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Full Research Article

The impacts to food consumers of a Transatlantic Trade and Investment Partnership#

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Abstract. Primary agriculture is a textbook example of competitive supply with many producers outputting homogenous products, in contrast to firms in the processed food sector produce heterogeneous products while differing in productivity. Our model of trade reform explicitly accounts for the differences between the markets for primary agriculture and food processing. To demonstrate this point, we use a computable general equilibrium (CGE) model to quantify potential impacts of a trade agreement between the EU and US. Crucially, our heterogeneity-firm setup allows for the allocation of NTMs as 'fixed costs', which provides an alternative angle to previous literature that only considered NTM costs in a more conventional framework (e.g., tariff equivalent). Further, the use of this framework allows us to provide detailed welfare impacts, providing more information on the impacts to consumers who purchase mainly processed food and little primary agricultural output, a point often unrepresented in previous analysis of NTM reform.

Keywords. Trade Policy, Imperfect competition, Heterogeneous firms, Simulations.

JEL Codes. F12, F14, F47.

1. Introduction

Primary agriculture is a textbook example of competitive supply with many producers outputting homogenous products while firms in the processed food sector produce heterogeneous products. Thus, there are important differences in productivity, size, and exporting behavior among these firms that should be reflected in quantitative analysis. While manufacturing has typically received the firm heterogeneity treatment, the potential Transatlantic Trade and Investment Partnership (TTIP)[1] provided an instance of using

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The findings and conclusions in this preliminary publication have not been formally disseminated by the U.S. Department of Agriculture and should not be construed to represent any agency determination or policy. This research was supported in part by the intramural research program of the U.S. Department of Agriculture, Economic Research Service.
[1] We note that the chances for implementation in the near future is slim; however, negotiations have not officially ended (unlike the Trans-Pacific Partnership). The United States Trade Representative still maintains a webpage devoted to the potential agreement. https://ustr.gov/ttip

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an agri-food sector (i.e., food processing) that exhibits firm heterogeneity characteristics. Luckstead and Devadoss (2016) analyze the potential impact of TTIP assuming heterogeneity of firm involved in food processing. However, that study uses a single sector model that neglects feedback with other sectors, including agriculture as a major upstream link of the processed food sector.

The potential TTIP agreement generated a large amount of research, which may not be surprising given that the agreement would have linked the world's two largest economies. Although the above mentioned paper incorporated a firm heterogeneity setup in their analysis of TTIP, most research still considers firms as homogenous (e.g., Arita *et al.* 2014, 2017; Beckman et. 2015; Beckman and Arita, 2017; Berden *et al.* 2009; Disdier *et al.* 2015; Egger *et al.* 2015; Fontagne *et al.* 2013; Welfens and Irawan 2014; Beghin *et al.*, 2016). Despite their traditional model approaches, these papers make two points relevant to trade policy analysis. First, tariffs are usually low in developed countries (relative to developing countries), especially for manufacturing and services. However, in developed countries, agriculture is usually more protected relative to other sectors, with higher tariffs, tariff-rate quotas, and non-tariff measures (NTMs).[2] Second, for developed countries, NTMs are becoming more of a trade barrier tariffs, with almost all of the papers that compare the two concluding that NTM removal (even partial removal) could generate larger trade gains than those from tariff removal. The NTM topic is also relevant for firm heterogeneity, since under the standard Armington assumption, NTMs are typically treated simply as ad-valorem equivalents (AVEs). This differs from the heterogeneous firm layout e.g. used in Akgul *et al.* (2016) or Luckstead and Devadoss (2016), that treats them (partly) as fixed costs of trade.

Our work here builds on the previous TTIP analysis, by starting with the view that reforming agri-food trade might generate the largest relative trade gains. We focus on the processed food sector as it accounts for the largest share of bilateral trade in agri-food between US-EU, and because it can be characterized as exhibiting all the signs of a sector with heterogeneous firms.[3] Berden *et al.* (2009) note that one percent of processed food firms account for 52 percent of total sales. these large firms regularly modify and improve the characteristics of their products to meet the requirements and changing preferences of different consumer groups and to differentiate themselves from competitors.[4] Following most TTIP analysis, we employ a CGE model that encompasses all sectors and their interactions, but integrate a firm heterogeneity approach for processed food and all other types of manufacturing. This firm heterogeneity specification allows us to provide more information on impacts to consumers with evidence on the impacts to consumer welfare from a change in the number of new varieties entering the processed food sector, information that is not available in a standard perfect competition setup. Our model also details welfare impacts in general, providing information on an aspect of TTIP so far largely ignored.

[2] One could examine the average Most Favoured Nation (MFN) tariffs reported to the World Trade Organization to confirm this point. The EU trade-weighted MFN rate for agriculture is 8.7% compared to 2.8% for non-agriculture. The U.S. rates are 2.3% and 4.0%. The largest gap is likely for Japan: 1.4% and 12.9%.

[3] Particularly relevant to TTIP, the EU and US account jointly for one third of global trade in processed food (UN Comtrade, 2015); and they trade (bilaterally) more processed food products than any other partners globally (FAS/USDA, 2014; Olper *et al.*, 2014).

[4] In addition, high product differentiation and considerable differences in firms' size and productivity has led some (e.g., Neff *et al.*, 1996; Francois *et al.*, 2013) to label the processed food sectors as monopolistic competition, which is often used to characterize firms with heterogeneity.

2. Modeling framework

Global CGE models are generally considered well suited for ex-ante appraisal of trade agreements as they consider bilateral trade and trade barriers in a consistent microeconomic behavioral framework and account for interlinkages between sectors. Here we use the flexible and modular CGE model by Britz and Van der Mensbrugghe (2017) extended by the heterogeneous firm module of Jafari and Britz (2018a) (see the online appendix for its detailed documentation[5]). Next, we discuss briefly the general structure of the model.

2.1 Perfect competitive sectors

Sectors with perfect competition are depicted as in the standard GTAP model (Hertel, 1997), with cost-minimizing behavior under constant returns to scale (CRS) production technologies along with utility maximizing consumers in competitive markets. Relevant to this work, the perfect competition sectors use an Armington trade setup where a constant elasticity of substitution (CES) function, specific for each agent, i.e. final consumers, government, savings and the different production sector, drives competition between domestically produced products and imports. A second CES nest, which is not agent specific, depicts the import demand composition from bilateral trade flows. Hence, the Armington setup considers commodities produced in the same region as homogenous, but different from commodities stemming from other regions. For example, all dairy products from the EU are assumed to be of the same quality and fetching the same price. On the supply side, production is defined as the Leontief aggregate of value added and intermediate inputs bundles; the value added composition is based on a CES aggregate of primary factors while the composition of intermediate demand is based on fixed physical input coefficients.

