IMPACTS OF THE TRANSATLANTIC TRADE AND INVESTMENT PARTNERSHIP ON PROCESSED FOOD TRADE UNDER MONOPOLISTIC COMPETITION AND FIRM HETEROGENEITY

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Food processing firms vary in size, exhibit productivity differences, produce highly differentiated products, and engage in monopolistic competition. As the Transatlantic Trade and Investment Partnership negotiation is gaining momentum and trade in processed food is becoming more important, it is worth analyzing the impact of this potential trade liberalization on the U.S. and E.U. processed food markets. This study develops a three-region (United States, European Union, and Rest of the World) monopolistic competition trade model with heterogeneous firms to analyze the effects of U.S.–E.U. bilateral tariff elimination and nontariff barrier harmonization on prices, domestic production, bilateral trade, productivity, measure of operating firms, and welfare in the processed food sector. The results show that this trade liberalization expands cross-hauling, with U.S. exports to the European Union increasing by about 95% and E.U. exports to the United States rising by about 87%. This increase in cross-hauling displaces exports from the Rest of the World to the United States and the European Union by approximately 3% and 8%, respectively. U.S. and E.U. total processed food production increases by about 4% and 0.4%, respectively. Because of lower prices and more consumption, net welfare expands in all three regions.

Key words: Cross hauling, heterogeneous firms, imperfect competition, nontariff barriers, tariffs, trade.

JEL codes: F12, F13, F15.

The food manufacturing segment is different than all other segments of the agricultural sector and food supply chain because of considerable firm size dispersion and a high degree of product differentiation. Food processors frequently modify, enhance, and change characteristics of their products to meet the constant change in consumers’ preferences and tastes, distinguish their products from competitors to survive in the industry, and earn profits. Furthermore, as consumers’ income and tastes for varieties have grown, the number of U.S. food, beverage, and tobacco product manufacturing establishments have also increased, growing by 47% from 20,912 in 1992 to 30,659 in 2012 (U.S. Census Bureau 2015). This highlights the growth in sales at the extensive margin as new firms, products, and varieties enter the market.

Because of the demand for a wide variety of processed meat, dairy, beverage, and cereal products, a large number of firms of varying sizes exist. For instance, Berden et al. (2009) observe that large food processing firms constitute only 1% of the total number of companies but account for about 52% of total sales, whereas small- and medium-sized enterprises comprise the remaining 99% of the companies but account for only about 48% of total sales. Because of product differentiation and size differences, food processing firms engage in

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monopolistic competition, which leads to cross-hauling\(^1\) between regions (Neff et al. 1996; Francois et al. 2013).

Food processing, more so than any other segment in the agricultural sector, has experienced substantial growth in exports, from $37 billion in 1998 to $104 billion in 2012, a 178% increase (BEA 2015). The European Union and the United States dominate the world processed food market, accounting for almost a third of global trade. In 2013, the European Union was the world’s largest processed food exporter with $97 billion worth of exports, which was almost twice the value of U.S. exports of $51 billion. However, E.U. exports of $67 billion were only slightly more than U.S. imports of $61 billion (UNComtrade 2016). The United States and European Union are also the largest bilateral trade partners in value-added food products (FAS/USDA 2014; Olper 2014), largely because of the similar tastes and preferences of their consumers and traditional trade links. In 2013, E.U. exports to the United States were valued at $16.5 billion, while imports from the United States were worth only $5.1 billion.

The lower E.U. imports from the United States are due to processed food trade restrictions, particularly tariffs; the E.U. trade-weighted import tariff is 14.6%, and, in contrast, the U.S. trade-weighted import tariff is 3.3% (Francois et al. 2013). In addition, because of sanitary and phytosanitary measures and disparate regulations, both the European Union and the United States protect their processed food sector more than any other manufacturing sector through significant nontariff barriers (NTBs) (Arita et al. 2014). In fact, NTBs\(^2\) have become more prominent and are considerably more egregious than tariffs, which have traditionally hampered U.S.–E.U. processed food trade (USTR 2013). Berden et al. (2009) estimated, because of cross-border NTB trade restrictions, that the European Union imposed a 56.8% additional cost to U.S. processed food exports and that the United States levied a 73.3% additional cost to E.U. exports. The United States is actively negotiating the Transatlantic Trade and Investment Partnership (TTIP) with the European Union to phase out trade restrictions and harmonize NTBs. The processed food sector is heavily targeted for trade liberalization under TTIP because elimination of the high trade barriers will enhance market access and increase bilateral trade, benefiting both regions significantly (Bridges 2015).

Studies have examined the impacts of TTIP on the agricultural sector as a whole using computable general equilibrium (CGE) models under perfect competition. Beckman (2015) employed the GTAP (Global Trade Analysis Project) model to evaluate U.S. and E.U. trade liberalization under TTIP, with a particular focus on tariff-rate quotas and NTBs. Disdier (2015) used the Modeling International Relationships in Applied General Equilibrium (MIRAGE) CGE model and found that tariff reduction and NTB harmonization from the TTIP agreement would potentially provide large benefits to the U.S. agri-food sectors (all sectors covered by the World Trade Organization’s Agreement on Agriculture plus fish and fish products) but only modest benefits to their trading partners. Specifically, they concluded that U.S. agri-food exports would increase by 159% but E.U. exports would expand only by 55.5%.\(^{3}\) These studies focused on the effect of TTIP agreement on the agricultural sector as a whole. However, as discussed above, the food manufacturing sector differs (product differentiation, wide firm-size dispersion, and imperfect competition) from the rest of the agricultural sector. Our study is the first to take into account these characteristics, which can lead to changes in sales both at the intensive and extensive margins, to quantify the effect of TTIP trade liberalization on the food processing industry.

