Global Trade Analysis Project

Impacts of Possible Chinese Protection of 25 Percent on US Soybeans and Other Agricultural Commodities

By

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Introduction

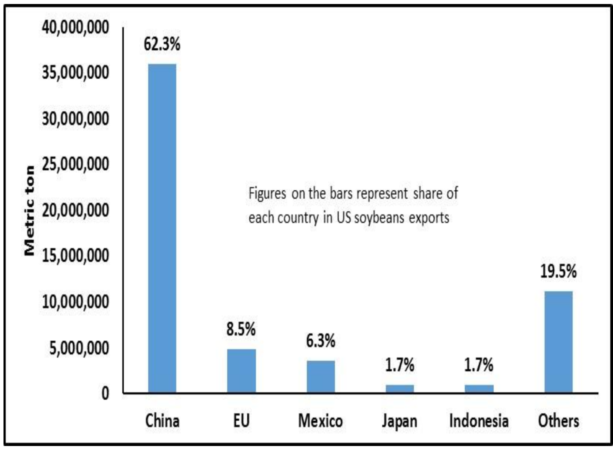
Previously we did a study for the U.S. Soybean Export Council on the possible medium term impacts of Chinese tariffs applied to soybeans, soybean products, and all food commodities [1]. Since that study was completed (February 2018), the Chinese have announced that if the US proceeds with its announced tariffs, it would apply 25% tariffs on US soybeans, wheat, corn, sorghum, beef, and other commodities. The purpose of this study is to estimate the possible medium to long run impacts if those tariffs were implemented. As of this writing, tariffs have not been implemented by either side.[1] The commodities included in this study are soybeans, wheat, sorghum, corn (represented in GTAP as other coarse grains, but the category is mainly corn), and beef (represented in GTAP as ruminant meat). In this report we retain some of the background information and data base update information from the original study so that this report can stand on its own. However, for this analysis, we decided to use the USDA FAS export data[2] to represent the US exports of wheat, sorghum, corn, and soybean by destination in updating our database for 2016. This data provides more precision in bi-lateral trade flows than the UN Comtrade data.

China is the world largest soybean importer and imported 93.5 Million Metric Tons (MMT) of soybeans in 2016, about 65% of global soybean imports. China imports soybeans mainly from Brazil, US, and Argentina. The shares of these three countries in China's imports were about 44%, 42%, and 9% in 2016. Canada, Uruguay, and Russia also export soybeans to China. The shares of these countries in total Chinese soybean imports were about 2.1%, 1.9% and 0.5% in 2016, respectively.

Currently, US and Brazil are the two largest soybean producers and exporters globally and to China. They produced 116.9 MMT and 114.1 MMT of soybeans in 2016, respectively. In 2016, US exported 59.2 MMT of soybeans and Brazil about 63.1 MMT.

The major destinations of US exports of soybeans are shown in Figure 1. China is by far the largest importer of US soybeans followed by the EU and Mexico. Historically, the US was the world's largest soybean producer and exporter until 2012. After that Brazil exported more soybeans than the US. While the US is still the largest soybean producer, Brazil could produce more soybeans than the US in the future. In recent years, production of soybeans has increased rapidly in Brazil, much faster than for the US. Production of soybeans in US and Brazil were about 75.1 MMT and 39.5 MMT in 2000, respectively. In 2000, US production was twice that of Brazil. Between 2000 and 2016 production of soybeans increased by 189% in Brazil, versus 56% for US as shown in Figure 2. In this period, Brazil adopted GMO soybeans, which helped it expand its soybean production rapidly.