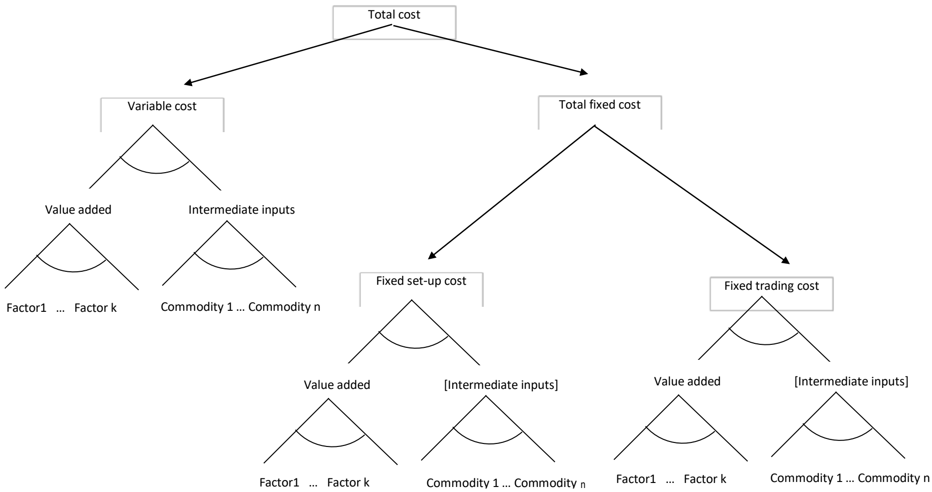
2.2 Heterogeneous sectors

In each sector there is a continuum of firms that are heterogeneous with regard to productivity, and each firm produces its own distinct variety. While firms are free to enter or exit the market, entrance requires covering fixed costs. Firms learn about their productivity level once they enter the market, and then choose to stay or exit. Firms with too low of a productivity level will not be able to cover their fixed cost, and therefore exit the industry. For those that survive, only the most productive ones are involved in exports since they can cover the fixed costs of exporting, while less productive firms only serve the domestic market.

In this framework, the number of firms operating on the domestic market and on the bilateral trade links depends on the characteristics of the domestic market and bilateral trade costs. Since each firm produces a single distinct variety, the total number of varieties available in any given country depends on the number of firms operating in the domestic market and the number of firms exporting to that country. Accordingly, the total number of varieties available to consumers in a given country is determined endogenously. In this

[5] Jafari and Britz (2018) published that online appendix as part of their paper, provided here again for ease.

Figure 1. Production structure in Melitz sectors.



Source: Authors' illustration.

context, any policy shock that leads to changes in variable or fixed costs can change the fraction of firms operating on domestic and on trade links, and therefore the number of varieties available to consumers.

On the demand side, the composite demand of each agent for each commodity is defined as the Dixit-Stiglitz composite of demand for average firm level varieties around the world[6]. That index can be interpreted as a standard CES aggregator where the import quantity impact is additionally multiplied by the change in the number of operating firms providing a love of variety effect.

Each heterogeneous firm produces one single unique variety and therefore, the number of varieties produced in a regional industry is equal to the number of operating firms. The production structure is shown in Figure 1, where total cost is the sum of variable and fixed costs per firm, the latter consists of fixed costs to enter the enter the industry and fixed cost on each trade link. The variable cost nest uses both primary factors and intermediates based on a constant return to scale technology, while fixed cost only relate to primary factors. However, if the overall total cost share of value-added in a sector is small, the fixed cost nest also comprises a share of intermediate composite. This alternative is identified by the intermediate composite in brackets. The value added and intermediate bundles are CES composites of primary factors of production and intermediate inputs, respectively. The total value added (not shown here) is the sum of value added used in both variable and fixed cost nesting. Similarly, the total uses of intermediate commodities and primary factors (not shown here) are the sum of their use in fixed and variable cost nesting.

[6] The heterogeneous firm model defines the so-called "average firm" depicting the average productivity of all firms operating on a specific trade link.

Consistent with the monopolistic competition assumption, each firm applies a markup pricing rule, i.e. it collects rent stemming from producing a specific variety, which covers its fixed costs. Marginal production costs are corrected for the average productivity effect of firms operating on each bilateral trade link. The average productivity of firms on each trade link is determined from a Pareto distribution function which encompasses a so-called cut-off productivity level. Only firms with productivity equal to or higher than that specific threshold level for each bilateral trade link will operate on that link, while the remaining firms are forced to exit. The number of operating firms on a link is derived from a zero profit condition where the revenue of the average firm must be equal to its bilateral fixed cost. However, ensuring zero profit for operating firms on each trade link does not ensure zero profits for the industry as a whole, due to the sunk costs associated with the entry of new firms in the industry. Therefore, zero profit at the industry level is assured by a free entry condition in the industry, indicating that the expected profit for firms over their lifetime must be equal to the overall industry fixed set up costs.

Trade liberalization filters through this type of model differently than in the standard Armington setup, beginning with the reallocation of resources between firms. For example, a policy that decreases bilateral export cost will encourage some firms that initially did not export (those with low productivity) to start trading. This leads both to an increase in the number of exporters and a decrease in the average productivity of exporters (since those firms that just entered the export market were less productive to begin with). Due to fixed cost per firm, an increase in the number of exporters implies that the industry as a whole uses more resources. This increases input prices in the domestic market, leading to some lower productive firms to exit the domestic market. As a result, the average productivity in the domestic market increases. Since some of the least productive firms exit the industry, the productivity for the industry increases and generates a welfare gain (as those firms that now enter the export market are relatively more productive than those leaving the domestic market). On the importing side, similar adjustments in industry structure take place while consumer benefits from more varieties being present on the import side.

2.3 Model parameterization and calibration

A major advantage of this firm heterogeneity model is that it does not require as much information on industries and consumers as the original Melitz (2003) model. Indeed, only two parameters are needed for each sector: one that describes the productivity distribution of the industry (based on a Pareto distribution) and another that is the elasticity of substitution among domestic and imported varieties. We use the estimate of 3.8 from Bernard *et al.* (2003) for the elasticity of substitution, and an estimate of 4.6 for the Pareto shape parameter from Balistreri *et al.* (2011).

2.4 Sectoral and regional aggregation

Table A1 in the Appendix provides details on how we treat the sectors in our application. We generally keep the full sectoral detail of GTAP sectors to prevent bias (Britz *et al.*,

2016) but aggregated the processed food sectors in the GTAP data base for two reasons. First, while there is in consensus in the literature that the processed food sector in general should be treated with heterogenous firms, there is no information on if some sectors (e.g., meat or dairy production) should be excluded and treated as homogenous instead. Second, as discussed below in more detail, data on the potential NTM reduction between the EU and the US suitable for our analysis is available only at the aggregated level.

