeneity. There are three new sources of economic gains from trade that can be captured in firm heterogeneity models. We can summarize them as: (i) productivity effect, (ii) love-of-variety effect, and (iii) scale effect (Melitz and Trefler, 2012; Zhai, 2008). These components are additional to the allocative efficiency and terms of trade effects which are the traditional channels of gains from trade in perfect competition models with Armington assumption.

Productivity effect is the result of within-industry compositional change of firms in favor of the high-productivity firms. As factors of production are reallocated towards more productive firms, overall efficiency in the industry rises which has a positive contribution to overall welfare. The productivity channel is unique to the firm heterogeneity model. The second channel is the Dixit-Stiglitz love-of-variety effect which results from the ability of the firm heterogeneity model to capture trade growth along the extensive margin. Trade contributes to overall welfare by allowing new varieties to become available to consumers who gain utility from the uniqueness of products. The third channel is the scale effect which is the result of increasing returns to scale technology available in the monopolistically competitive industries. As trade expands, there are fewer firms left in the market which face lower average costs and operate at a higher scale generating additional gains from trade.

Aggregate welfare effects of the unilateral fixed export cost reduction and tariff cut in the firm heterogeneity model are presented in Table 4.10. The provide additional insights about the contribution of firm heterogeneity mechanisms, we compare the outcomes of this model to that of the standard GTAP model with Armington assumption of national product differentiation and perfectly competitive industries.

Table 4.10. Welfare Effects of Two Scenarios under Firm Heterogeneity: Equivalent Variation in millions of US$.

Regions	**Aggregate Welfare Effect**	**Allocative Efficiency Effects**	**Productivity Effects**	**Terms of Trade Effects**	**IS Effects**	**Scale Effects**	**Variety Effects**
Fixed Export Cost Reduction							
EU	460	456	-42	-45	-2	6	87
USA	-9	-13	-71	49	15	5	7
Brazil	-1	0	0	0	-1	0	0
Argentina	0	0	0	0	0	0	0
Uruguay	0	0	0	0	0	0	0
Australia	-1	-1	-1	0	0	0	0
Canada	-1	0	0	0	0	0	-1
Mexico	-3	-2	0	0	-1	0	0
China	-6	0	-2	1	-5	0	0
India	1	1	0	2	-1	0	-1
ROW	-38	-24	-5	-6	-5	0	2
World Total	403	417	-121	0	0	11	96
Tariff Reduction							
EU	261	371	-43	-45	-2	5	-25
USA	-23	-10	50	38	14	28	-143
Brazil	-1	0	0	0	-1	0	0
Argentina	0	0	0	0	0	0	0
Uruguay	0	0	0	0	0	0	0
Australia	-1	-1	-1	1	0	0	0
Canada	-1	0	0	1	0	0	-2
Mexico	-3	-2	0	2	-1	0	-2
China	-6	0	-2	1	-5	0	0
India	1	1	0	1	-1	0	-1
ROW	-33	-21	-4	0	-5	-1	-2
World Total	195	337	0	0	0	32	-174

The firm heterogeneity model predicts a global welfare gain of \$403 million from the fixed export cost reduction. This is much higher than what the tariff reduction scenario predicts which is about a \$195 million global welfare gain. Here we should note that the higher welfare gains predicted by the fixed cost scenario is not simply the result of the bigger shock we imposed on fixed costs. In fact, since trade responses are equalized between the two scenarios, welfare differences are attributed to the differential effects of each policy instrument on the responses of productivity and extensive margin.

Welfare decomposition can provide more insights into these findings. Looking at the experience of each country in the firm heterogeneity model reveals that welfare of the EU increases under both scenarios, \$460 million with fixed cost reduction and \$261 million with tariff cut. The main driving force of these economic gains is due to the traditional allocative efficiency effect. As the EU welcomes increasing levels of beef imports from the US, a considerable amount of tariff rents are collected which contributes positively to the welfare of EU (\$456 million). Even in the case of tariff reduction, the EU benefits from rents (\$371 million) because tariffs are not completely eliminated and beef imports from the US increases by the same rate as in the fixed cost scenario. As expected, terms of trade contribution is negative (-\$45 million under both scenarios) due to terms of trade deterioration in the EU (-0,002%).

The new channels in firm heterogeneity paint a more detailed picture of the welfare change. We see that the loss in average productivity in the beef industry as well as in other heterogeneous industries reduces welfare by \$42 million in the case of fixed cost reduction and \$43 million in the case of tariff cut. The loss caused by productivity and terms of trade effects are offset by the variety effects (\$87 million) under fixed cost reduction. Increased domestic varieties of manufacturing products more than compensates for the loss in domestic beef varieties ultimately contributing to the welfare gain. The opposite happens in the tariff cut scenario where the private sector suffers from the loss in domestic beef varieties which eventually reduces welfare by \$25 million.

The firm heterogeneity model predicts a welfare loss in the US (-\$9 million and -\$23 million under the respective scenarios). This is contrary to the predictions of the Armington-based model reported in Table 4.11 which estimates a \$40 million welfare gain under the tariff cut scenario and a more modest \$8 million gain under the fixed cost reduction scenario. The divergent findings across model specifications result from the additional channels of economic gains in the firm heterogeneity model. In the fixed cost reduction scenario, we see that the negative welfare in the US is driven by the loss in average productivity (-\$71 million). This is due to within-industry compositional change in favor of the low-productivity firms. In this context, trade growth causes welfare loss by allowing inefficient marginal firms to survive in domestic and export markets. This can be thought of as trade diversion in the sense that lower fixed costs makes production and exporting profitable for inefficient firms. Therefore, part of the trade is diverted away from high-productivity firms.

Table 4.11. Welfare Effects of Two Scenarios under Perfect Competition: Equivalent Variation in millions of US$.

Regions	**Aggregate Welfare Effect**	**Allocative Efficiency Effects**	**Productivity Effects**	**Terms of Trade Effects**	**IS Effects**	**Scale Effects**	**Variety Effects**
			Fixed Cost Reduction				
EU	41	34	10	-3	0	0	0
USA	8	-1	0	6	2	0	0
Brazil	0	0	0	0	0	0	0
Argentina	0	0	0	0	0	0	0
Uruguay	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0
Canada	-1	0	0	0	0	0	0
Mexico	0	0	0	0	0	0	0
China	0	0	0	0	-1	0	0
India	0	0	0	0	0	0	0
ROW	-3	0	0	-2	-1	0	0
World Total	43	33	10	0	0	0	0
			Tariff Reduction				
EU	120	140	0	-19	-2	0	0
USA	40	-3	0	31	12	0	0
Brazil	-2	0	0	-1	0	0	0
Argentina	-2	0	0	-1	0	0	0
Uruguay	-1	0	0	-1	0	0	0
Australia	-1	0	0	-1	0	0	0
Canada	-3	0	0	-2	0	0	0
Mexico	-2	-1	0	-1	0	0	0
China	-2	0	0	1	-4	0	0
India	0	0	0	0	0	0	0
ROW	-13	-2	0	-6	-4	0	0
World Total	134	134	0	0	0	0	0

On the other hand, welfare loss under the tariff cut scenario is driven by the negative variety effect (-\$143 million). US consumers suffer from the loss of domestic varieties in the beef industry as well as the manufacturing industry. In particular, the impact of domestic variety loss of beef is most severe on private households, while the impact of domestic variety loss of manufactures is most severe on firms that use manufacturing products as inputs. Even though the imported varieties of beef and manufactures increases in the US, it is no match for the loss of domestic varieties when we account for the preference bias of home goods. Overall, we see that the choice of policy instruments matters for the responses of each welfare mechanism.