Zhai (2008) developed a CGE model of 12 regions and 14 sectors and incorporated Melitz’s framework of heterogeneity in all sectors except for the agriculture and energy sectors. Using this model, Zhai conducted a generic trade liberalization analysis, but not

\(^1\) Cross hauling means a product is both exported and imported.

\(^2\) NTBs in processed food trade include sanitary and phytosanitary measures, genetically modified organism and food labeling requirements, certification, traceability, classifications, security-related measures, geographical indications, and differences in trademark legislation (also, see Josling 2014).

\(^3\) Fontagné (2013) also obtained similar results from TTIP trade liberalization.
in the context of TTIP. In contrast, given the importance of food manufacturing in agriculture and TTIP, our study focuses only on the processed food market to examine the effect of tariff and NTB reductions under TTIP not only on U.S. and E.U. firms, but also on rest of the world (ROW) firms.

The specific objectives of this study are to develop a multiregional trade model with monopolistic competition, heterogeneous firms, and endogenous operating decisions; to calibrate the model to the U.S., E.U., and ROW processed food sectors; and to simulate the effects of tariff removal and NTB harmonization under TTIP on prices, production, bilateral trade flows, productivity, measure of firms, and welfare. The contributions of our study are as follows. First, we develop an imperfect competition model by incorporating the unique characteristics of firm heterogeneity, the existence of few big firms and a large number of smaller firms, and the monopolistic competition in the processed food industry. Second, we provide a simple calibration of the model for parameters not available in the literature. Third, we quantify the impacts of both tariff and NTB reductions under TTIP on endogenous variables. Because of this modeling approach, in contrast to modeling the processed food industry under perfect competition, we are able to generate trade liberalization results not only for total exports and imports, but also for cross-hauling, cutoff productivities, and firm measures that are not found in the literature for TTIP.

The results of our analysis indicate that a reduction in U.S. and E.U. variable trade cost makes it profitable for more U.S. and E.U. firms to operate in the bilateral export market, which is reflected in a lower cutoff productivity for exporting, a higher measure of exporting firms, and larger bilateral U.S.–E.U. trade flows. As a result, domestic U.S. and E.U. firms face greater competition and inefficient firms no longer operate, leading to higher cutoff productivities and a reduction in domestic production. An increase in U.S.–E.U. cross-hauling leads to higher total production and availability of a wider range of food products, resulting in lower price indices in both regions. The modeling of three asymmetric regions results in U.S. firms diverting their exports from ROW to the European Union, whereas, because of the fierce competition from U.S. firms, E.U. firms are reallocating their sales from the domestic market to both the United States and ROW. Our study also finds that TTIP not only augments U.S. and E.U. welfare but also ROW welfare. Since no other studies have specifically analyzed the impacts of TTIP on the processed food industry, particularly in the context of an imperfect competition model, we cannot directly compare our results to any other studies; this highlights the contribution of this study to the literature.

Though less-efficient firms enter into the export market, the overall aggregate productivity rises because of the exodus of inefficient domestic firms. This result corroborates the econometric findings by Ruan and Gopinath (2008), Vanvaeten and de Frahan (2011), and Olper (2014). These studies also highlight the prevalence of firm heterogeneity in the processed food industry.

**Model**

We develop a three-region model (United States, European Union, and ROW) for the food manufacturing industry based on monopolistic competition (Krugman 1980) and firm heterogeneity studies (Melitz 2003; Chaney 2008). Our model departs from the standard Melitz’s (2003) framework in four key aspects to accurately model the processed food industry. First, since processed food accounts for only about 2% of total GDP in the United States (U.S. Census Bureau 2015), we specify a partial equilibrium model by treating income spent on processed food as exogenous and the fixed operating and exporting costs as constant exogenous values (as opposed to being paid in terms of inputs). Second, we assume that countries are asymmetric by accounting for

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4 Ruan and Gopinath (2008) observed that global trade liberalization increases average productivity in the food processing sector and benefits countries with higher productivity growth. Vancaveren and de Frahan (2011) concluded that harmonization of the Dutch and E.U. food processing industry increases the total factor productivity of firms due to competitive pressure. Olper (2014) found that an increase in import penetration positively influenced productivity growth for nine food industries in 25 European countries.

5 Also, see Melitz and Ottaviano (2008) for a trade model with firm heterogeneity and nonconstant markups. Kugler and Verhoogen (2012) extended Melitz’s (2003) model to incorporate input choice and its impact on the quality of food output. They showed that larger plants not only charge more for outputs but also pay a premium on production inputs. Tseng and Sheldon (2015) developed a theoretical framework to include the quality of intermediate inputs in a heterogeneous firms model and concluded that larger and exporting firms produce higher-quality goods and charge higher prices. While these latter two studies incorporated processed food quality characteristics, our study focuses on analyzing the effects of TTIP trade liberalization.
differences in preferences across countries, firm-level production technologies, regional sizes, and NTB and tariff trade policies. However, this assumption does not allow us to explore comparative static results. Consequently, we present the impacts of TTIP trade liberalization through empirical simulation. Third, inputs used in processed food production are supplied through a well-behaved supply function (as opposed to inelastically supplied inputs). Thus, we do not specify a numeraire, and both output and input prices are determined endogenously. Fourth, following the trade literature (Kortum 1997; Helpman 2004; Kugler and Verhoogen 2012; Tseng and Sheldon 2015), we assume that productivity differences across firms follow the Pareto distribution, which is consistent with data on firm-level size distribution, where only a small proportion of firms are large and highly productive.

Next, we present the consumers’ problem, the producers’ problem, the producer’s decision of whether or not to operate, the market-clearing conditions, the aggregate output, and welfare.