To capture the impact of a proposed TTIP agreement on third countries, we aggregate the GTAP data base to 10 regions (European Union, United States, Canada, MERCOSUR, China, ASEAN 10, Mediterranean countries, Other Northern Europe[7], low-income countries, Other OECD and Rest of World). Our mapping of regions to the low-income countries aggregate follows the current World Bank classification.

3. Quantifying the policy experiment

The model is calibrated based on version 9 of the Global Trade Analysis Project (GTAP) database (Aguiar *et al.*, 2016), which provides a snapshot of world economy in 2011. Figure 2 reports bilateral ad-valorem trade weighted tariffs from the database. It reveals that processed food, beverage and tobacco products, and textile and clothing are the sectors subjected to the highest tariffs. In most cases, the applied rate of the EU is lower than that for the US.

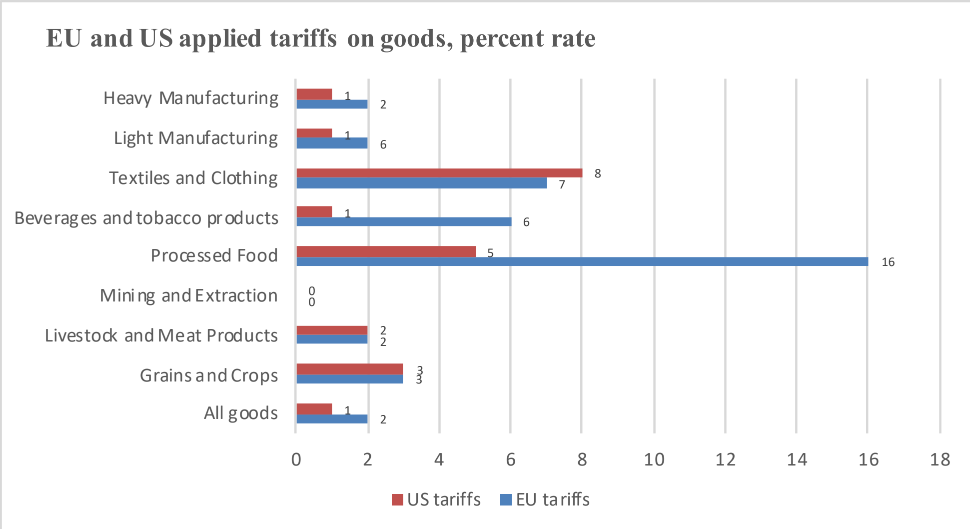
NTMs are not explicit in the data base and need to be incorporated before they can be subjected to policy experiments. The AVEs of NTMs that are potentially removable if a deep trade agreement is reached are taken from Egger *et al.* (2015), the estimated AVE for processed food is 33.83%.[8] It is not based on the latest negotiations status of TTIP, but rather more generally reflects the expected change if the two trade partners move to a deep FTA agreement given the empirical evidence from past FTAs.

We analyze two scenarios (see Table 1): the first scenario considers completely removing import tariffs for all commodities between the EU and the US, while the second one adds NTM reform. Removing existing tariffs is straightforward as they are part of the data base, whereas the second scenario requires allocating the NTM costs estimated by Egger *et al.* (2015). CGE models treat the trade cost effects of NTMs as either rent-generating or cost creating. Modeling the rent-generating effect is straightforward using either an "export tax equivalent" – changing export taxes or a "tariff equivalent" approach—changing import taxes, depending on where the rent are assumed to occur. Changes in the cost generating basis of NTMs are modeled by changing the variable portion of trade costs (since there are no fixed costs in an Armington model). However, NTM costs often reflect a 'fixed cost' component. For example, the US is able to export beef to the EU, but that beef is produced differently than how most beef sold domestically in the US is produced. To be able to export beef to the EU, US producers must have separate facilities or incur other fixed cost type of costs. As our firm heterogeneity structure is able to account for

[7] Other Northern Europe include Switzerland, Norway and Rest of European Free trade Association (EFTA)

[8] It should be noted that one would expect the NTMs between the US and the EU to be region specific (i.e., asymmetric). However, Egger *et al.* (2015) estimated the trade cost equivalents of a deep trade agreement between two regions. Therefore, these estimates should not be interpreted as the current level of NTMs but rather as the trade costs that two regions could reduce due to NTM removal when moving to a deep FTA.

Figure 2. Applied MFN tariff on transatlantic trade.



Source: Data extracted from version 9 of the Global Trade Analysis Project (GTAP) database (Aguiar *et al.*, 2016).

fixed cost, we explicitly change variable and fixed costs for EU-US trade links drawing on Jafari and Britz (2018a). One should note that NTMs could also have demand side effects when regulations affect consumer behavior, typically captured by changing either the consumer willingness to pay (as in Walmsley and Minor, 2016) or Armington elasticities. Although TTIP might provoke such demand side shifting effects, we leave them out due to missing empirical evidence.

Breden *et al.* (2009) suggested 60% of NTMs in EU-US are cost generating and 40% are rent generating. The later is then allocated by 2/3 to import duties and 1/3 to export taxes following Francoise *et al.* (2013) and Egger *et al.* (2015), (see Table 1). The cost portion of the NTM is allocated to variable and bilateral fixed costs in equal shares following Jafari and Britz (2018a).

4. Scenario analysis

While we presume that costs related to NTMs are already observed in the global SAM, rents related to NTMs probably hide in capital income flows and are clearly so far not allocated bi-laterally. We therefore first run a simulation to include the rent generating effects associated with NTMs currently in place between the US and the EU by introducing respectively increasing bi-lateral import and/or export taxes. That augmented database serves as the benchmark. In the following, we discuss the simulated impacts of both scenarios on trade, production, and welfare. Then, we turn to the specific outcomes for the food processing sector with a focus on the information given by the firm heterogeneity model.

Table 1. Scenario layout.

	Tariffs shocks	AVEs shocks			
		Total AVEs reduction divided into the last three columns	Import tax	Export tax	Bilateral fixed and variable trade cost
	(1)	(2)	(2)*0.4*2/3	(2)*0.4*1/3	(2)*0.6
Scenario 1	-100% reduction for all economic sectors	-	-	-	-
Scenario 2	-100% reduction for all economic sectors	-33.83%	-9.0%	-4.50%	-20.3%
Modeled as	Reduction in bilateral import tariff		Reduction in import tariffs representing rents in importer country	Reduction in export taxes representing rents in exporter country	Converted to an equivalent reduction in bilateral fixed and variable trade cost

Source: authors.