Comparison of results between firm heterogeneity and perfect competition indicates that the US benefits from lower fixed costs if the productivity and variety channels are not taken into account. In particular, without the trade diverting effect of lower average productivity in the case of fixed costs and the utility reducing effect of variety loss in the case of tariffs, welfare in the US increases due to positive terms of trade effects. However, this leaves out important economic information which can be paramount for policy recommendation.

Overall, the firm heterogeneity model predicts larger welfare gains for the world compared to the perfect competition model. Including firm-level heterogeneity in the model allows for tracing out the welfare implications of NTM reduction due to new channels which are unexplored in Armington-based perfect competition models. By ignoring the significant variation across firms, NTM removal scenarios miss the effect of productivity change and the extensive margin on global welfare.

4.4 Sensitivity Analysis and Limitations

The policy analysis in this chapter relies on the assumptions we make in model calibration and parameterization to determine the values of substitution elasticities between varieties, shape parameters and the associated fixed costs in the domestic and export markets. In this section, we check the sensitivity of the model results to alternative assumptions about the model parameters. The key issue in this sensitivity analysis is to use parameter values that will satisfy the parametric restriction in the model, $\gamma > \sigma - 1$. This parametric restriction is important in the calibration of fixed costs and variable costs in value-added which we turn to now.

4.4.1 Calibration of Fixed Costs and Parametric Restrictions

In this study we assume that fixed costs for the domestic and export markets are composed of value-added only. For the initial value of fixed costs we follow Zhai (2008) in calibrating fixed costs to the base year bilateral sales data because the GTAP data base does not have information about fixed costs. This method imposes certain restrictions on the parametric space that allows the model to run. In this section we discuss these restrictions and present the set of parameters for the beef industry that satisfy these restrictions. We start with briefly summarizing the main aspects of the calibration.

Using the optimal demand and price for the differentiated variety, we find fixed costs to be proportional to sales where the proportionality constant depends on our parametric choice. The calibration for fixed costs in both domestic and export markets is given as follows:

$$N_{irs} W_{ir} F_{irs} = \frac{P_{irs} Q_{irs}}{T_{irs}} \frac{\gamma_i - \sigma_i + 1}{\sigma_i \gamma_i}, \tag{4.1}$$

where P_{irs} is the price of product i produced in region r and sold in region s, Q_{irs} is the quantity of product i produced in r sold in s, N_{irs} is the number of exporters of i that sell on the $r - s$ trade route, W_{ir} is the cost of one value-added bundle that is used by firms in region r that sell product i to cover fixed costs and F_{irs} is the number of value-added bundles required to cover fixed costs of sales of i from region r to region s.

The left-hand side in equation (4.1), $N_{irs}W_{ir}F_{irs}$, gives the fixed cost of selling product i from source r to destination s aggregated over all firms that are active in that market. The right hand side has two components. The first one, $\frac{P_{irs}Q_{irs}}{T_{irs}}$, gives the total revenue of selling product i from r to s which equals total cost of exporting that particular good to market s. The second component, $\frac{\gamma_i-\sigma_i+1}{\sigma_i\gamma_i}$, is a proportionality constant that depends on preferences and the heterogeneity of the industry. As preferences become more homogeneous, i.e. higher σ_i, firms have little incentive to invest in differentiating their varieties because the markup gets smaller. As a result, in this model fixed export costs decrease with the elasticity of substitution. Similarly, a higher shape parameter, i.e. less heterogeneity across firms, reduces fixed costs of exporting.

The rest of the value-added costs are attributed to the variable portion of production. Then, variable value-added costs are calculated as residuals from fixed costs. Based on the parametric choice, initial fixed and variable cost calibration could give negative values. In order to avoid negative values, we need to restrict the parametric space to a particular region where the parameter combinations give positive values for fixed costs as well as for variable costs in the initial data base. The parametric restriction for the beef industry is shown in Figure 4.1.

Figure 4.1 plots the combinations of the substitution elasticity and Pareto shape parameter for the beef industry. The range of parameters considered is $[1, 13]$. The lower bound is selected based on the model assumptions, i.e. $\sigma > 1$ and $\gamma > 1$. We limit the upper bound for both parameters at 13 for representative purposes. For the shape parameter, the value of the upper bound is in line with empirical studies where the estimate 12.86 found in Eaton and Kortum (2002) is one of the highest shape parameter estimates in the relevant literature.

The shaded region in Figure 4.1 represents the elasticity and shape parameter combinations that lead to positive values for the initial fixed and variable value-added costs in the beef industry. The upper bound of this region is the well-known linear restriction $\gamma > \sigma - 1$, while the lower bound is nonlinear. In order to ensure positive values in the initial data base our parametric choice for the beef industry must be within the shaded region in Figure 4.1. This limits the options for valid elasticity and shape values that we can use for the sensitivity analysis.

Since the literature does not provide a range of elasticity and shape parameter combinations for the beef industry in a firm heterogeneity model, we calibrate elasticity values that are consistent with the shape parameter estimates provided in Spearot

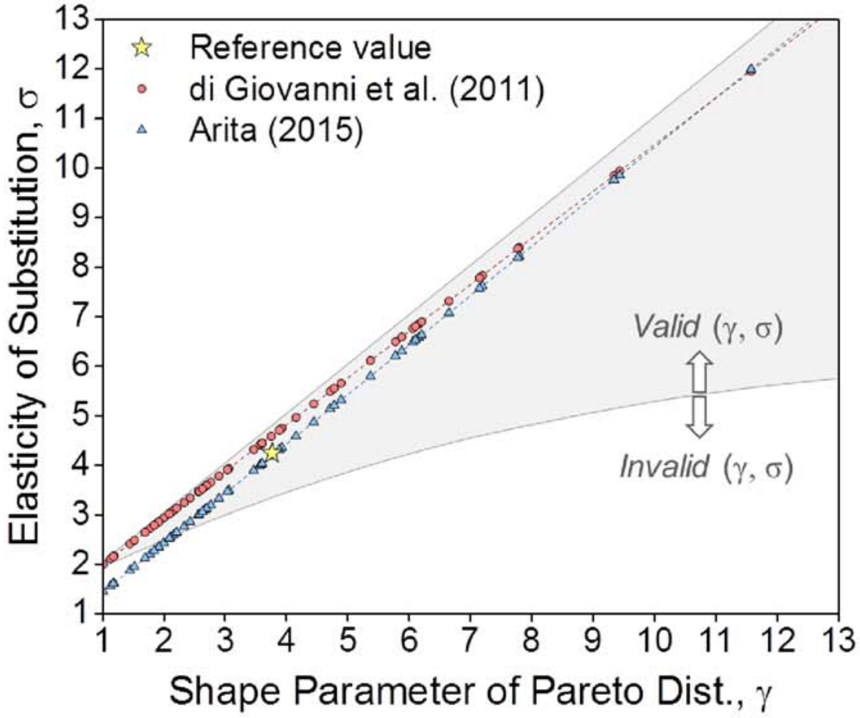

Figure 4.1. Parameter Space for the Beef Industry.

(2015) within the bounds of the model. The parameter combination for the beef industry that we used in our policy analysis is reported as the ‘reference value’ in Figure 4.1, where $\gamma = 3.78$ and $\sigma = 4.21$. The shape parameter estimate is from Spearot (2015) which is the mean value for 59 countries. The elasticity value that corresponds to this shape parameter is found by following the empirical study in Chapter 3.