[1] However, on April 18, 2018, China announced a 179% tariff on sorghum. That tariff is not considered in this analysis. Clearly, the impacts would be much stronger than the 25% level used in this analysis.
[2] This data is available at: https://apps.fas.usda.gov/gats/default.aspx



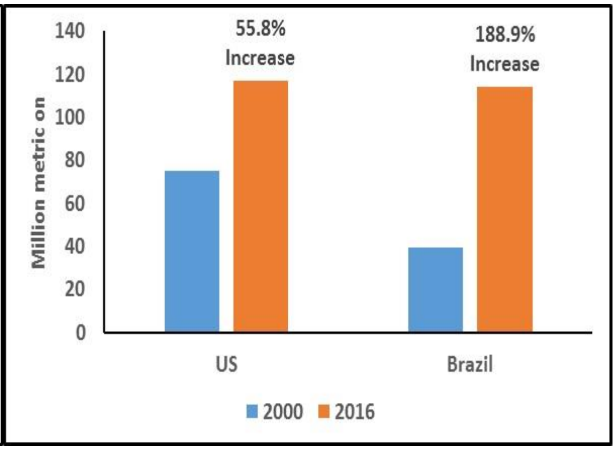


Figure 1. US Soybean exports by major destinations (Source: USDA)	Figure 2. US and Brazilian soybean production growth between 2000 and 2016 (Source: USDA)

Brazil competes very closely with the US in the world soybean market. Since China is the largest soybean importer and imports massive amounts of soybeans from US and Brazil, any changes in China's soybean trade policies could have major implications for both US and Brazil. Currently, trade of soybeans is relatively unrestricted by tariffs and other border measures. However, that could change in the future. It is prudent to evaluate what might be the possible consequences on US production and exports if China were to impose trade restrictions on US imports.

In addition to soybeans, China imports significant quantities of wheat, sorghum, and corn from the US as well. It imported 0.9 MMT of wheat, 5.4 MMT of sorghum, and 0.3 MMT to corn from US in 2016. The shares of China in the US exports of these commodities were 3.8%, 78.8, and 0.5% in 2016. Clearly China is an important export market for sorghum in addition to soybeans.

In general, imposing a trade barrier (either tariff or other restrictions) on China's soybeans, sorghum, wheat, and corn imports from US could generate major adverse consequences for the US soybean and sorghum producers and the US agricultural sector in general. This research consists of economic analyses to understand these consequences.

To accomplish this task, we use the GTAP model as a vehicle to project impacts of imposing a tariff on China's key agricultural commodity imports from the US. While China might not use a tariff, but use Sanitary and Phytosanitary (SPS) or other measures instead, we can proxy the impact of any form of trade restriction by evaluating the impacts of a tariff. GTAP was initially developed to study the economic implications of trade policies and has been used in this area more than any other economic model. We are using an advanced version of this model, named GTAP-BIO. This model has been developed and frequently used to examine the economic and land use impacts of biofuel production and policies. This model can trace production, consumption, and trade of all types of goods and services (including soybeans, soybeans oil, and soybean meals) at the global scale. Taheripour, Cui and Tyner [2] and Taheripour, Zhao, and Tyner [3] described the latest version of this model and its improvements over time. Figure 3 represents the GTAP-BIO main components and structure.