Consumers’ Problem

A representative consumer in region \( j \) derives utility from consumption of processed foods \( c_{ij}(z) \) produced in region \( i \) (\( i \) and \( j \) are alias indexing U.S., E.U., ROW). For example, \( c_{US,US}(z) \) is consumption from domestically produced goods, and \( c_{E,U,US}(z) \) and \( c_{ROW,US}(z) \) are U.S. consumption of imports from the European Union and ROW, respectively. As explained in the next subsection, \( z \) refers to a continuum of firms with different productivity parameters. Thus, \( c_{ij}(z) \) is consumption of the continuum of varieties corresponding to different firms. The consumer maximizes a Dixit-Stiglitz utility function

\[
(1) \quad \max_{c_{ij}} \left( \sum_i n_i \int_{z_{ij}} c_{ij}(z)^{\rho_i} dG_i(z) \right)^{\frac{1}{\rho_i}}
\]

subject to the budget constraint

\[
(2) \quad \sum_i n_i \int_{z_{ij}} p_{ij}(z)c_{ij}(z)dG_i(z) \leq I_j
\]

where \( n_i \) is the measure of firms in region \( i \), \( z_{ij} \) is the cutoff productivity of the marginal firm that produces in \( i \) and sells in \( j \) and earns zero profits, \( \rho_i \in (0, 1) \) is the Constant Elasticity of Substitution (CES) parameter with elasticity of substitution \( \sigma_j = \frac{1}{\rho_j} > 1 \), and \( p_{ij}(z) \) is the price of \( c_{ij}(z) \) inclusive of all transfer costs and expressed in U.S. dollars. The Pareto cumulative distribution function of the productivity random variable \( z \) is

\[
G_j(z) = 1 - \left( \frac{\mu_j}{z} \right)^{\alpha_j}, \quad \text{with the location parameter} \quad \mu_j \in (0, Z] \quad \text{and shape parameter} \quad \alpha_j > 1.
\]

Income spent on processed food is \( I_i \). Solve the first-order conditions of the above utility maximization problem to obtain demand functions \( c_{ij}(z) \):

\[
(3) \quad c_{ij}(z) = \frac{I_j}{F_j} \left( \frac{p_{ij}(z)}{P_j} \right)^{-\sigma_j}
\]

where \( P_j \) is the aggregate price index

\[
(4) \quad P_j = \left( \sum_i n_i \int_{z_{ij}} (p_{ij}(\xi))^{-\sigma_j}dG_i(\xi) \right)^{-\frac{1}{\sigma_j}}.
\]

Firms’ Problem

Consider a continuum of firms that each produce a different variety of food indexed by the productivity parameter \( z \), which has a one-to-one correspondence with varieties consumed; this relationship explicitly captures the market clearing conditions defined below in equation (9). Given the production technology \( l_{ij}(z) = \frac{y_{ij}(z)}{z} \), the profit function for a firm producing in \( i \) and selling in \( j \) with productivity \( z \) is

\[
(5) \quad \pi_{ij}(z) = \frac{p_{ij}(z)}{1 + t_{ij} + \phi_{ij} + \eta_{ij}} y_{ij}(z) - w_i l_{ij}(z) - f_{ij}
\]

where the ad valorem trade cost consists of transport costs \( t_{ij} \), tariffs \( \phi_{ij} \), and ad valorem equivalent NTBs \( \eta_{ij} \). \( y_{ij}(z) \) is firm-level output, \( l_{ij}(z) \) is a composite input comprised of intermediate inputs, labor, and capital, and \( f_{ij} \) is the fixed cost of a firm operating in region \( i \) and selling in region \( j \). Using the demand

\[6 \text{ The online supplementary appendix provides key steps to derive various equations.}\]
function from equation (3), profit maximization yields the pricing rule

$$p_{ij}(z) = \frac{w_i \left(1 + t_{ij} + \phi_{ij} + \eta_{ij}\right)}{z \rho_j}.$$  

(6)

This pricing rule differs from competitive pricing as evident from the markup \(\frac{1}{\rho_j}\) due to product differentiation.

A firm operates only if it earns non-negative profits, and the minimum (cutoff) productivity level, \(\bar{z}_{ij}\), at which a firm is willing to operate satisfies

$$\pi_{ij}(\bar{z}_{ij}) = 0.$$  

(7)

This equation implies that the marginal food manufacturing firm earns zero profits, while firms with productivity greater than \(\bar{z}\) earn positive profits. A firm with productivity between \(\bar{z}_{ij}\) and \(\bar{z}_{ij}\) will sell only in the domestic market, whereas a firm with productivity above \(\bar{z}_{ij}\) will sell both in the export and domestic markets. Because export firms have higher fixed costs and compete with firms in other countries, they have to be more productive than firms that only sell domestically, implying \(\bar{z}_{ij} > \bar{z}_{ij}\). We assume that the measure of firms \(n_i\) that can potentially operate in region \(i\) is exogenous (Chaney 2008; Zhai 2008). Given the cutoff productivity, the measures of firms that actually operate \(\bar{n}_{ij}\) in region \(i\) and export to region \(j\) is given by

$$\bar{n}_{ij} = n_i \left(\mu_{ij} / \bar{z}_{ij}\right)^{\bar{z}_{ij}}.$$  

(8)

### Market Clearing

The market-clearing condition for each food item is

$$c_{ij}(z) = y_{ij}(z)$$  

(9)

where consumption is equal to production. Market clearing for the composite input in each region is

$$\gamma_i w_i^g = n_i \sum_j l_{ij}(z) dG_i(z)$$  

(10)

where the term on the left-hand side is the input supply function, with \(\gamma_i\) and \(e_i\) representing scale and elasticity of supply parameters, and the term on the right-hand side is sum of composite variable input use.