Spearot (2015) provides shape parameter estimates for the beef industry by country. This gives us a range of shape parameter estimates that vary across 59 countries. However, he does not provide corresponding elasticity values. Therefore, we rely on empirical studies in order to find a way to disentangle elasticity values that correspond to the Pareto shape estimates in Spearot (2015). The first candidate is the firm-level study conducted by Arita et al. (2015) for the beef industry in Europe. Arita et al. (2015) estimates the dispersion of firm-level export sales by following the approach in Helpman et al. (2004) which gives an estimate of a combination of the Pareto shape parameter and the elasticity of substitution. The resulting coefficient estimate is $\gamma - \sigma + 1 = 0.62$. We fit the elasticities to this empirical relationship using the shape parameter values in Spearot (2015). The resulting parameter combinations are plotted in Figure 4.1 and referred to as Arita et al. (2015). As is shown on the figure, several parameter combinations do not satisfy the parametric restriction and are in the invalid region.

In order to compare the parameter combinations with an alternative fit for elasticities, we also consider the empirical work of di Giovanni et al. (2011) where the Power Law exponent of firm sales are estimated by regressing log of rank on log of sales by based on French firm-level data. The resulting coefficient estimate is the Power Law exponent which gives a value of $\frac{\gamma}{\sigma-1} = 1.06$. This is for an average of 25 tradeable industries. The resulting parameter combinations are plotted in Figure 4.1

and referred to as di Giovanni et al. (2011). The parameter values on this fit are very close to the fit with Arita's (2015) estimate. However, in this case all parameter combinations are within the valid region.

Table 4.12 reports the parameter values used in our sensitivity analysis. The reference values presented in the table are the parameter values we use in the original policy analysis in Section 4.3.3. The low and high values for Arita et al. (2015) and di Giovanni et al. (2011) are selected such that the parameter values are within the valid region. The lower and higher values for the shape parameter are selected to be the same in Arita et al. (2015) and di Giovanni et al. (2011) in order to be able to compare the effect of a different elasticity fit on simulation results.

Table 4.12. Parameter Values for the Beef Industry used in the Sensitivity Analysis.

		Arita (2015)		di Giovanni et al. (2011)	
Parameters	Reference Value	Low Value	High Value	Low Value	High Value
Shape parameter, γ	3.78	2.17	11.60	2.17	11.60
Elasticity of substitution, σ	4.21	2.55	11.98	3.05	11.94

Notes: Reference Value reports the parameter values used in this dissertation for policy analysis, Arita (2015) reports the parameter combinations that fits elasticities to the estimates found in Arita (2015) and shape parameters in Spearot (2015), di Giovanni et al. (2011) reports the parameter combinations that fits elasticities to the estimates found in Arita (2015) and shape parameters in Spearot (2015).

Since the Pareto shape parameter and the elasticity of substitution move in tandem based on the parametric restriction of the model and fit, low values correspond to lower values for both parameters. In other words, if the Pareto shape parameter is low, then the associated elasticity is also low. Similarly, high values correspond to higher values for both parameters.

4.4.2 Simulation Results with Alternative Parameter Values

Table 4.13 presents the welfare effects of the two policy scenarios analyzed in Section 4.3.3 under alternative parameter values. Low and high values correspond to the parameter combinations in Table 4.12 under Arita (2015).

Results in Table 4.13 show that welfare changes under the fixed cost scenario are not very sensitive to parameter values. For the EU, welfare gains are slightly higher under higher parameter values. The US experiences welfare loss under all parameter values considered; however, there is no clear relationship as to how the parameter values affect the magnitude of the change. Compared to the reference value, the US experiences a larger welfare loss both under lower parameter values and higher parameter values.

Table 4.13. Welfare Effects under Alternative Parameter Values (Elasticities are fitted to Arita et al. (2015)): Equivalent Variation in millions of US$.

Region	Fixed Cost Scenario			Tariff Scenario		
	Low Value	Reference Value	High Value	Low Value	Reference Value	High Value
EU	450	460	464	165	261	386
USA	-17	-9	-11	-29	-23	-18
Brazil	-1	-1	-1	0	-1	-1
Argentina	0	0	0	0	0	0
Uruguay	0	0	0	0	0	0
Australia	-1	-1	-1	-1	-1	-1
Canada	-1	-1	-1	0	-1	-1
Mexico	-3	-3	-3	-2	-3	-3
China	-6	-6	-6	-7	-6	-6
India	1	1	1	1	1	1
ROW	-35	-38	-40	-27	-33	-40
Total	388	403	403	99	195	317

Sensitivity analysis for the tariff cut scenario presents a clearer comparison. For the EU, welfare gains are much higher as parameter values are increased. On the other hand, the US experiences a smaller welfare loss as parameter values are increased. We see that the impact of parameter values on the effects of tariff cut is more pronounced.

Welfare effects are much more sensitive to parameter values under the tariff cut scenario compared to the fixed cost scenario.

Table 4.14 presents the effects of using alternative parameter values on changes in export values for beef under the two policy scenarios. The results show that export values are not very sensitive to parameter values under either scenario. The EU experiences a loss in beef exports which is lower under higher parameter values. On the other hand, there is a considerable increase in US beef exports, the magnitude of which gets lower as parameter values are increased.

Table 4.14. Changes in the Value of Beef Exports under Alternative Parameter Values (Elasticities are fitted to Arita et al. (2015)), $US millions.

Region	Fixed Cost Scenario			Tariff Scenario		
	Low Value	Reference Value	High Value	Low Value	Reference Value	High Value
EU	-46	-46	-43	-34	-37	-39
USA	585	583	579	579	574	561
Brazil	1	1	0	1	1	1
Argentina	0	0	-1	0	0	-1
Uruguay	0	0	0	0	0	0
Australia	7	5	5	7	7	7
Canada	3	2	2	4	4	5
Mexico	1	1	1	1	1	1
China	0	0	0	0	0	0
India	2	1	1	1	1	1
ROW	4	3	2	4	4	5
Total	557	550	545	565	555	541

Table 4.15 presents the effects of using alternative parameter values on the percentage change of average productivity in the beef industry under the two policy scenarios. The sensitivity analysis on welfare results may depend on how we fit the elasticity values. An alternative fit for elasticities may paint a different picture for the welfare results. Table 4.16 presents the welfare effects of the two policy scenarios under an alternative elasticity fit using the estimates in di Giovanni et al. (2011).

The welfare gains under alternative parameter values are similar for the EU in the fixed cost scenario. On the other hand, there is a huge difference in the welfare

Table 4.15. Changes in Average Productivity in the Beef Industry under Alternative Parameter Values (Elasticities are fitted to Arita et al. (2015)), % Change.

Region	Fixed Cost Scenario			Tariff Scenario		
	Low Value	Reference Value	High Value	Low Value	Reference Value	High Value
EU	-0.001	-0.001	0.000	-0.001	-0.001	0.000
USA	-0.178	-0.084	-0.025	-0.059	0.044	0.097
Brazil	-0.001	0.000	0.000	-0.001	0.000	0.000
Argentina	0.000	0.000	0.000	0.000	0.000	0.000
Uruguay	-0.004	-0.001	0.000	-0.004	-0.001	0.000
Australia	-0.010	-0.004	-0.001	-0.010	-0.005	-0.002
Canada	-0.004	-0.002	-0.001	-0.005	-0.003	-0.001
Mexico	-0.005	-0.002	0.000	-0.005	-0.002	0.000
China	0.000	0.000	0.000	0.000	0.000	0.000
India	-0.008	-0.003	-0.001	-0.006	-0.003	-0.001
ROW	0.000	0.000	0.000	0.000	0.000	0.000
Total	-0.210	-0.096	-0.027	-0.091	0.029	0.093

Table 4.16. Welfare Effects under Alternative Parameter Values (Elasticities are fitted to di Giovanni et al. (2011)): Equivalent Variation in millions of US$.