4.1 Effects on trade flows

Table 2 shows simulated changes in the volume of aggregate exports. Removing import tariffs (scenario 1) increases EU exports to the US increase by 4.78%, while US exports to the EU increase by 6.8%.[9] Adding NTM reform on top of tariff removal boosts bilateral trade further, by 9.7% from the EU to the US, and by 8.5% from the US to the EU. However, with increases of 0.2% (tariff removal only) and 0.5% (NTM reform included), respectively, the changes in global EU exports are minor; while total US exports expand more significantly (by 1.4% and 2.6%). These findings are comparable with Francois *et al.* (2013). Some regions including China, ASEAN 10, "low-income countries", and "Other Northern Europe" have marginally increases in their exports to either the EU or US, depending on the scenario. In the first scenario, Canada has a decrease in their bilateral exports to both regions, but in the second scenario, Canada has an increase in their exports to the EU. In summary of these changes in regional trade flows, overall world trade increases marginally by 0.3% and 0.4%, respectively.

Table 3 focuses on export flows for the processed food sector. The higher tariff protection in that sector leads to larger changes compared to the results reported above: EU exports to the US of processed food increase by 39% while US exports to the EU increase by 121% (for tariff removal). These findings are consistent with the partial-equilibrium model results of Luckstead and Devadoss (2016), but the magnitude of the impacts found here is different due to the use of different elasticities and feedback effects in our CGE modelling. As the AVE estimates of the expected changes in existing NTMs between the

[9] Bilateral changes are not presented here, but are available upon request from the authors.

Table 2. Change in aggregate exports by region [% change].

Regions	Scenario 1			Scenario 2		
	EU	US	Total	EU	US	Total
World	0.2	1.1	0.3	0.4	1.8	0.4
EU	-0.2[1]	4.8	0.2	-0.3	9.7	0.5
Other Northern Europe	0.1	0.2	0.2	0.0	-0.4	-0.1
US	6.8		1.4	8.5		2.6
Canada	-0.1	-0.3	-0.2	1.3	-0.1	0.2
Mercosur	-0.2	0.1	0.0	-0.1	-0.5	-0.1
China	0.0	0.3	0.2	0.5	-0.5	0.1
ASEAN 10	-0.4	0.5	0.7	0.2	-0.7	0.2
Other OECD	-0.2	0.0	0.0	0.5	-0.6	0.0
EU Mediterranean Partners	-0.3	0.3	-0.1	0.1	-0.5	0.0
Low Income	-0.3	0.3	-0.1	0.1	-0.1	0.0
Rest of World	-0.2	0.1	0.0	0.1	-0.5	0.0

Notes: exporters in rows, importers in columns.
Source: model results.
[1] The reader should note that the numbers presented in the column "EU" showing EU to EU exports is due to an aggregation effect. Sales to the domestic market of a nation are not reported as exports in the SAM. However, if we aggregate individual EU countries, the former bi-lateral trade links between two EU nations occur now inside one aggregate and become the diagonal trade flow in this column. The domestic sales of the EU aggregate are defined from adding up the domestic sales of individual EU countries.

EU and US are quite high and exceed existing tariff levels, bilateral trade volumes increase considerably for processed food in the second scenario. EU exports to the US almost quadruple, while US exports to the EU multiply by more than seven. This leads to changes in total exports of processed food for the EU by almost 9% and by 63% for the US. The trade diversion effects of that second scenario in the processed food sector is accordingly sizeable: most EU trading partners lose about 4% of their exports while exports to the US from the non-EU countries decreases by around 10%.

Trade impacts for primary agriculture are minor (see Table A2 and A3) which reflects low tariffs (see Figure 2) and low exports values. EU exports of primary agricultural products to the US amount to about 83 million, vice versa it is 6 million. Our analysis also shows that the impact on average manufacturing trade between two regions is small (see Table 4.4) due to low tariffs between the regions.

4.2 Effects on domestic output quantities

Table 4 presents information on production changes across all sectors. For processed food, the EU faces a decrease in both scenarios, while the US increases its production. However, the increase in US production is small, as the 63% increase in exports is mostly offset by an increase in imports (46 %) (See Table 3). Opposite and stronger effects are simulated for beverages and tobacco, with a 5% increase in EU production and a 16%

Table 3. Export volumes by region for "processed food" [% change].

Regions	Scenario 1			Scenario 2		
	EU	US	Total	EU	US	Total
World	1.5	5.3	1.1	7.2	46.2	7.4
EU	0.2	39.4	1.2	-1.7	394.2	9.3
Other Northern Europe	-0.7	-0.1	-0.4	-5.4	-10.8	-4.4
US	120.9		9.4	748.5		63.4
Canada	-1.0	-0.4	-0.4	-5.7	-11.3	-8.6
Mercosur	-0.7	0.0	-0.2	-3.9	-9.1	-1.6
China	-0.7	0.0	-0.1	-3.9	-9.3	-2.4
ASEAN 10	-1.0	-0.3	-0.3	-3.7	-8.9	-1.7
Other OECD	-0.7	-0.1	-0.1	-3.8	-9.3	-2.7
EU Mediterranean Partners	-0.6	0.0	-0.3	-4.5	-9.7	-2.5
Low Income	-0.6	0.0	-0.3	-4.5	-9.5	-2.5
Rest of World	-0.7	0.0	-0.2	-4.1	-9.4	-2.1

Source: model results.

decrease in the US. This happens for two reasons: 1) the EU has larger base exports of beverages and tobacco relative to the US; 2) the US has relatively higher tariffs on beverages and tobacco compared to processed food. Other sectors of the economy show only marginal changes. An exception is the output of "Textiles and Clothing", which has a 2.5% increase in the EU in the first scenario. This gain disappears in the second scenario as resources flow to beverages and tobacco in order to meet the large increase in production. Overall, the domestic output of processed food sectors in the EU is simulated to increase by 1.4% in the second scenario, while US output drops by 2.9%. This result is different from that found in other TTIP studies. Those studies generally conclude that the US has large production gains at the expense of the EU.

4.3 Effects on welfare

Welfare impacts are measured based on the equivalent variation (EV) criterion, i.e., the amount of money to be added to the regional household's benchmark income at benchmark prices to reach the same utility as under simulated income and prices. There are global welfare gains of 5.6 billion USD when tariffs are removed (see Table 5), of which 2.8 billion USD accrue to the EU and 5 billion USD to the US (the results are comparable with Francois *et al.*, 2013); the remaining countries, with the exception of China, have losses below 1 billion USD. Both changes in the intensive and extensive margin of trade are important in determining the welfare changes in other countries: Following a reduction in trade barriers between the US and EU, the intensive margin of trade between the two regions increases, diverting trade with other countries and causing welfare to decrease. However, a reduction in trade barriers between the EU and US helps increase the average productivity of firms operating on the domestic market and/or operating on

Table 4. Industrial output by sector [% change].