In the above model, the endogenous variables are \(c_{ij}(z), p_{ij}(z), \pi_{ij}(z), n_{ij}, \bar{z}_{ij}, l_{ij}(z),\) and \(w_i\), and the parameters and exogenous variables include \(t_{ij}, \phi_{ij}, \eta_{ij}, \sigma_i, I_i, \varepsilon_i, \bar{n}_i, \bar{z}_i, \mu_i, f_{ij},\) and \(\gamma_i\).

### Aggregation, Productivity, and Welfare

Using the demand function in equation (3), the market clearing in equation (9), and the Pareto distribution, we obtain total production in region \(i\), which is sold in the domestic and export markets,

$$Y_i = \sum_j n_j \bar{\alpha}_j \mu_{ij} \left(\frac{I_j}{p_{ij} - \sigma_i}\right)^{-\sigma_i} \left(\frac{w_i \left(1 + t_{ij} + \phi_{ij} + \eta_{ij}\right)}{\rho_j}\right)^{1 - \sigma_i} \left(\frac{\bar{z}_{ij}}{\bar{z}_{ij} - \bar{z}_{ij}}\right)^{\sigma_j - \sigma_i} \frac{\bar{z}_{ij}}{\bar{z}_{ij} - \bar{z}_{ij}}.$$  

(11)

The average productivity for firms producing in \(i\) and selling in \(j\), which is computed as the average of operating firms’ productivities, is

$$Z_{ij} = \frac{\bar{z}_i}{\bar{z}_i - 1} \bar{z}_{ij}.$$  

(12)

Because of the partial equilibrium setting (exogenous income and fixed operating and export costs), we compute welfare due to trade liberalization in terms of changes in producer surplus, consumer surplus, and government revenues. Producer surplus (\(PS_i\)) is defined as profits above variable cost

$$PS_i = \sum_j \frac{n_i I_j \bar{\alpha}_j \mu_{ij}^{\bar{z}_{ij}}}{\left(1 + t_{ij} + \phi_{ij} + \eta_{ij}\right) \sigma_i} \left(\frac{1}{p_j} \right)^{1 - \sigma_i} \left(\frac{\bar{z}_{ij}}{\bar{z}_{ij} - \bar{z}_{ij}}\right)^{\sigma_j - \sigma_i - 1} \frac{\bar{z}_{ij}}{\bar{z}_i + 1 - \sigma_i}.$$  

(13)

Therefore, the change in producer surplus (\(\Delta PS_i\)) is the difference in producer surplus before and after trade liberalization. The change in consumer surplus (\(\Delta CS_i\)) is the area...
between two prices and to the left of the demand curve of all domestic and imported processed food items:

\[
\Delta CS_i = \sum_j n_j I_j \left( \frac{1}{\sigma_i - 1} \right)^{2 - \sigma_i} \left( \frac{1}{P_i} \right)^{1 - \sigma_i} \frac{\alpha_j \mu_j \beta_i - \alpha_j - \gamma_j - 1}{\alpha_i - \alpha_j - 1} \times \left( w^B_j \left( 1 + t_{ij} + \phi_j + \eta_j \right) \right)^{1 - \sigma_i} - \left( w^A_j \left( 1 + t_{ij} + \phi_j + \eta_j \right) \right)^{1 - \sigma_i} \]

where \( w^k_j, \phi_j^k, \) and \( \eta_j^k \) are the composite input price, tariff, and NTBs in the baseline \((k = B)\) and alternate \((k = A)\) scenarios. Government tariff revenue is the ad valorem tariff times the price times imports:

\[
(15) GR_i = \sum_j n_j \varphi_{ij} w_j \left( 1 + t_{ij} + \phi_j + \eta_j \right) \rho_j
\]

\[
= \frac{I_j}{P_i} \left( w_j \left( 1 + t_{ij} + \phi_j + \eta_j \right) \right)^{-\sigma_i} \frac{\alpha_j \mu_j \beta_i - \alpha_j - \gamma_j - 1}{\alpha_i + 1 - \sigma_i} \]

The change in tariff revenue \((\Delta GR_i)\) is the difference in government revenue in the alternate scenario and baseline. Therefore, the net change in welfare is \(\Delta NW = \Delta PS_i + \Delta CS_i + \Delta GR_i\).

**Discussion of the Model**

We present a summary of key features of the model that differ from other firm heterogeneity trade models found in the literature. As elaborated above, our model is partial equilibrium because of exogenous income \(I_j\) (equation [3]), fixed operating cost \(f_{ij}\), fixed export cost \(f_{ij}\) (equation [5]), and input supply functions (equation [10]).

Trade liberalization reverberates differently in a partial equilibrium model than in a general equilibrium model in the following four ways. First, in a general equilibrium model, free trade will eliminate tariff income going to consumers and could have negative income effect on consumption, in addition to the positive effect through price reduction. However, income is exogenous in a partial equilibrium model, which eliminates the income effect. Second, free trade in processed food markets will expand input use and increase input prices, which will increase fixed cost in a general equilibrium model. Though output will also increase, the average fixed cost may rise or fall. But in the partial equilibrium model, since fixed cost is constant, the higher output will result in lower average fixed cost. As a result, more incentive exists to enter into the processed food market in the partial equilibrium analysis. Third, in a general equilibrium model, inputs are supplied inelastically. In contrast, we specify an input supply function in our partial equilibrium model. Expanded production due to trade liberalization leads to higher demand for inputs, resulting in higher input price. However, because of the positively sloped input supply function, the increase in input price will be smaller in our partial equilibrium model than in a general equilibrium model. Fourth, the partial equilibrium model entails that welfare measures are represented by consumer surplus, producer surplus, and government revenue, as opposed to the real income index (utility) in a general equilibrium model.