Region	Fixed Cost Scenario			Tariff Scenario		
	Low Value	Reference Value	High Value	Low Value	Reference Value	High Value
EU	455	460	464	174	261	386
USA	4	-9	-11	-25	-23	-18
Brazil	-1	-1	-1	0	-1	-1
Argentina	0	0	0	0	0	0
Uruguay	0	0	0	0	0	0
Australia	-1	-1	-1	-1	-1	-1
Canada	-1	-1	-1	0	-1	-1
Mexico	-3	-3	-3	-3	-3	-3
China	-6	-6	-6	-7	-6	-6
India	1	1	1	1	1	1
ROW	-37	-38	-40	-30	-33	-40
Total	412	403	403	109	195	317

response of the US to changes in parameter values. The US experiences a welfare gain under low parameter values, while it experiences a welfare loss under high parameter values. The sensitivity of welfare changes to parameter values can be traced back to the sensitivity of the variety effects to parameter values. As parameter values get higher, the variety effect turns from positive to negative.

The different results under alternative fits to elasticities highlight the importance of proper parameterization of the firm heterogeneity model. A better parameterization of the model is paramount for improving the performance of the model.

4.4.3 Limitations

An outstanding issue in this study is the parametric restrictions imposed by the theory and the calibration of fixed costs. As initial values for fixed costs and variable value-added depend on the parametric choice, we are restricted to the parameter combinations which provide positive values for fixed and variable value-added costs.

In order to improve the model, alternative methods of parameterization should be considered. Expansion of the parametric space can relax the dependency of the model on parameters which requires an alternative method to calibrate or estimate initial fixed costs. Estimation of fixed costs is difficult as their identification depends on their nonlinear effects on market participation patterns. Das et al. (2007) develops a structurally dynamic framework which allows for the estimation of fixed export costs based on plant-level data. In particular, Das et al. (2007) identify fixed costs by using the differences in the exporting frequency of plants with similar profit streams but different export participation history. We do not attempt to solve this issue in this study. However, using empirical information for initial fixed costs may improve the flexibility of the model for alternative parameters.

4.5 Concluding Remarks

Reducing NTMs as a means to increase market access and harmonizing the standards in trade between the US and the EU has been the main target of recent TTIP negotiations. EU's hormone ban on US beef is one of the frequently discussed issues in these negotiations. Removal of the fixed costs associated with US beef imports into the EU is expected to generate significant economic gains.

This study focuses on the implications of reducing beef hormone ban imposed on US imports. We contribute to this line of literature by taking firm-level heterogeneity and extensive margin effects prevalent in the monopolistically competitive beef market into account. For this purpose we use the newly developed firm heterogeneity module of GTAP which (i) accounts for fixed costs in domestic and export markets; (ii) traces out self-selection of firms into export markets based on productivity differences and (iii) captures trade growth along the extensive margin. We compare the effects of using different policy instruments to capture NTM reductions. Moreover, we provide insights into welfare implications of firm heterogeneity model and compare them with that of the perfect competition model.

Our findings show that the mass of US exporters into the EU beef market increases significantly under both scenarios. The compositional change in US beef export market is such that low-productivity firms expand their market shares as a result of lower productivity thresholds. We find that reducing fixed export costs cause aggregate productivity in the US beef industry to fall since it allows less efficient marginal firms to survive in the industry and expand into export markets. This has significant welfare implications. Reduced average productivity in the beef industry causes an overall welfare loss in the US. We find that the choice of policy instrument alters the underlying mechanisms at play that cause the welfare loss. When NTMs are captured as tariff equivalents in the firm heterogeneity model, we see that the US experiences a higher welfare loss despite the rising average productivity in the beef market. The tariff cut causes a significant loss of domestic varieties in the beef and manufacturing industries which more than offset the welfare gain of improved productivity.

Overall, we find important productivity and variety impacts of NTM reductions consistent with much of the firm heterogeneity literature on trade integration. The comparison with Armington-based GTAP model highlights the importance of productivity and variety impacts captured by the theory of firm heterogeneity. While the Armington-based GTAP model predicts positive welfare gains in the US under both policy scenarios, the firm heterogeneity specification predicts negative welfare gains. The different welfare predictions across model specifications is due to the productivity and variety effects captured by the theory of firm heterogeneity. Since Armington-based CGE models fail to account for these effects, their welfare predictions are not sufficiently informative.

In this study we focus only on the impact of reducing beef hormone ban. However, there are other trade barriers prevalent in the beef industry such as non-technical NTMs known as tariff rate quotas (TRQ). In fact, the EU has a restrictive TRQ policy on US beef imports which further impedes US exports. There can be interactive effects between the TRQ policy and the hormone ban which deserves further analysis. In fact, the potential interplay between the hormone ban and TRQs on US beef imports is explored in Beckman and Arita (2015). They find that the binding TRQ is the limiting constraint which has significant implications for trade flows. This is a promising venue for an extension of this study.

CHAPTER 5. SUMMARY

This thesis contributes to the international trade literature by extending the tools available to analyze trade policies with a mainstream policy model introducing the theory of firm heterogeneity. These extensions encompass the development and inclusion of the related theory, calibration, estimation and simulation. These tools will become available to the entire community of GTAP users. The broader availability of these tools provide the basis for a more thorough policy analysis and strengthen the link between CGE analysis and broader trade literature.

Chapter 2 presents the implementation of firm heterogeneity theory in the GTAP model and illustrates the behavioral characteristics of the new model in a stylized tariff removal scenario whereby Japanese tariffs on US manufactures are eliminated. Results are compared across different model specifications such as monopolistic competition based on Krugman (1980) and perfect competition based on the Armington (1969) assumption of national product differentiation. Significant productivity, variety and scale effects are observed under the firm heterogeneity model which lead to more pronounced welfare responses compared to the monopolistic and perfect competition models. Exit of less efficient firms from the industry due to higher competition is found to be the main source of overall productivity increase in the manufacturing industry of the US. This contributes positively to the welfare change. The loss in domestic varieties due to the exit of firms results in negative variety effects which reduces welfare.

Chapter 3 proposes a theoretically-consistent way to parameterize the firm heterogeneity model with a focus on the elasticity of substitution across varieties. Intensive and extensive margins of trade are distinguished in a multi-sector, multi-country firm heterogeneity model resulting in two estimating equations. Elasticity of substitution consistent with firm heterogeneity theory is obtained conditional on the shape parameter estimates of Spearot (2015). Results show that the elasticity values that are consistent with the firm heterogeneity theory are considerably lower than Armington elasticities used in the standard GTAP model. This implies that current implementations of Melitz-type models which use elasticities of substitution estimated in the absence of firm heterogeneity will give overly large trade volume responses to policy reforms.

Chapter 4 investigates the implications of reducing non-tariff measures on US-EU beef trade associated with the beef hormone ban imposed on US imports. Two alternative policy instruments are used: fixed export costs and tariff equivalents of the hormone ban. Results show that while the EU benefits from these scenarios, the US experiences a welfare loss. The choice of policy instrument is found to have important welfare implications. Welfare loss in the US is found to be driven by the decline in aggregate productivity under fixed cost reduction, while it is found to be driven by the loss in domestic varieties under the tariff cut. Results are also compared across model specifications. Findings indicate that welfare change in the US is reversed under perfect competition. Since the perfectly competitive model does not account for productivity and variety effects, terms of trade improvement dominates the welfare response. As a result, welfare increases in the US. The different welfare implications highlights the importance of taking firm heterogeneity into account in policy analysis.

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APPENDICES

Appendix A: Appendices to Chapter 2

A.1 Derivation of the Zero Profit Condition

The variables and value flows used in Chapter 2 are listed in Table A.1 along with their definitions.

Table A.1. List of Variables and Value Flows Used in This Paper, where `i` ∈ `ENDW_COMM` for endowments, `i` ∈ `TRAD_COMM` for intermediate inputs, `j` ∈ `MCOMP_COMM` for monopolistically competitive industry, and `r,s` ∈ `REG` for regions.