Sectors	EU		US	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Total	0.00	-0.01	0.02	0.00
Processed food	-0.11	-0.05	0.30	0.46
Beverages and Tobacco	0.13	5.67	-0.23	-16.00
Grains and Crops	-0.13	0.29	0.23	-0.24
Livestock	-0.08	0.03	0.22	0.23
Mining and Extraction	-0.01	-0.05	-0.05	0.07
Textiles and Clothing	2.52	-0.01	0.28	1.11
Light Manufacturing	-0.09	-0.24	0.51	0.15
Heavy Manufacturing	-0.13	-0.40	-0.25	0.30
Utilities and Construction	0.00	0.00	0.05	-0.01
Transport and Communication	0.02	0.07	0.01	0.02
Other Services	-0.01	0.01	-0.01	0.02

Source: model results.

trade links other than EU-US trade link. This results in an increase in the intensive margin of trade (i.e., increase in varieties) in other countries, which is welfare increasing. The total welfare impact on third countries is therefore determined based on the total volume of trade, i.e., the sum of changes in intensive and extensive margins of trade.

All regions are better off compared to the first scenario if NTMs are also reduced, several regions besides the EU and US now experience welfare increases, which results in a global welfare gain of 22.4 billion USD. The removal of NTMs increases average domestic productivity, simulating the extensive trade margin, and improving welfare compared to the first scenario. Still, welfare losses occur in Canada, Mercosur, ASEAN 10, and other OECD countries. The EU has the largest additional welfare gains, increasing from 2.8 billion USD to 13.8 billion USD under the second scenario. The US has an additional 5 billion USD added in the second scenario to reach a total of 7.8 billion USD. The welfare improvements in the second scenario match findings by Balistreri *et al.* (2011) who reports that NTM reduction in the Melitz (2003) framework increases welfare considerably.

Further, our welfare decomposition analysis reveals that the largest portion of welfare gains are associated with the scale effect (associated with the increase in returns to scale), the productivity effect (expansion in market shares of efficient firms), and variety effects (i.e., increases in the number of varieties face by consumers). While term of trade and allocative efficiency contribution is small, the fixed cost effect (due to the increase in firms fixed cost payments) reduces welfare (Table 6).

4.4 Firm-level impact of policy shocks in processing food sectors

Table 7 shows the change to the average firm (as shown in rows) associated with the production and sale of processed food in the EU for different bilateral trade markets. The

Table 5. Changes in welfare [Billion USD].

Regions	Scenario 1	Scenario 2
World	5.6	22.4
EU	2.8	13.8
Other Northern Europe	-0.2	0.1
US	5.0	7.8
Canada	-0.1	-0.1
Mercosur	-0.1	-0.1
China	0.0	0.6
ASEAN 10	-0.2	-0.1
Other OECD	-0.7	-0.2
EU Mediterranean Partners	-0.2	0.2
Low Income	-0.1	0.1
Rest of World	-0.7	0.3

Source: model results.

Table 6. Welfare decomposition analysis.

	Scenario 1	Scenario 2
EU	2.8	13.8
Allocative efficiency	0.0	0.5
Term of trade effect	0.1	1.1
Variety effect	1.3	5.2
Scale effect	1.9	9.7
Productivity effects	0.9	4.2
Fixed cost effects	-1.3	-6.9
Other effects	-0.1	0.0
US	5.6	22.4
Allocative efficiency	0.3	0.9
Term of trade effect	-0.1	1.7
Variety effect	1.8	4.7
Scale effect	3.6	11.7
Productivity effects	2.6	8.5
Fixed cost effects	-2.3	-5
Other effects	-0.2	-0.1

Source: Authors' calculations based on model results.

first column refers to the domestic market, the second column denotes intra-EU trade, the third and fourth columns show EU trade with the US and other regions not included in the transatlantic trade block (hereafter referred as nonTTIP). The last column relates to overall industry performance.

Table 7. Average firm results for EU domestic sales and exports of processed food [% change].

	Scenario 1					Scenario 2				
	Domestic sales	EU	US	nonTTIP	Total sale	Domestic sales	EU	US	nonTTIP	Total sale
Firm price	-0.2	-0.1	9.5	0.0	0.8	-0.9	-0.9	17.6	0.0	1.3
Number of operating firms	-0.6	0.1	52.7	0.0	4.3	-2.9	-2.7	666.5	0.9	55.8
Avg. output per firm	0.2	0.1	-8.7	0.1	0.1	1.0	1.0	-35.5	0.1	0.8
Avg. productivity per firm	0.1	0.0	-8.8	0.0	-0.9	0.7	0.7	-35.7	0.0	-2.9
Industry Fix costs	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-24.2	0.0	-0.1
Fix costs per unit	0.3	-0.2	-28.3	0.0	-2.1	2.0	1.9	-84.7	0.0	-7.3
Industry Variable costs	-0.6	0.1	52.7	0.0	-0.2	-3.0	-2.6	481.2	1.2	-0.4
Variable costs per unit	-0.3	-0.1	9.5	0.0	0.8	-1.1	-0.9	17.6	0.0	1.2
Total output sold	-0.4	0.2	39.4	0.1	0.0	-1.9	-1.7	394.2	1.3	0.7

Source: Based on model results.

The changes in the EU-US trade link for the tariff removal scenario shows a typical reaction of the firm heterogeneity model: tariff removal reduces the average import price in the US, allowing less productive EU firms to operate on that trade link. This increases the number of firms and varieties exported to the US (52%), providing benefits to US consumers. Per unit fix costs drops by 28%; however, lower average productivity increases the variable costs per unit by about 9.5%. There is an increase in total output sold to the US of 39%, but increasing the number of operating firms decreases the average productivity of the firms operating on that trade link (-8.8%).[10] Thus, the average size of these firms also drops – average output per firm decreases by about the same percentage. The average firm exporting to the US after these changes is less productive and smaller. Together, these changes constitute a new equilibrium with zero profits for the firms operating on that trade link, while monopolistic prices charged are equal to the willingness to pay for the specific quality delivered on that trade link given the number of varieties available.

The impacts of the second scenario on EU-US bilateral trade are more pronounced: besides tariff removal, we also shock variable and fix costs related to NTMs for EU-US bilateral trade. This amplifies the effect compared to the first scenario, as now all firms face a higher willingness to pay in bilateral trade, and experience cost savings before supply and demand adjust. This allows far less efficient firms to operate in bilateral trade: the number of the EU firms exporting to the US increases by 666%[11] while average productivity (35%) and firm size (-35%) on the trade link drop. Average per unit variable costs increase by 18%, which translates into changes in the average firm price, while total output for EU-US bilateral trade almost quadruples. The fix cost of the industry operating on

[10] Note that in Table 7 and subsequent tables, even though the number of operating firms increases, the total output change is small because each firms now produces less output. This is equivalent to saying that large increases in the extensive margin are compensated by a reduction in the intensive margin of trade.