**Quantitative Analysis**

Equations (3)–(10) define a system of sixty equations in sixty variables \(c_{ij}(z), P_i, \pi_{ij}(z), \rho_{ij}(z), n_{ij}, \beta_i, I_j, \) and \(w_j\). However, before proceeding to the numerical analysis, we first combine the zero profit condition (7) and input market clearing condition (10) using the demand function (3), profit equation (5), pricing rule (6), and output market clearing condition (9), which yields:

\[
\pi_{ij}(\beta_i) = \left( 1 + t_{ij} + \phi_{ij} + \eta_{ij} \right)^{-\sigma_i} \frac{I_j}{\rho_j^{-\sigma_i}} \left( w_i \right)^{1 - \sigma_i} - f_{ij} = 0
\]

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8 Note that any equation that has a dependent variable with subscripts \(ij\) contains nine equations, and any equation that has a dependent variable with a subscript \(i\) contains three equations. Similarly, any variable with subscripts \(ij\) contains nine variables, and a variable with a subscript \(i\) contains three variables.
Similarly, substituting the pricing rule (6) into the price index equation (4) yields

\[
\pi_i = \frac{X}{\sum_{j} \frac{n_j z_{ji}}{\rho_j} \left(1 - \sigma_i \right)^{-\sigma_i} \left(1 + t_{ij} + \phi_{ij} + \eta_{ij} \right) \frac{w_j}{\rho_j} \left(1 + t_{ij} + \phi_{ij} + \eta_{ij} \right)}.
\]

Equations (16)–(18) represent a reduced system of fifteen equations that can be numerically solved for the fifteen endogenous variables \( \tilde{z}_{ij}, w_t, \) and \( P_t \) to fully characterize the model. Using the solutions of these variables and the other equations, we can obtain the values of the remaining endogenous variables. This system of fifteen equations contains fifty-seven parameters, \( t_{ij}, \phi_{ij}, \eta_{ij}, \sigma_i, I_i, \epsilon_i, \tilde{n}_i, z_{ij}, \mu_i, f_{ij}, \) and \( \gamma_i \). The values of these parameters come from data, literature, and calibration, which are elaborated in the next section.

### Data and Calibration

We use processed food (code numbers 19–26 corresponding to sectors CMT, OMT, VOL, MIL, PCR, SGR, OFD, and B_T)\(^9\) data for 2011 from the GTAP 9 Data Base. From this data base, we obtain data for the value of domestic production, inputs, imports, exports, transport costs, and tariffs. Because the GTAP database contains only value data, to compute quantities we divide values by unit prices. However, the GTAP database does not contain unit prices. We obtain the unit prices using the value and quantity data of U.S. imports from the European Union and the ROW from the Foreign Agriculture Service (FAS) data base (FAS 2015). We calculate unit prices for each commodity by dividing the value of U.S. imports from the European Union and the ROW by their respective quantity data. Using the U.S.–E.U. price, U.S.-ROW price, and transfer costs (transport costs, tariffs, and NTBs), we construct unit prices for other bilateral trade flows. Then, unit price indexes are calculated as trade-value weighted averages.

Of the fifty-seven parameters employed in the model, forty-two come from the data and literature and the remaining fifteen are calibrated. Table 1 documents bilateral transfer (transport, tariff, and NTB) costs collected in the literature and data. As indicated above, the bilateral transport cost and tariff data come from the GTAP 9 Data Base. The bilateral NTB data come from Berden et al. (2009) and Dean et al. (2009).

Table 2 presents the region-specific parameters collected from the data and literature. We compute the elasticity of substitution (\( \sigma \)) for the United States using the elasticities of substitution given in Broda and Weinstein (2006) at the HS 3 level. We take a weighted average of the elasticities of substitution with weights based on the values of trade

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\(9\) The descriptions of processed food items correspond to the code numbers and sectors is as follows: 19 CMT is meat from cattle, sheep, goats, and swine; 20 OMT is fresh and chilled fowl and turkey meat and products; 21 VOL is vegetable oils and fats; 22 MIL is dairy products; 23 PCR is processed rice; 24 SGR is sugar; 25 OFD is other food products such as flour, cocoa, processed fruit and vegetables, and seafood products; and 26 B_T is beverages and tobacco products.
collected from UNComtrade (2016). These computations yield an elasticity of substitution of 3.38 for the United States. The elasticities of substitution of 3.51 for the European Union and 3.60 for ROW reflect a greater degree of substitution of processed foods in these two regions. The differences in these elasticities highlight the differences in preference across regions. We calculate total income spent on processed food for each region as the sum of spending on processed food produced domestically and imported. We use a parameter value of 0.9 for the elasticity of supply \( e_i \) for the composite input and normalize the measure of firms to one in all three regions. We also conduct sensitivity analysis for key parameters such as \( r_i \) and \( C_{15} \) to verify the robustness of the results.

The food processing industry is characterized by a small number of high-productivity firms and a large number of low-productivity firms. The Pareto distribution, characterized by shape and scale parameters, captures this size dispersion of the food processing industry. Rau and van Tongeren (2009) estimate a shape parameter of 3.99, which we use in this study. We then calibrate (discussed in detail below) the scale parameters using the processed food data. For this calibration, we need the proportion of firms that operate in the domestic and export markets. Bernard et al. (2007) report that 12% and 23% of food manufacturing (NAICS Code 311) and beverage and tobacco product (NAICS Code 312) firms export, respectively. Therefore, we consider that in all three regions, 90% of firms operate domestically and 16% of these firms also export. This implies that 17.8% of the firms that operate domestically also export, which is within the range of the percentage of exporting firms reported by Bernard et al. (2007).