Price Variables	**Definitions**
`ps(j,r)`	supply price of commodity i in region r
`avc(j,r)`	average variable cost of production in industry j in region r
`pf(i,j,r)`	firms' price for commodity i for use by j in r
`pfe(i,j,r)`	firms' price for endowment commodity i in ind. j, region r
`pvaf(j,r)`	price of fixed value added of j in region r
`pvafd(j,r)`	price of fixed value added for domestic costs of j in source r
`pvafx(j,r,s)`	price of fixed value added for export costs of j in source r
`pvav(j,r)`	price of variable value added of j in region r
Quantity Variables	**Definitions**
`qo(j,r)`	industry output of commodity i in region r
`qf(i,j,r)`	demand for commodity i for use by j in region r
`qfe(i,j,r)`	demand for endowment i for use in ind. j in region r
`qvaf(j,r)`	fixed value added demanded by all firms in industry j in r
`qvafd(j,r)`	value added demand by the monop. comp. industry for fixed domestic costs
`qvafx(j,r,s)`	value added demand by the monop. comp. industry for fixed export costs
`qvav(j,r)`	variable value added in monop. comp. industry i of region r
`qof(j,r)`	quantity of output per firm in industry i of region r
`qox(j,r,s)`	quantity of output per exporting firm in industry i of r
`n(j,r)`	number of firms active in industry i of region r
`nx(j,r,s)`	number of active firms in industry i that export from r to s
Technology Parameters	**Definitions**
`ao(j,r)`	output augmenting technical change in sector j of r
`af(j,r)`	composite intermed. input i augmenting tech change by j of r
`avafd(j,r)`	tech change in fixed domestic costs of j in r
`avafx(j,r,s)`	tech change in fixed export costs of j from r to s
`avav(j,r)`	variable value added augmenting tech change in sector j of r
Value Flows	**Definitions**
`VOA(j,r)`	value of commodity i output in region r at agent's prices
`VC(j,r)`	variable cost in the production of the monop. comp. commodity
`VFA(i,j,r)`	producer expenditure on i by j in r valued at agent's prices
`VA(j,r)`	value added in activity j in region r
`VAF(j,r)`	fixed value added demanded by the monop. comp. industry
`VAFD(j,r)`	fixed domestic costs of industry i in region r
`VAFX(j,r,s)`	fixed export costs of industry i in r to enter market s
`VAV(j,r)`	variable value added demanded by the monop. comp. industry

This section provides the derivation of the zero profit condition in the monopolistically competitive industry with heterogeneous firms. In the monopolistically competitive industry, total cost (TC) is composed of variable (VC) and fixed (FC) costs. In order to obtain the average total cost (ATC) and hence the output price (P), we normalize both the right-hand side and left-hand side variables by the level of output (Y) as follows:

$$TC\left(w,p,Y\right) = VC\left(w,p,Y\right) + FC(w,p,) \tag{A.1}$$

$$\frac{TC}{Y}\left(w,p,Y\right) = \frac{VC}{Y}\left(w,p,Y\right) + \frac{FC(w,p)}{Y}, \tag{A.2}$$

$$ATC\left(w,p,Y\right) = P = AVC\left(w,p,Y\right) + \frac{FC\left(w,p\right)}{Y}. \tag{A.3}$$

Using GTAP notation, (A.1) corresponds to,

$$\begin{aligned} PS(j,r) &= AVC\left(j,r\right) + \frac{VAF(j,r)}{QO(j,r)}, \\ &= AVC\left(j,r\right) + \frac{PVAF\left(j,r\right)\ QVAF(j,r)}{QO(j,r)}, \end{aligned} \tag{A.4}$$

where $j \in MCOMP\_COMM$ for monopolistically competitive industries and $r \in REG$ for regions. Total differentiation of (A.4) yields:

$$\begin{aligned} dPS\left(j,r\right) = dAVC\left(j,r\right) + \frac{QVAF\left(j,r\right)}{QO\left(j,r\right)} dPVAF\left(j,r\right) \\ + \frac{PVAF\left(j,r\right)}{QO\left(j,r\right)} dQVAF\left(j,r\right) \\ - \frac{PVAF\left(j,r\right) QVAF(j,r)}{QO(j,r)} \frac{dQO(j,r)}{QO(j,r)}, \end{aligned} \tag{A.5}$$

We divide and multiply both sides of the equation by price and quantity variables to obtain percentage changes in the corresponding variables.

$$\begin{aligned} PS\,(j,r)\,\frac{dPS\,(j,r)}{PS\,(j,r)} &= AVC\,(j,r)\,\frac{dAVC\,(j,r)}{AVC\,(j,r)} \\ &+ \frac{PVAF\,(j,r)\,QVAF\,(j,r)}{QO\,(j,r)}\frac{dPVAF\,(j,r)}{PVAF\,(j,r)} \\ &+ \frac{PVAF\,(j,r)\,QVAF\,(j,r)}{QO\,(j,r)}\frac{dQVAF\,(j,r)}{QVAF\,(j,r)} \\ &- \frac{PVAF\,(j,r)\,QVAF(j,r)}{QO(j,r)}\frac{dQO(j,r)}{QO(j,r)}, \end{aligned} \tag{A.6}$$

If we rearrange and use lowercase letters to denote percentage changes in the corresponding uppercase variables, we obtain

$$\begin{aligned} VOA\,(j,r)\,ps(j,r) &= VC\,(j,r)\,avc\,(j,r) + VAF\,(j,r)\,pvaf\,(j,r) \\ &+ VAF\,(j,r)\,qvaf\,(j,r) - VAF\,(j,r)\,qo(j,r). \end{aligned} \tag{A.7}$$

Recall that average variable cost is determined by the following equation:

$$\begin{aligned} VC\,(j,r)\,avc\,(j,r) &= \sum_{i=TRAD\_COMM} VFA\,(i,j,r)\,[pf\,(i,j,r) - af\,(i,j,r)] \\ &+ VAV\,(j,r)\,[pvav\,(j,r) - avav\,(j,r)] - VC\,(j,r)\,ao(j,r). \end{aligned} \tag{A.8}$$

Substituting (A.8) into (A.7) we obtain:

$$\begin{aligned} VOA\,(j,r)\,ps(j,r) &= \sum_{i=TRAD\_COMM} VFA\,(i,j,r)\,[pf\,(i,j,r) - af\,(i,j,r)] \\ &+ VAV\,(j,r)\,[pvav\,(j,r) - avav\,(j,r)] - VC\,(j,r)\,ao(j,r) \\ &+ VAF\,(j,r)\,pvaf\,(j,r) + VAF\,(j,r)\,qvaf\,(j,r) \\ &- VAF\,(j,r)\,qo(j,r). \end{aligned} \tag{A.9}$$

Note that total fixed cost, $VAF(j,r)$ is composed of fixed domestic costs and fixed export costs:

$$VAF\,(j,r) = VAFD\,(j,r) + \sum_{s=REG} VAFX(j,r,s). \tag{A.10}$$

Substituting (A.10) into (A.9) yields:

$$\begin{aligned} VOA\,(j,r)\,ps\,(j,r) = & \sum_{i=TRAD_{COMM}} VFA\,(i,j,r)\,[pf\,(i,j,r) - af\,(i,j,r)] \\ & + [VAV\,(j,r)\,pvav\,(j,r) + VAF\,(j,r)\,pvaf\,(j,r)] \\ & - VAV\,(j,r)\,avav\,(j,r) \\ & - VC\,(j,r)\,ao\,(j,r) + VAF\,(j,r)\,qvaf\,(j,r) \\ & - [VAFD\,(j,r) + \sum_{s=REG} VAFX(j,r,s)]qo(j,r)]. \end{aligned} \tag{A.11}$$