[11] Only a small share of firms operate on the link before trade liberalization which are the firms with the highest productivity. Given the shape of the productivity distribution, a significant decrease in bilateral trade cost leads to a nover-proportional increase in that share and increase at the same also the number of traded varieties on the link.

Table 8. Average firm results for US domestic sales and exports of processed food [% change].

	Scenario 1				Scenario 2			
	Domestic sales	EU	nonTTIP	Total sale	Domestic sales	EU	nonTTIP	Total sale
Firm price	-0.1	24.6	0.0	2.3	-2.0	35.6	0.0	3.1
Number of operating firms	-0.6	174.9	-0.9	15.1	-5.0	1421.0	4.0	132.0
Avg. output per firm	0.3	-19.6	0.3	0.2	1.9	-44.2	0.0	1.6
Avg. productivity per firm	0.2	-19.7	0.0	-1.9	1.4	-44.5	0.0	-4.1
Industry Fix costs	0.1	0.1	0.0	0.1	-0.1	-24.4	0.0	-0.2
Fix costs per unit	0.4	-54.7	0.0	-4.6	3.1	-91.1	0.0	-8.0
Industry Variable costs	-0.4	175.2	-0.4	0.4	-5.5	1050.5	3.6	-0.4
Variable costs per unit	-0.1	24.6	0.0	2.2	-2.5	35.6	0.0	2.9
Total output sold	-0.3	120.9	-0.3	0.4	-3.1	748.5	3.7	1.3

Source: Based on model results

that link decreases by 24%, reflecting our assumption of reduced trade costs (see Table 1). However, the original reduction is partly offset by the loss in average productivity, and at the same time distributed to a much higher output quantity. The combined impact on per unit fix costs on that link drops by around -85%. The finding is in line with the literature emphasizing the importance of the extensive margin of trade (e.g., Hummel and Klenow, 2005; Chaney, 2008; among others). No significant changes occur on the EU-nonTTIP link, such that overall changes in trade reflect only the discussed EU-US bilateral changes.

The expansion in exports combined with an on average less productive firm that trades, increases the overall input demand in the economy. This in turn bids up factor and other intermediate prices. As a first order impact, production costs increase and profits on other trade links decline, which induces some of the less productive firms to exit the EU domestic market. The number of operating firms in the domestic market decreases by 0.6% and 2.9% in the first and second scenario. As firms with lower productivity exit, factors are reallocated towards higher-productive and larger firms, thus the average productivity of firms operating in the domestic market rises by 0.1% and 0.7%. This leads to a decline in variable per unit costs of 0.3% and 1.1%, and an increase in average output per firm of 0.2% and 1%. However, the increase in average firm output does not compensate for the decrease in the number of firms operating in the domestic market. Consequently, domestic sales decline by 0.4% and 1.9%. This, along with lower firm prices of -0.2% and -0.9%, reflects the increased competition with US imports.

The impact on export flows of processed food from the US to the EU is presented in Table 8. Note first the impact on US-EU trade: following the reduction in border protection and trade cost, less productive firms find it profitable to enter the trade market. Thus, the number of operating firm on the US-EU link increases by a factor of 1.7 in the first scenario and by 14[12] in the second scenario. This lowers average productivity on that link, such that there are increases in the average firm price and output. Still, US exports to the

[12] Please see footnote 12.

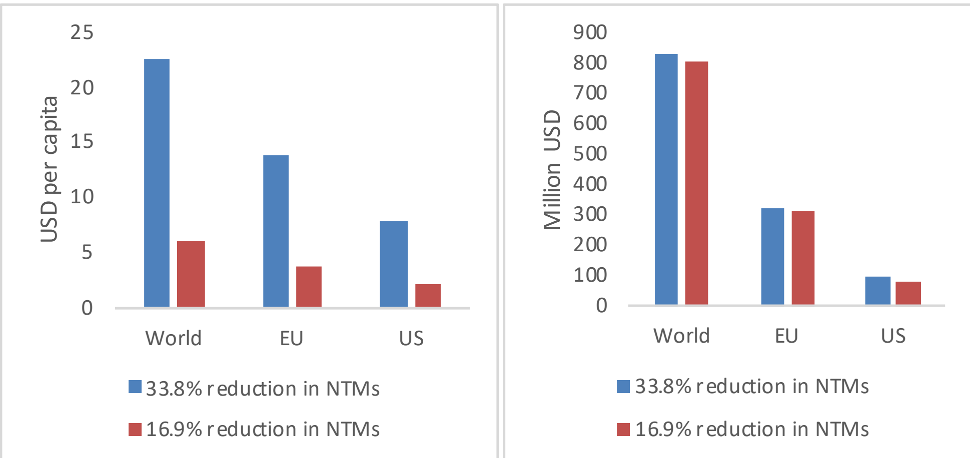
EU increase considerably (by a factor of 1.2 and 7.5), which reflects tariff removal plus an increased willingness to pay due to a higher number of varieties. Export expansion ultimately negatively affects the output sold in the domestic market by 0.3% in the first scenario and 3% in the second. Accordingly, total US processed food sales increases by only 0.4% (in the first scenario) and 1.3% (in the second).

5. Sensitivity analysis

The policy shock, model structure and parameterization jointly determine the model results. We check their robustness with regard to welfare and the volume of exports in the processed food sector. Given the uncertainties on the future of TTIP negotiations, we first perform a sensitivity analysis with regard to tariff and NTM reduction. To do so, we impose a 50% tariff shock (similar to Francois *et al.*, 2013) instead of the 100% removal in the benchmark. This essentially takes into account agricultural products that could be exempted from tariff removal. Our results (not shown here) indicate negligible impacts on trade in processed food and welfare and a small impact on overall primary agriculture trade. We also perform a sensitivity analysis for the NTM reduction scenario, but allowing for only half of the reduction in NTM costs. Figure 3 shows that the simulated changes in trade in processed food are 75-95% and welfare gains are 27-30% lower compared to the earlier results.