We calibrate the remaining fifteen parameters \( (\mu_i, f_{ij}, \text{and } \gamma_i) \) by solving a system of fifteen equations (three equations from equation \[11\], nine equations from the Pareto cumulative distribution function, and three equations from input supply functions) simultaneously (see table 3). To solve these fifteen equations, we also need expressions for nine endogenous \( \bar{z}_{ij} \) and three endogenous \( w_i \), which are obtained using nine zero profit conditions \[16\] and three input market clearing conditions \[17\]. Once \( \bar{z}_{ij} \) and \( w_i \) are substituted into the system of fifteen equations, we can calibrate the values for \( \mu_i, f_{ij}, \text{and } \gamma_i \) to match the total production for domestic and export sales data, the percentage of firms that operate in the domestic and export markets, and total input use data. To the best of our knowledge, our study is the first to employ this approach to calibrate these parameters.

### Simulation Analysis

We numerically simulate the model to quantify the impacts of TTIP trade liberalization. This simulation analysis consists of the baseline and TTIP scenarios. Based on the above calibration, the baseline simulation replicates the GTAP 9 data with tariffs and NTBs in place. The TTIP scenario considers complete elimination of U.S.–E.U. bilateral tariffs and partial reduction of bilateral NTBs. We consider complete elimination of tariffs because TTIP negotiations are likely to remove all tariffs. However, as reported by Berden et al. (2013), complete elimination of NTBs is not feasible due to sanitary and phytosanitary reasons and complex regulations and restrictions, which cannot be readily harmonized. They conclude the best the United States and the European Union could do is to reduce NTBs by only about half. Therefore, as a more realistic scenario, we consider a 30% reduction in NTBs. We compare the TTIP and baseline simulation results to quantify the impacts of trade liberalization. Table 4 reports the results for bilateral trade flows.

#### Table 2. Parameters from the Literature and Data

| Variable | Description | U.S. | E.U. | ROW |
|----------|-------------|------|------|------|
| \( \sigma_i \) | Elasticity of substitution | 3.38 | 3.51 | 3.60 |
| \( I_i \) | Income ($ billion) | 593 | 914 | 2,597 |
| \( \varepsilon_i \) | Elasticity of composite input supply | 0.9 | 0.9 | 0.9 |
| \( \bar{n}_i \) | Measure of potential entrants | 1 | 1 | 1 |
| \( \gamma_i \) | Pareto shape parameter | 4 | 4 | 4 |

#### Table 3. Parameters Calibrated

| Regions | Fixed Cost \( (f_i) \) | U.S. | E.U. | ROW |
|---------|------------------------|------|------|------|
| U.S.    | 0.53                   | 0.26 | 0.27 |
| E.U.    | 0.21                   | 0.72 | 0.28 |
| ROW     | 0.92                   | 1.38 | 2.64 |

| Regions | Pareto Scale Parameter \( (\mu_i) \) | U.S. | E.U. | ROW |
|---------|-------------------------------------|------|------|------|
| U.S.    | 0.20                               | 0.18 | 0.16 |
| E.U.    | 0.44                               | 0.88 | 11.00 |

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consistent with the results of other studies (see footnote 11). Tariff liberalization and 30% NTB cuts are plausible and also decrease in cross-hauling of 94.92% and 87.31% in response to full turpacity of (excess) demand under monopolistic competition, the in-crease in cross-hauling of 94.92%, while E.U. exports to the United States expanded only by 55.5%. Under a similar TTIP policy scenario, Disdier (2015) concluded that U.S. agri-food exports to the European Union rose by 159% and E.U. exports to the United States expanded by 55.5%. These studies examined the entire agricultural sector. In contrast, our study focuses on processed foods, which are heavily protected by NTBs relative to other agricultural exports. Our results are consistent with the findings of these two studies.

Next, we discuss the impacts of TTIP on the cutoff productivities and measures of operating firms.12 Trade liberalization reduces protection to domestic firms from foreign competition. As a result, domestic firms must compete with highly efficient foreign firms (as evident from the increased cross-hauling between the United States and the European Union), which causes less-efficient firms to reduce their sales and become unprofitable. Because of this fierce competition, the minimum productivity needed for the survival of U.S. and E.U. firms that operate only in their domestic markets rises by 2.90% and 2.10%, respectively. As profits decline and only the more efficient firms remain in business, the measure of firms that produce for the U.S. and E.U. domestic markets declines by 10.81% and 7.98%, respectively; these are the firms that stop producing altogether. Trade liberalization reduces the variable cost of exporting, and consequently more firms find it profitable to operate in the export market, which lowers the cutoff productivity for U.S. firms exporting to the European Union by 20.32% and for E.U. firms exporting to the United States by 18.62%. As a result, U.S. firms exporting to the European Union increase by 148.07%, and E.U. firms exporting to the United States rise by 128.05%. This implies that of all U.S. (E.U.) firms an

table 4. Bilateral Impacts of TTIP in Percent Changes

| Regions   | Trade Flows yij | U.S. | E.U. | ROW |
|-----------|-----------------|------|------|-----|
| U.S.      | −9.50           | 94.92| −6.16|     |
| E.U.      | 87.31           | −5.17| 3.01 |     |
| ROW       | −3.21           | −7.61| 0.36 |     |
| Cutoff Productivity z_{ij} | U.S. | E.U. | ROW |
| U.S.      | 2.90            | −20.32| 1.67|
| E.U.      | −18.62          | 2.10 | −0.68|
| ROW       | 1.19            | 2.77 | −0.03|
| Measure of Operating Firms n_{ij} | U.S. | E.U. | ROW |
| U.S.      | −10.81          | 148.07| −6.40|
| E.U.      | 128.05          | −7.98| 2.75 |
| ROW       | −4.61           | −10.35| 0.11|

Note: For TTIP, we consider a complete tariff removal and 30% NTB reduction.