Recall that the demand price of value-added composite is a share-weighted summation of prices of fixed and variable value-added composites. This is given as follows:

$$\begin{aligned} \sum_{i=ENDW\_COMM} VFA(i,j,r)pva\,(j,r) &= VAV\,(j,r)\,pvav\,(j,r) + VAF\,(j,r)\,pvaf(j,r) \\ VA(j,r)pva\,(j,r) &= VAV\,(j,r)\,pvav\,(j,r) + VAF\,(j,r)\,pvaf(j,r). \end{aligned} \tag{A.12}$$

Substituting (A.12) into (A.11) we obtain:

$$\begin{aligned} VOA\left(j,r\right)ps\left(j,r\right) = & \sum_{i=TRAD_{COMM}} VFA\left(i,j,r\right)\left[pf\left(i,j,r\right) - af\left(i,j,r\right)\right] \\ & + VA\left(j,r\right)pva\left(j,r\right) - VAV\left(j,r\right)avav\left(j,r\right) \\ & - VC\left(j,r\right)ao\left(j,r\right) + VAF\left(j,r\right)qvaf\left(j,r\right) \\ & - VAFD\left(j,r\right)qo\left(j,r\right) - \sum_{s=REG} VAFX(j,r,s)qo(j,r). \end{aligned} \tag{A.13}$$

Note that demand for fixed value-added is composed of demand for domestic and export markets as follows:

$$\begin{aligned} VAF(j,r)qvaf\left(j,r\right) = & VAFD\left(j,r\right)qvafd\left(j,r\right) \\ & + \sum_{s=REG} VAFX\left(j,r,s\right)qvafx(j,r,s). \end{aligned} \tag{A.14}$$

Substituting (A.14) into (A.13) yields:

$$\begin{aligned} VOA\left(j,r\right)ps\left(j,r\right) = & \sum_{i=TRAD_{COMM}} VFA\left(i,j,r\right)\left[pf\left(i,j,r\right) - af\left(i,j,r\right)\right] \\ & + VA\left(j,r\right)pva\left(j,r\right) - VAV\left(j,r\right)avav\left(j,r\right) \\ & - VC\left(j,r\right)ao\left(j,r\right) + VAFD\left(j,r\right)qvafd\left(j,r\right) \\ & + \sum_{s=REG} VAFX\left(j,r,s\right)qvafx(j,r,s) \\ & - VAFD\left(j,r\right)qo\left(j,r\right) - \sum_{s=REG} VAFX(j,r,s)qo(j,r). \end{aligned} \tag{A.15}$$

Note that demand for value-added is further determined by the following equations:

$$qvafd\left(j,r\right) = n\left(j,r\right) - avafd(j,r), \tag{A.16}$$

$$qvafx\left(j,r,s\right) = nx\left(j,r,s\right) - avafx(j,r,s). \tag{A.17}$$

Substituting (A.16) into (A.15) we obtain:

$$\begin{aligned}
VOA\,(j,r)\,ps\,(j,r) = &\sum_{i=TRAD_{COMM}} VFA\,(i,j,r)\,[pf\,(i,j,r) - af\,(i,j,r)] \\
&+ VA\,(j,r)\,pva\,(j,r) - VAV\,(j,r)\,avav\,(j,r) \\
&- VC\,(j,r)\,ao\,(j,r) \\
&+ VAFD\,(j,r)\,[n\,(j,r) - avafd\,(j,r)] \\
&+ \sum_{s=REG} VAFX\,(j,r,s)\,[nx\,(j,r,s) - avafx\,(j,r,s)] \\
&- VAFD\,(j,r)\,qo\,(j,r) \\
&- \sum_{s=REG} VAFX(j,r,s)qo(j,r).
\end{aligned} \tag{A.18}$$

Output per firm and output per exporter are determined by the following equations:

$$qo\,(j,r) = qof\,(j,r) + n\,(j,r) \tag{A.19}$$

$$qox\,(j,r,s) = qo\,(j,r) - nx\,(j,r,s) \tag{A.20}$$

$$\tag{A.21}$$

Substituting (A.19) into (A.18) yields:

$$\begin{aligned} VOA(j,r)\,ps(j,r) = & \sum_{i=TRAD_{COMM}} VFA(i,j,r)\left[pf(i,j,r) - af(i,j,r)\right] \\ & + VA(j,r)\,pva(j,r) - VAV(j,r)\,avav(j,r) \\ & - VC(j,r)\,ao(j,r) \\ & + VAFD(j,r)\left[n(j,r) - avafd(j,r)\right] \\ & + \sum_{s=REG} VAFX(j,r,s)\left[nx(j,r,s) - avafx(j,r,s)\right] \\ & - VAFD(j,r)\left[qof(j,r) + n(j,r)\right] \\ & - \sum_{s=REG} VAFX(j,r,s)\left[qox(j,r,s) + nx(j,r,s)\right] \end{aligned} \tag{A.22}$$

After simplification (A.22) becomes:

$$\begin{aligned} ps(j,r) = & \sum_{i=TRAD_{COMM}} \frac{VFA(i,j,r)}{VOA(j,r)}\left[pf(i,j,r) - af(i,j,r)\right] \\ & + \frac{VA(j,r)}{VOA(j,r)}pva(j,r) - \frac{VAV(j,r)}{VOA(j,r)}avav(j,r) \\ & - \frac{VC(j,r)}{VOA(j,r)}ao(j,r) \\ & - \frac{VAFD(j,r)}{VOA(j,r)}\left[qof(j,r) + avafd(j,r)\right] \\ & - \sum_{s=REG} \frac{VAFX(j,r,s)}{VOA(j,r)}\left[qox(j,r,s) + avafx(j,r,s)\right] \end{aligned} \tag{A.23}$$

A.2 Data Description and Transformation

In the monopolistic competition model imports are sourced by agent as mentioned in the previous sections. The structure of the standard GTAP database is not compatible with sourced imports. Therefore, we transform the standard GTAP database following

Swaminathan and Hertel (1996). This section outlines the steps in making this transformation.

There are three steps to generate the monopolistically competitive data base:

- Sourcing agent demand at market prices
- Sourcing agent demand at agents prices
- Trade data

We summarize each step in this section for completeness purposes. For more details, we refer the reader to Swaminathan and Hertel (1996).

A.2.1 Sourced Imports at Market Prices

In the standard GTAP database, consumption expenditure on domestic and imported goods are given separately. For instance, the private household consumption expenditure is `VDPM(i,s)` (for domestic goods) and `VIPM(i,s)` (for imported goods). The first step is to transform agents domestic and import demands into sourced demands valued at market prices. Share of imports from a particular source country in all imports of the destination country is applied to value of agent purchases. Let $MSHRS(i,r,s)$ be the market share of source r in total imports of i by region s which is calculated as follows:

$$MSHRS(i,r,s) = \frac{VIMS(i,r,s)}{\sum_k VIMS(i,k,s)}, \tag{A.24}$$

where $VIMS(i,r,s)$ is the value of imports of i by source r to destination s. Applying this share to agent purchases yields the consumption of imports of i from source r to destination s by agent. For instance, for the private household, we use VIPM(i,s) and the import share MSHRS(i,r,s) to generate VPMS(i,r,s). If the source region, r, is the same as the destination region, s, agents purchases of domestically produced i are also taken into account. An example for private household is given as follows:

$$VPMS(i,r,s) = MSHRS(i,r,s) * VIPM(i,s) \, for \, r \neq s, \tag{A.25}$$

$$VPMS(i,r,s) = MSHRS(i,r,s) * VIPM(i,s) + VDPM(i,r,s) \, for \, r = s. \tag{A.26}$$

As a result, agents domestic and import demands, i.e. `VDPM(i,s)` and `VIPM(i,s)`, are replaced by sourced demands, `VPMS(i,r,s)`. The change in GTAP notation is outlined in Figure A.1, Panel A.