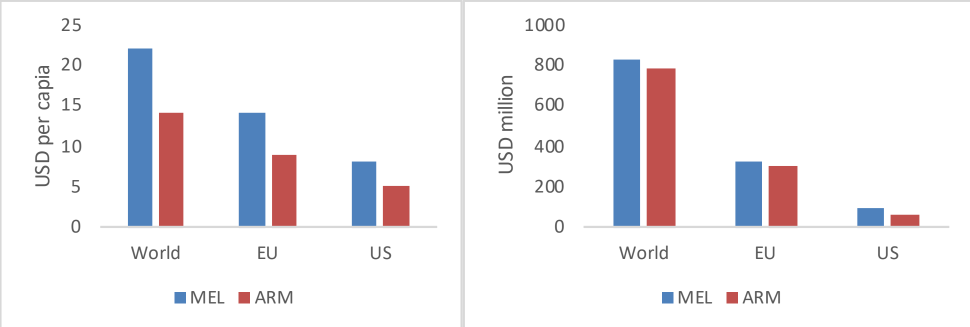
Next, we compare changes in welfare and trade in processed food in the tariff/NTM removal between model setups, i.e. proceed food and all manufacturing sectors have the firm heterogeneity setup (*MEL*), and the more conventional structure where all the sectors follow the standard Armington specification (*ARM*). Welfare in *ARM* scenario is about 40-50% and trade effects are 10-30% lower compared to the firm heterogeneity configura-

Figure 3. Change in welfare [Equivalent variant per capita in constant USD] and export volumes [Million constant USD] under lower reduction of NTMs.



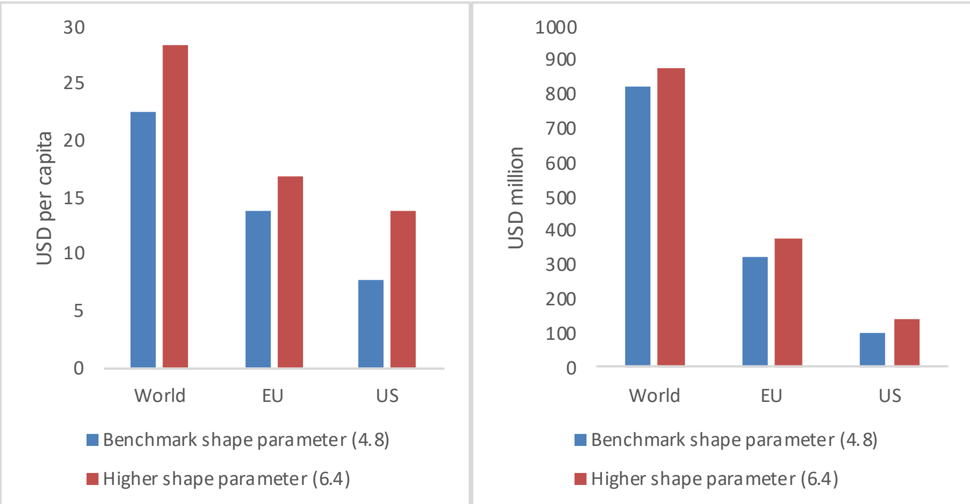
Source: Simulation results.

Figure 4. Change in welfare [Equivalent variant per capita in constant USD] and export volumes [Million constant USD] under the under Melitz and Armington specification.



Source: Simulation results.

Figure 5. Change in welfare [Equivalent variant per capita in constant USD] and export volumes [Million constant USD] under different shape parameters of the Pareto distribution of firm productivity.



Source: Simulation results.

tion (Figure 4). Comparable relative differences in welfare and trade flows are reported by Hosoe (2017), and Jafari and Britz (2018b) for a simulation of Brexit in a CGE model.

Lastly, an additional sensitivity analysis shows that trade expansion and welfare gains are higher under a higher shape parameter, i.e. if the distribution of firms' productivity becomes steeper. In Figure 5, we compare the results when the shape parameter is one-third higher than the benchmark value. The gain in welfare is 30-80% and trade in processed food is 20-40 % higher than under the default parameters across different regions. The results are comparable with Zhai (2008), who simulated a 50% reduction in manufacturing tariffs across the world. We also test the implication of increasing the benchmark Armington elasticities by one-third but keeping the original shape parameter. Our results (not shown here) reveals that that under this assumption, exports are about 10-12% lower across regions, with only a modest impact 4-5% increase in welfare.

6. Conclusion

This study employs a CGE model with a firm heterogeneity setup for processed food and manufacturing to simulate impacts of a potential TTIP agreement on the EU, the US and other countries. This setup allows us to trace the impacts on the intensive and extensive margin of trade as well as on firm productivity. In addition, in accounting for firm heterogeneity by allowing fixed costs to vary, we can more flexibly allocate NTM compared to the more conventional Armington set-up. We simulate the impacts of (i) removing all bilateral tariffs currently in place between the EU and the US; and (ii), an additional removal of NTMs in food processing sectors. Dismantling bilateral import tariffs leads to bilateral trade impacts that are below +10%, and limited welfare and trade diversion effects. As empirical estimates in the previous literature of the welfare impacts of NTMs suggest that these form considerable barriers, and the results of our second scenario are consistent with those of the earlier studies. In particular, EU welfare increases from 2 billion USD under the first scenario to 13.8 billion USD under the second. The larger increase in exports for food processing stems almost entirely from more firms exporting, which underlines the importance of the Melitz model in the analysis. However, increased exports are offset by lower domestic sales in both regions, such that overall industry output changes little. A sensitivity analysis on the core parameters used in the model shows the robustness of the overall results.

Our results differ from previous analysis of TTIP, which suggested that the US would see larger increases than the EU in agri-food production and exports. While this is still somewhat the case for primary agriculture, our results indicate that the EU could see larger production gains for processed food with the U.S. experiencing a decrease in output. Our results also indicate that tariff removal alone could benefit both regions once productivity gains are considered—something that cannot be shown with the typical Armington model setup. In the end, consumers could benefit most from a TTIP agreement as prices are likely to fall and the diversity of products available increase.

Our study could only draw on rather aggregate estimates of the costs caused by NTMs in the food processing sector. Thus, as the sector is highly heterogeneous, future work could try to provide more disaggregated estimates of costs related to NTMs and their composition (rents in importer and exporter country, variable or fixed cost of trade, demand shifting etc.). That would clearly not only improve the analysis of a potential TTIP agreement, but more generally economic impact assessment of FTAs and multilateral trade liberalization.

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Appendix. Supplemental tables

Table A1. Sectoral correspondence of GTAP 9 sector to new sectors.