10 Given the elasticities of substitution of 3.38 for the United States and 3.51 for the European Union, which are also the elasticity of (excess) demand under monopolistic competition, the increase in cross-hauling of 94.92% and 87.31% in response to full tariff liberalization and 30% NTB cuts are plausible and also consistent with the results of other studies (see footnote 11).

11 Fontagné (2013) considered full tariff liberalization and a 25% cut in NTBs under TTIP and found that U.S. agricultural exports to the European Union increased by 168.5% and E.U. agricultural exports to the United States increased by 149.5%.

Under a similar TTIP policy scenario, Disdier (2015) concluded that U.S. agri-food exports to the European Union rose by 159% and E.U. exports to the United States expanded only by 55.5%. These studies examined the entire agricultural sector. In contrast, our study focuses on processed foods, which are heavily protected by NTBs relative to other agricultural exports. Our results are consistent with the findings of these two studies. 12 We can also compute average bilateral productivity Z_{ij} using equation (12). The impacts of TTIP on this average productivity mimic the cutoff productivity both in sign and magnitudes because of the scaling factor in equation (12).
additional 23.69% (20.49%) now serve both the domestic and export markets and 40.58% (46.33%) have not changed their supply chain (not reported in table 4).

Because U.S. exporting firms gain by diverting exports from ROW to the European Union, profitability in the ROW market declines. As a result, only more-efficient firms operate in ROW, leading to an increase in the cutoff productivity of 1.67%. Consequently, less-efficient U.S. exporting firms no longer operate in the ROW market, and the measure falls by 6.40%. In contrast, E.U. firms find it profitable to export to ROW, and thus more E.U. firms enter into this market, resulting in a decline of 0.68% in the cutoff productivity and an increase of 2.75% in the measure of firms. Because of U.S.–E.U. bilateral trade liberalization, ROW exporting firms face intense competition in the United States and the European Union, and their profits and exports decline. As a result, the minimum productivity needed for ROW firms exporting to the United States and the European Union rises by 1.19% and 2.77%. Consequently, the measure of ROW firms exporting to the United States and the European Union falls by 4.61% and 10.35%. Because of greater competition in the U.S. and E.U. markets, ROW firms find it more profitable to sell domestically, which expands domestic production. Higher profits enable less-efficient firms to survive, causing the cutoff productivity to fall by 0.03% and the measure of operating firms to rise by 0.11%. This implies that of all ROW firms, an additional 0.1% of firms are now operating in the domestic market and 80% have maintained their supply chain (not reported in table 4).

Next, we discuss the impacts of a TTIP agreement on aggregate variables such as the price index, total production, and welfare (table 5). The higher competition due to trade liberalization lowers the aggregate price index in the United States by 1.45%, the European Union by 2.97%, and ROW by 0.25%, which implies that real income in all three regions rises. The higher U.S. exports to the European Union (94.92%) offset the decline in production for domestic sales (9.50%) and exports to ROW (6.16%), leading to an increase in total U.S. processed food production by 4.31%. Similarly, the expansion of E.U. exports to the United States (87.31%) and ROW (3.01%) exceeds the decline in E.U. production for domestic sales (5.17%), resulting in a rise in total E.U. production of 0.40%. However, the decline in ROW exports to the United States (3.21%) and the European Union (7.61%) outweighs the rise in production for domestic sales (0.36%), leading to a decline in total ROW production of 0.33%.

In the United States, the producer surplus from the domestic market and the ROW export market falls because U.S. sales in these markets decline; in contrast, U.S. producers exporting to the European Union gain due to higher exports, which outweighs the producer surplus loss in the other two markets, resulting in a net gain of $3.03 billion. However, in the European Union, the gain in producer surplus from additional exports to the United States and ROW does not fully compensate the producer surplus loss from the decline in domestic sales, resulting in a net loss of $2.90 billion. Furthermore, in ROW, the gain in producer surplus from higher domestic sales does not offset the producer surplus loss from lower exports to the United States and European Union, causing a loss of $4.14 billion. Consumers gain in all three regions as the number of products available increases and price indices fall, with E.U. consumers gaining the most ($22.72 billion), followed by ROW consumers ($6.63 billion) and U.S. consumers ($4.81 billion). As a result of U.S. and E.U. bilateral tariff elimination and decline in imports from ROW, U.S. and E.U. tariff revenues fall by $986.99 million and $7.19 billion, respectively. For ROW, the decline in tariff revenues due to the decrease in

| Table 5. Aggregate and Welfare Impacts from TTIP |
|-----------------------------------------------|
| Aggregate Price and Production (% Change)     |
| U.S.  | E.U.  | ROW  |
| $P_i$ | $-1.45$ | $-2.97$ | $-0.25$ |
| $Y_i$ | $4.31$  | $0.40$  | $-0.33$ |
| Changes in Welfare ($ Billions)               |
| U.S.  | E.U.  | ROW  |
| Producer surplus | $3.03$ | $-2.90$ | $-4.14$ |
| Consumer surplus | $4.81$ | $22.72$ | $6.63$ |
| Government revenue | $-0.99$ | $-7.19$ | $-0.22$ |
| Net welfare | $6.85$ | $12.62$ | $2.26$ |

Note: TTIP is a complete tariff removal and 30% NTB reduction.