A.2.2 Sourced Imports at Agent's Prices

The second step is to generate the sourced import demands valued at agents prices. Sourced imports at market prices have already been obtained in step one. Value flows at market prices will be used to generate sourced imports at agents prices by using the power of average (ad volarem) tax on total demand by an agent ($TP(i,s)$, $TG(i,s)$, and $TF(i,j,s)$). The formula to calculate the power of the tax for private household is as follows:

$$TP(i,s) = \frac{VIPA(i,s) + VDPA(i,s)}{VIPM(i,s) + VDPM(i,s)}. \tag{A.27}$$

The same method is used for private households, government and firm intermediate input demands. To obtain the sourced purchases at agents prices, $TP(i,s)$ is applied to $VPMS(i,r,s)$ as follows:

$$VPAS(i,r,s) = TP(i,s) * VPMS(i,r,s) \tag{A.28}$$

As a result, agents domestic and import demands, i.e. `VDPA(i,s)` and `VIPA(i,s)`, are replaced by sourced demands, `VPAS(i,r,s)`. The data transformation in this step is summarized in Figure A.1, Panel B.

A.2.3 Trade Data

The third step is to generate the trade data. Trade data does not go through sourcing since it is already sourced. There are just two changes: (a) notation (exports and imports are renamed as sales and demands respectively), and (b) inclusion of domestic sales to ensure market equilibrium (for r = s, aggregate domestic sales are also taken into account). The following formulas are used for exports:

$$VSMD(i,r,s) = VXMD(i,r,s)\, for\, r \neq s, \tag{A.29}$$

$$VSMD(i,r,s) = VXMD(i,r,s) + VDM(i,r)\, for\, r = s. \tag{A.30}$$

where $VDM(i,r)$ is the value of aggregate domestic sales of i in r at market prices:

$$VDM(i,r) = VDPM(i,r) + VDGM(i,r) + \sum_j VDFM(i,j,r). \tag{A.31}$$

The following formulas are used for imports:

$$VDMS(i,s,r) = VIMS(i,r,r)\, for\, r \neq s, \tag{A.32}$$

$$VDMS(i,s,r) = VIMS(i,s,r) + VDM(i,r)\, for\, r = s. \tag{A.33}$$

Swaminathan and Hertel (1996) note that there are hardly any consumption tax on domestic demand which allows the addition of domestic sales into value flows for exports and imports when $r = s$. However, they highlight the fact that if domestic sales are very large relative to intra-regional trade, then intra-regional trade may be distorted.

The same transformation is done for export and import flows at world prices. The data transformation in this step is summarized in Figure A.1, Panel C.

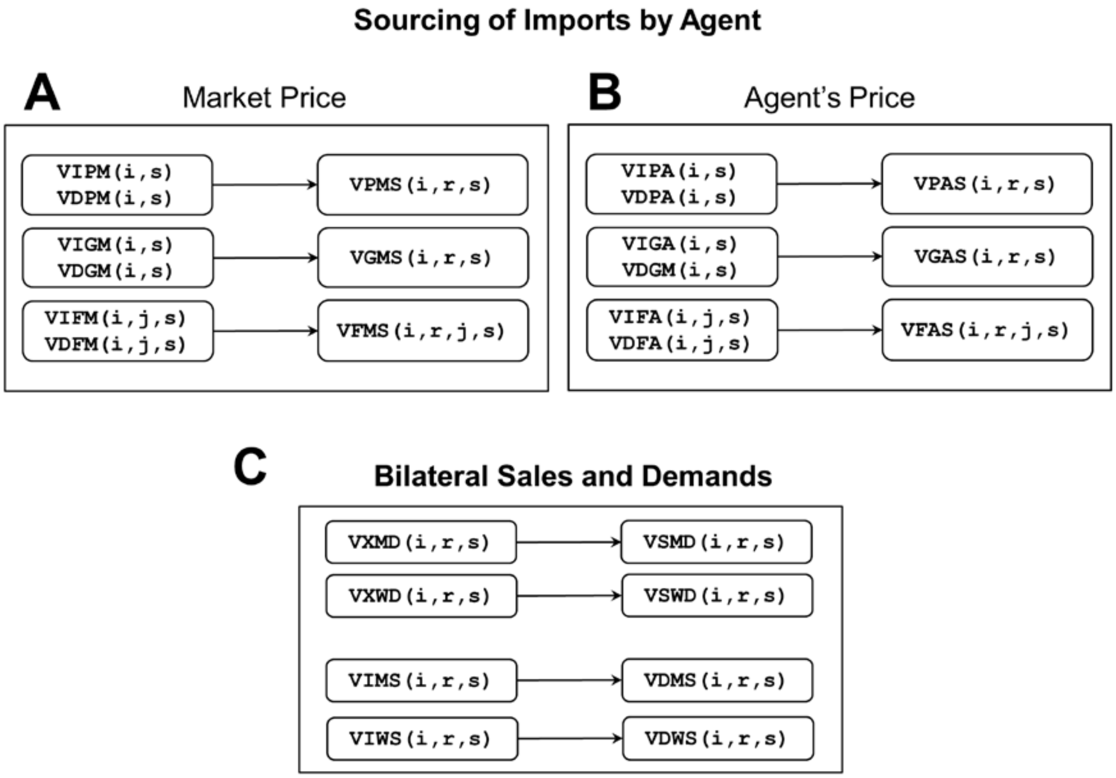

Figure A.1. Transformation of the Data Base: Sourcing Imports by Agent where `i` ∈ `TRAD_COMM`, `j` ∈ `PROD_COMM`, `r,s` ∈ `REG`

Appendix B: Data Appendix to Chapter 3

This section defines the variables used in the empirical analysis and describes the data sources. We used two sources to obtain the data. The bilateral trade flows are from the GTAP Data Base Version 8.1 (Narayanan et al., 2012). This version includes 57 GTAP commodities and 134 GTAP regions of which 113 country titles are available. We use the time series bilateral trade data of this version that covers the period 1995 to 2009 with 2007 as the reference year.

The gravity data have been obtained from the CEPII distance and gravity databases (http://www.cepii.fr/CEPII/en/bdd_modele/bdd.asp). *GeoDist* is CEPIIs distance database developed by Mayer and Zignago (2005). In our paper, data on distance, contiguity, common language, colonial links and landlocked countries are obtained from *GeoDist*. There are two files available in this database: a country-specific dataset geo_cepii.xls (geo_cepii.dta) which includes geographical variables for 225 countries and a dyadic dataset dist_cepii.xls (dist_cepii.dta) which includes different measures of bilateral distances between 224 countries. The content of these files and details about the variables included in these files are explained in Mayer and Zignago (2011). *Gravity* is CEPIIs gravity database gravity_cepii (gravdata_cepii.dta) based on Head et al. (2010). This database covers an exhaustive set of variables for 224 countries for the period 1948 to 2006. Details about the sources used in creating this database are explained in Head et al. (2010). In our paper, data on common legal origins, common currency, FTA and GATT/WTO membership are obtained from Gravity.

The time period considered in this paper is from 1995 to 2006 to match the time series of bilateral trade from GTAP and the gravity variables from CEPII. In particular, we drop the years 2007-2009 from the GTAP time series data and we drop the years 1948-1994 from the CEPII Gravity data. Our final dataset is obtained by merging

GTAP data with CEPII data for motor vehicles and parts industry, 113 country titles and it covers the period from 1995 to 2006.

Table B.1. List of Countries.