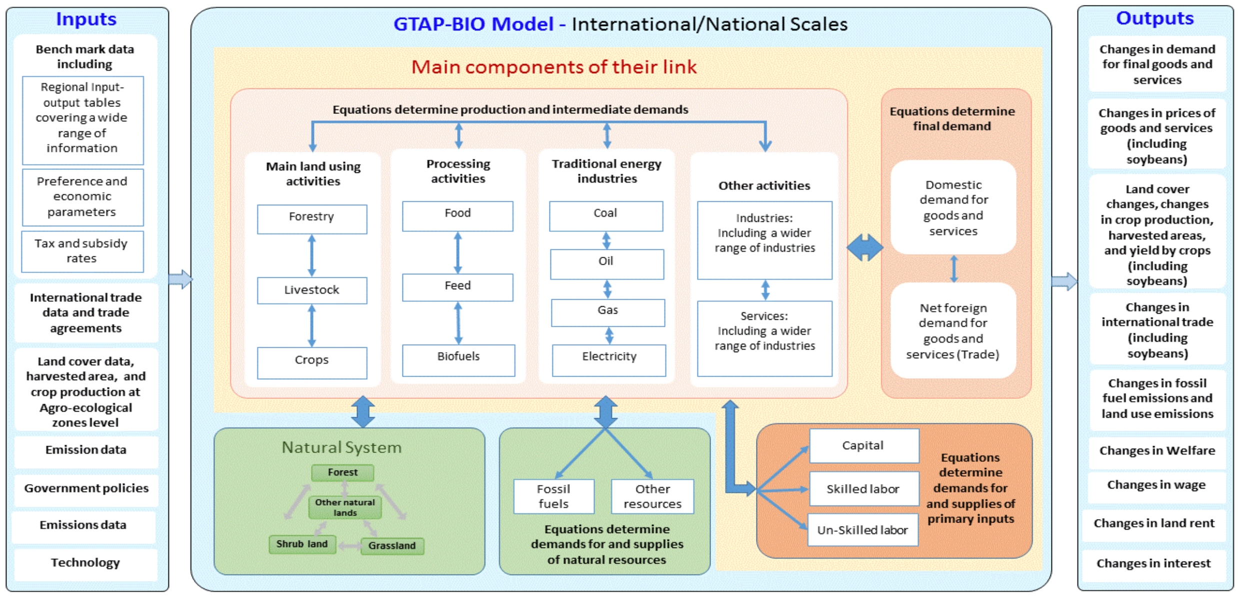


Figure 3: Structure of GTAP-BIO model

This model traces production, consumption, and trade of all goods and services at the global scale by country. The primary factors of production factors are labor, land, capital, and resources. In each country land is divided by Agro Ecological Zones (AEZ) to represent heterogeneity in land quality within each country. Forest, pasture, and cropland are the tree land cover items in this model. Crop sectors use cropland to produce all types crops produced across the world. Crops are aggregated into 9 groups including: rice, wheat, sorghum, other coarse grains (mainly corn), soybeans, rapeseed, palm fruit, other oilseeds, sugar crops, and other crops. The simulations made by this model determine: changes in demands and supplies of all good services and their prices in each region; changes in bilateral trade among all trade partners for all goods and services; changes in allocation of resources; changes in economic gains or losses (welfare) country by country; and many more other outputs.

The latest version of this model represents the world economy in 2011. Since in recent years the global soybean market (and also markets for other agricultural products) experienced major changes in production and trade, we have updated our data base to represent the world economy in 2016, to provide more up-to-date analyses. The original BTAP-BIO model aggregates the whole world into 19 regions. In this research we aggregated the geographical distribution into 6 main regions:

- USA,
- European Union (EU27),
- Brazil,
- China and Hong Kong (CHIHKG),
- South America (S. America),
- Rest of the world (Other).

This aggregation includes all major players who play an important role in the markets for soybeans, soybean oil and soybean meals and the other key agricultural commodities.

Update of the GTAP-BIO data base

We collected data needed to update our 2011 data base to represent the global economy in 2016. To accomplish this task, we obtained data on macroeconomic variables such as population, GDP, and capital formation by country at the global scale for the time period of 2011-16. These data items are obtained from the World Bank data base. In addition, we collected data on crop production, harvested area, and land cover items by country from the Food and Agricultural Organization (FAO) of the United Nations (UN). We also collected data on biofuels produced across the world from the OECD data bases. We also used data provided by the US Department of Agriculture on US crop exports for 2016. With this data, we used the GTAP-Adjust program to update the global economy from 2011 to 2016. In what follows we briefly explain the database updates.

Table 1 represents GDP at constant and current prices for the 6 regions mentioned above. This table indicates that GDP of CHIHKG at constant prices has increased by 41.2% in 2011-2016. The expansion in GDP of CHIHKG at current prices was slightly higher, 47.3%, which represents an increase in the GDP implicit price index. One could expect that the expansion in GDP of CHIHKG plus population growth in this country jointly generated more demand for food, in particular more demand for animal-based food products, leading to higher demand for soybeans, a major food and feed item in CHIHKG.