Number	Code	Description	Pre model Aggregation	Post model aggregation	Market Structure
1	PDR	Paddy rice	Paddy rice	Grains and Crops	PC
2	WHT	Wheat	Wheat	Grains and Crops	PC
3	GRO	Cereal grains nec	Cereal grains nec	Grains and Crops	PC
4	V_F	Vegetables, fruit, nuts	Vegetables, fruit, nuts	Grains and Crops	PC
5	OSD	Oil seeds	Oil seeds	Grains and Crops	PC
6	C_B	Sugar cane, sugar beet	Sugar cane, sugar beet	Grains and Crops	PC
7	PFB	Plant-based fibers	Plant-based fibers	Grains and Crops	PC
8	OCR	Crops nec	Crops nec	Grains and Crops	PC
9	CTL	Bovine cattle, sheep and goats, horses	Bovine cattle, sheep and goats, horses	Livestock	PC
10	OAP	Animal products nec	Animal products nec	Livestock	PC
11	RMK	Raw milk	Raw milk	Livestock	PC
12	WOL	Wool, silk-worm cocoons	Wool, silk-worm cocoons	Livestock	PC
13	FRS	Forestry	Forestry	Mining and Extraction	PC
14	FSH	Fishing	Fishing	Mining and Extraction	PC
15	COA	Coal	Coal	Mining and Extraction	PC
16	OIL	Oil	Oil	Mining and Extraction	PC
17	GAS	Gas	Gas	Mining and Extraction	PC
18	OMN	Minerals nec	Minerals nec	Mining and Extraction	PC
19	CMT	Bovine meat products	Processed food	Processed food	FH
20	OMT	Meat products nec			
21	VOL	Vegetable oils and fats			
22	MIL	Dairy products			
23	PCR	Processed rice			
24	SGR	Sugar			
25	OFD	Food products nec			
26	B_T	Beverages and tobacco products	Beverages and tobacco products	Beverages and tobacco products	FH
27	TEX	Textiles	Textiles	Textile and clothing	FH
28	WAP	Wearing apparel	Wearing apparel	Textile and clothing	FH
29	LEA	Leather products	Leather products	Light Manufacturing	FH
30	LUM	Wood products	Wood products	Light Manufacturing	FH
31	PPP	Paper products, publishing	Paper products, publishing	Light Manufacturing	FH
32	P_C	Petroleum, coal products	Petroleum, coal products	Heavy Manufacturing	FH

Number	Code	Description	Pre model Aggregation	Post model aggregation	Market Structure
33	CRP	Chemical, rubber, plastic products	Chemical, rubber, plastic products	Heavy Manufacturing	FH
34	NMM	Mineral products nec	Mineral products nec	Heavy Manufacturing	FH
35	I_S	Ferrous metals	Ferrous metals	Heavy Manufacturing	FH
36	NFM	Metals nec	Metals nec	Heavy Manufacturing	FH
37	FMP	Metal products	Metal products	Light Manufacturing	FH
38	MVH	Motor vehicles and parts	Motor vehicles and parts	Light Manufacturing	FH
39	OTN	Transport equipment nec	Transport equipment nec	Light Manufacturing	FH
40	ELE	Electronic equipment	Electronic equipment	Heavy Manufacturing	FH
41	OME	Machinery and equipment nec	Machinery and equipment nec	Heavy Manufacturing	FH
42	OMF	Manufactures nec	Manufactures nec	Light Manufacturing	FH
43	ELY	Electricity	Electricity	Utilities and Construction	PC
44	GDT	Gas manufacture, distribution	Gas manufacture, distribution	Utilities and Construction	PC
45	WTR	Water	Water	Utilities and Construction	PC
46	CNS	Construction	Construction	Utilities and Construction	PC
47	TRD	Trade	Trade	Transport and Communication	PC
48	OTP	Transport nec	Transport nec	Transport and Communication	PC
49	WTP	Water transport	Water transport	Transport and Communication	PC
50	ATP	Air transport	Air transport	Transport and Communication	PC
51	CMN	Communication	Communication	Transport and Communication	PC
52	OFI	Financial services nec	Financial services nec	Other Services	PC
53	ISR	Insurance	Insurance	Other Services	PC
54	OBS	Business services nec	Business services nec	Other Services	PC
55	ROS	Recreational and other services	Recreational and other services	Other Services	PC
56	OSG	Public Administration, Defense, Education, Health	Public Administration, Defense, Education, Health	Other Services	PC
57	DWE	Dwellings	Dwellings	Other Services	PC

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

Table A2. Export volume by region for "crop products" [% change].

Exporters	Partners										
	EU	Other Northern Europe	US	Canada	Mercosur	China	ASEAN 10	Other OECD	EU Mediterranean Partners	Low Income	Rest of World
	First scenario										
World	0.3	0.0	1.4	-0.2	-0.2	-0.3	-0.2	-0.2	-0.3	-0.2	-0.3
EU	-0.3	0.0	16.4	0.5	-0.2	0.0	0.0	0.4	-0.1	-0.1	0.0
US	15.1	-1.1		-0.7	-1.3	-1.2	-1.1	-0.7	-1.2	-1.2	-1.2
	Second Scenario										
World	0.5	-1.8	2.8	-1.7	-0.6	-0.5	-1.2	-0.8	-0.4	-0.3	-0.5
EU	-0.1	-1.7	17.4	-0.1	-0.7	0	-0.8	0.2	-0.1	-0.2	-0.1
US	14.1	-4	0	-2.8	-2.9	-2.5	-3.2	-2.1	-2.4	-2.5	-2.5

Table A3. Export volume by region for "livestock products" [% Change].

Exporters	Partners										
	EU	Other Northern Europe	US	Canada	Mercosur	China	ASEAN 10	Other OECD	EU Mediterranean Partners	Low Income	Rest of World
	First scenario										
World	0.2	-0.2	1.3	0.0	-0.1	-0.2	-0.1	0.0	-0.2	-0.1	-0.1
EU	0.0	-0.2	9.9	0.2	-0.2	-0.1	-0.1	0.2	-0.2	-0.1	-0.1
US	11.5	-0.5		-0.1	-0.6	-0.4	-0.4	-0.2	-0.5	-0.4	-0.4
	Second Scenario										
World	-0.5	-0.9	-2.2	4.9	-0.1	0	-0.2	1.2	0.2	-0.1	0
EU	-0.6	-0.8	9.4	3.4	0	0.3	0	0.9	0.2	0.3	0.2
US	13.5	1.5	0	5.8	2.1	2.6	2.2	3	2.5	2.5	2.4

Table A4. Export volume by region for overall manufacturing sectors [% Change].

Exporters	Partners										
	EU	Other Northern Europe	US	Canada	Mercosur	China	ASEAN 10	Other OECD	EU Mediterranean Partners	Low Income	Rest of World
	First scenario										
World	0.3	-0.1	1.3	0.0	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	0.0
EU	-0.2	0.0	3.9	0.3	-0.1	0.0	0.1	0.1	0.1	0.1	0.1
US	5.2	-0.4		-0.2	-0.5	-0.5	-0.4	-0.4	-0.4	-0.3	-0.4
	Second Scenario										
World	0.4	-0.1	1.4	-0.4	-0.4	-0.1	0.0	-0.1	-0.1	-0.1	-0.1
EU	-0.3	-0.1	3.6	-0.3	-0.5	-0.3	-0.2	-0.3	-0.2	-0.2	-0.2
US	5.3	-0.4	0.0	-0.6	-0.9	-0.6	-0.6	-0.6	-0.5	-0.5	-0.5