13 Even though the aggregate consumer surplus gain is larger in ROW than in the United States, on a per capita basis, U.S. consumer surplus is higher than that in ROW.
imports from the United States outweighs the increase in tariff revenues from higher imports from the European Union, leading to a tariff revenue loss of $220.56 million. However, TTIP generates a net welfare gain, not only for the United States and European Union, but also for ROW. In the United States, the increase in producer surplus and consumer surplus is greater than the decline in tariff revenues, leading to net welfare gain of $6.85 billion. In both the European Union and ROW, the gain in consumer surplus exceeds the loss in producer surplus and tariff revenues, resulting in net welfare gains of $12.62 billion and $2.26 billion, respectively.

Sensitivity Analysis

To assess the validity of the simulation results, we conduct sensitivity analysis for key parameters $\sigma_i$ and $\epsilon_j$ and report the results for selected variables. The elasticity of substitution $\sigma_i$ is an important parameter because of product differentiation, and the magnitude of $\sigma_i$ plays a critical role in the simulation analysis. A large increase or decrease in $\sigma_i$ does impact the results. Consequently, for sensitivity analysis, we consider a 10% increase and decrease in $\sigma_i$. Furthermore, stability of the model requires $\alpha > \sigma - 2$, which entails that $\sigma$ cannot be changed by larger magnitudes. These sensitivity analyses reveal that the results are fairly robust to modest changes in $\sigma_i$ (table 6). A higher elasticity of substitution implies that consumers view the different varieties of goods as closer substitutes, which lessens producers’ market power, resulting in a lower markup in each region. This leads to higher prices, smaller changes in total production, and larger net welfare for the United States relative to the results reported in table 5. Table 7 presents the simulation results for a 10% increase and decrease in the elasticity of input supply $\epsilon_j$. The simulation analyses indicate that the results are stable to changes in $\epsilon_j$. In particular, the price indices show marginal changes, and aggregate output and net welfare also exhibit only small changes.

We also carry out sensitivity analysis for different levels of NTB liberalizations. Because of the contentious nature of the NTB negotiations, a large NTB cut is not feasible. Consequently, we examine 10% and 20% NTB reductions, which is consistent with Disdier (2015), who considered 0% to 25% for their sensitivity analysis. The results indicate, compared to the impacts of a 30% NTB cut, changes in bilateral trade flows, cutoff productivities, and the measure of operating firms are relatively proportional for the 10% and 20% NTB reductions. For example, U.S. processed food exports to the European Union increase by 50.11% and 70.88% for the 10% and 20% NTB liberalizations, respectively. The U.S. cutoff productivity changes for exporters to the European Union show about a 3.72% difference between the 10% and 20% NTB reductions, which is comparable to the 3.64% difference between the 20% and 30% NTB reductions. The measure of U.S. firms exporting to the European Union increases by 40.54% when the NTB cut changes from 10% to 20% and by 33.33% for NTB cuts from 20% to 30%. Other bilateral trade flows, cutoff productivities, and measure of operating firms exhibit similar patterns.

Conclusion and Discussion

We develop a three-region (United States, European Union, and ROW) monopolistic competition trade model with heterogeneous

| Variables                          | $\sigma$ Higher by 10% | $\sigma$ Lower by 10% |
|------------------------------------|------------------------|-----------------------|
|                                    | U.S. | E.U. | ROW | U.S. | E.U. | ROW |
| $P_i$ (% change)                   | -1.65| -3.48| -0.22| -1.85| -3.19| -0.29|
| $Y_i$ (% change)                   | 2.52 | 0.46 | 0.06 | 3.84 | 0.84 | -0.44|
| Net welfare change ($ billions)    | 8.21 | 17.87| 3.22 | 7.58 | 11.81| 2.12 |

14 We cannot implement sensitivity analysis for parameters $\mu_i$, $f_p$, and $\gamma_i$, because they are calibrated from the data. In the interest of brevity, we report sensitivity results only for $P_i$, $Y_i$, and net welfare.
firms to analyze the effects of potential trade liberalization in the processed food sector under the TTIP trade agreement on prices, domestic production, bilateral trade, cutoff productivity levels, measure of firms, and welfare. The model is calibrated to data for the processed food market and simulated to quantify the effects of TTIP through U.S.–E.U. bilateral tariff removal and a 30% NTB reduction.

U.S.–E.U. bilateral trade liberalization expands total production in the United States and European Union, and this competition reduces net production for ROW. TTIP leads to higher productivities in the U.S. and E.U. domestic markets because fierce competition causes inefficient firms to be unprofitable and stop producing. However, trade liberalization lowers the variable trade costs, which provides incentives for more inefficient U.S. and E.U. firms to enter the U.S.–E.U. bilateral export market, leading to a decline in cutoff productivities. Since the trade liberalization is only between the United States and the European Union, bilateral trade flows between these two countries expand.

We consider asymmetric regions as the United States, European Union, and ROW differ in sizes, tastes and preferences, and technology. These differences cause U.S. firms to increase exports to the European Union but decrease their exports to ROW. In contrast, E.U. firms increase their exports to both the United States and ROW. This result would not be possible under a symmetric countries assumption.

TTIP causes an expansion of varieties at the extensive and intensive margins and lowers the price index in all regions, which augments real income and benefits consumers in all three regions. The increase in consumer welfare outweighs the decrease in tariff revenues and producer surplus for the European Union and ROW. The net welfare change for the United States is also positive as both consumer and producer surplus increase and are greater than the tariff revenue loss. Thus, this analysis reveals an important welfare result: the bilateral TTIP agreement will expand welfare for not only the United States and European Union but also the ROW.

Supplementary material

Supplementary material is available online at http://oxfordjournals.org/our_journals/ajae/online.

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