List of Countries

Albania
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahrain
Bangladesh
Belarus
Belgium - Lux.
Benin
Bolivia
Botswana
Brazil
Bulgaria
Burkina Faso
Cambodia
Cameroon
Canada
Chile
China
Colombia
Costa Rica
Cte d'Ivoire
Croatia
Cyprus
Czech Republic
Denmark
Ecuador
Egypt
El Salvador
Estonia
Ethiopia
Finland
France
Georgia
Germany
Ghana
Greece
Guatemala
Guinea
Honduras
Hong Kong
Hungary
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Kazakstan
Kenya
Korea
Kuwait
Kyrgyzstan
Laos
Latvia
Lithuania
Luxembourg
Madagascar
Malawi
Malaysia
Malta
Mauritius
Mexico
Mongolia
Morocco
Mozambique
Namibia
Nepal
Netherlands
New Zealand
Nicaragua
Nigeria
Norway
Oman
Pakistan
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Russian Federation
Rwanda
Saudi Arabia
Senegal
Singapore
Slovakia
Slovenia
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Taiwan
Thailand
Togo
Tunisia
Turkey
Uganda
Ukraine
United Arab Emirates
United Kingdom
United Rep. of Tanzania
United States of America
Uruguay
Venezuela
Viet Nam
Zambia
Zimbabwe

All of the variables used in our empirical work are summarized below with details about the respective data sources resorted to obtain them. To facilitate comparison with the gravity literature we adopt the convention in Helpman et al. (2008) for several of the variable definitions.

Bilateral Trade: is the bilateral trade between exporter r and importer s in millions of US dollars. We use GTAP database for information about bilateral trade flows. In particular, we use value of export sales evaluated at world (FOB) prices which corresponds to 'VXWD in GTAP. The dependent variable in our empirical work is value of export sales in logs.

Distance: the population-weighted bilateral distance between the biggest cities of exporter r and importer s in kilometers. For distance, we use the dist_cepii file of the CEPII *GeoDist* database. This uses city level data to evaluate the geographic distribution of population inside each country. There are two population-weighted distance measures reported in this database. We use the one named as ‘distw which is calculated by setting the sensitivity of trade flows to bilateral distance as 1. We use log(distance) in the regression equations.

Contiguity: a dummy variable that equals one if exporter r and importer s are adjacent countries, i.e. are contiguous, and zero otherwise. For contiguity, we use the dist_cepii file of the CEPII *GeoDist* database. The name of the variable in the database is ‘contig.

Common Colony: a dummy variable that equals one if exporter r and importer s have had a common colonizer after 1945. For common colony, we use the dist_cepii file of the CEPII *GeoDist* database. The name of the variable in the database is ‘comcol.

Colonial Link: a dummy variable that equals one if exporter r and importer s have ever had a colonial link, and zero otherwise. For colonial link, we use the dist_cepii file of the CEPII *GeoDist* database. The name of the variable in the database is ‘colony.

Common Language: a dummy variable that equals one if exporter r and importer s share a common official language, and zero otherwise. For common language, we use the dist_cepii file of the CEPII *GeoDist* database. The name of the variable in the database is ‘comlang.off.

Landlocked: a dummy variable that equals one if both exporter r and importer s are landlocked countries, i.e. no direct access to sea, and zero otherwise. For landlocked countries, we use the geo_cepii file of the CEPII *GeoDist* database. The name of the variable in the database is ‘landlocked. This database is country specific; therefore, landlocked is defined as a dummy variable that equals one if the particular country is landlocked. We define a new dummy variable for our purposes using the country-specific information available in geo_cepii.

Common Legal Origins: a dummy variable that equals one if exporter r and importer s share a common legal origin, and zero otherwise. For common legal origins, we use the gravity_cepii file of the CEPII *Gravity* database. The name of the variable in the database is ‘comleg.

Common Currency: a dummy variable that equals one if exporter r and importer s use the same currency, and zero otherwise. The data on currency unions come from the gravity_cepii file of the CEPII *Gravity* database. The name of the variable in the database is ‘comcur.

GATT/WTO Membership: a dummy variable that equals one if both exporter r and importer s are GATT/WTO members, and zero otherwise. The data on GATT/WTO membership comes from the gravity_cepii file of the CEPII *Gravity* database. This database has separate information about the GATT/WTO membership of exporter r (gatt_o) and importer s (gatt_d). Therefore, we define a new dummy variable to incorporate the membership information on both countries which matches our definition above.

FTA/RTA: a dummy variable that equals one if both exporter r and importer s belong to the same regional trade agreement, and zero otherwise. FTA data comes from the gravity_cepii file of the CEPII *Gravity* database. The name of the variable in the database is ‘rta.

Appendix C: Sector Aggregation in Chapter 4

Table C.1. Sector Aggregation: GTAP Version 9.1 Pre-release.

No	Code	Description	Aggregation	Market Structure
1	pdr	Paddy rice	Primary Food	PC
2	wht	Wheat	Primary Food	PC
3	gro	Cereal grains nec	Primary Food	PC
4	v_f	Vegetables, fruit, nuts	Primary Food	PC
5	osd	Oil seeds	Primary Food	PC
6	c_b	Sugar cane, sugar beet	Primary Food	PC
7	pfb	Plant-based fibers	Primary Food	PC
8	ocr	Crops nec	Primary Food	PC
9	ctl	Bovine cattle, sheep and goats, horses	Primary Food	PC
10	oap	Animal products nec	Primary Food	PC
11	rmk	Raw milk	Primary Food	PC
12	wol	Wool, silk-worm cocoons	Primary Food	PC
13	frs	Forestry	Extraction	PC
14	fsh	Fishing	Extraction	PC
15	coa	Coal	Extraction	PC
16	oil	Oil	Extraction	PC
17	gas	Gas	Extraction	PC
18	omn	Minerals nec	Extraction	PC
19	cmt	Bovine meat products	Beef	FH
20	omt	Meat products nec	Processed Food	FH
21	vol	Vegetable oils and fats	Processed Food	FH
22	mil	Dairy products	Processed Food	FH
23	pcr	Processed rice	Processed Food	FH
24	sgr	Sugar	Processed Food	FH
25	ofd	Food products nec	Processed Food	FH
26	b_t	Beverages and tobacco products	Processed Food	FH
27	tex	Textiles	Manufactures	FH
28	wap	Wearing apparel	Manufactures	FH
29	lea	Leather products	Manufactures	FH
30	lum	Wood products	Manufactures	FH
31	ppp	Paper products, publishing	Manufactures	FH
32	p_c	Petroleum, coal products	Manufactures	FH
33	crp	Chemical, rubber, plastic products	Manufactures	FH
34	nmm	Mineral products nec	Manufactures	FH
35	i_s	Ferrous metals	Manufactures	FH
36	nfm	Metals nec	Manufactures	FH
37	fmp	Metal products	Manufactures	FH
38	mvh	Motor vehicles and parts	Manufactures	FH
39	otn	Transport equipment nec	Manufactures	FH
40	ele	Electronic equipment	Manufactures	FH
41	ome	Machinery and equipment nec	Manufactures	FH
42	omf	Manufactures nec	Manufactures	FH
43	ely	Electricity	Services	PC
44	gdt	Gas manufacture, distribution	Services	PC
45	wtr	Water	Services	PC
46	cns	Construction	Services	PC
47	trd	Trade	Services	PC
48	otp	Transport nec	Services	PC
49	wtp	Water transport	Services	PC
50	atp	Air transport	Services	PC
51	cmn	Communication	Services	PC
52	ofi	Financial services nec	Services	PC
53	isr	Insurance	Services	PC
54	obs	Business services nec	Services	PC
55	ros	Recreational and other services	Services	PC
56	osg	Public Administration, Defense, Education, Health	Services	PC
57	dwe	Dwellings	Services	PC

Notes: FH: Firm heterogeneity, PC: Perfect Competition (Armington).

VITA

VITA

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