GDP at constant prices has increased in US (by 11.1%) and EU27 (by 5.4%), but dropped in Brazil (by -2.4%) and South America (by -14.6%) which are the main US competitors in the soybean market. Brazil and South America experienced a recession in recent years. GDP at constant prices has increased by 17% in the rest of the world. Table 1 shows that GDP at current prices dropped everywhere, except for US and CHIHKG. The updated 2016 data base represents the world economy with these current GDP values.

Table 2 shows gross fixed capital formation at constant prices and population for 2011-2016. As shown in this table, among the six regions, CHIHKG experienced the largest expansion in capital formation (by 73.5%), while its total capital formation in 2016 is less than the corresponding figure for EU27 and US. On the other hand, EU27 has large capital formation, but it only increased by 4.1% in 2011-2016.

Table 1. GDP at constant and current prices in 2011 and 2016

Region	GDP at constant prices (billion US$)			GDP at current prices (billion US$)		
	2011	2016	% Change	2011	2016	% Change
USA	15204	16888	11.1	15518	18624	20.0

EU27	17006	17929	5.4	18066	16152	-10.6
Brazil	2297	2248	-2.1	2616	1796	-31.3
CHIHKG	6922	9774	41.2	7821	11520	47.3
S. America	1719	1468	-14.6	1789	1486	-16.9
Other	24900	29221	17.4	27469	26266	-4.4
Total	68048	77527	13.9	73280	75845	3.5

Source: World Bank: World Development Index data base

Table 2. Gross fixed capital formation and population in 2011 and 2014

Region	Gross fixed capital formation at constant prices (billion US$)			Population (million persons)		
	2011	2016	% Change	2011	2016	% Change
USA	25914	28389	9.6	312	323	3.7
EU27	31010	32296	4.1	495	503	1.5
Brazil	3231	3772	16.8	199	208	4.5
CHIHKG	14247	24725	73.5	1351	1386	2.6
S. America	2181	2733	25.3	201	213	5.9
Other	47732	56086	17.5	4455	4810	8.0
Total	124315	148001	19.1	7013	7442	6.1

Source: World Bank: World Development Index data base

At the global scale population has increased by about 429 million (6.1%) over 2011-2016. Population has increased by 35 million (2.6%) in CHIHKG, by 11 million (3.7%) in US, by 8 million in EU27 (1.5%), 9 million in Brazil (4.5%), 12 million (5.9) in S. America, and 355 million (8%) in other regions. One could expect major expansion in demand for food due to population and income growth all across the world.

To update the GTAP-BIO database to 2016, we also obtained data on changes in crop production, harvested area, and land cover changes by country at the global scale for 2011-16. To accomplish this task, data on production and harvested area were obtained from the FAO data set and aggregated to the crop categories used in GTAP-BIO model and then aggregated to the 6 regions mentioned above.

Table 3 shows global production of crops for 2011 and 2016. In general, this table shows that production of many crops has increased. Among all crops, soybeans has increased significantly across the world except in CHIHGK. Total production of soybeans has increased from 262.4 million metric tons in 2011 to 336 million metric tons in 2016, about 28% increase in just 5 years. This is the largest expansion across all crops. Production of soybeans has increased in US, Brazil, and South America by 39.1%, 28.7%, and 20.9%, respectively.

Production of palm fruit also has increased significantly from 241 million metric tons in 2011 to 296.2 million metric tons in 2016, about 22.9% increase in 5 years. Most of this increase occurred in Malaysia and Indonesia. Production of coarse grains (identified as Oth-CrGr in Table 3) has also increased from 1108.4 metric tons in 2011 to 1295.5 million metric tons in 2016, about a 16.9% increase in 5 years. Most of this expansion occurred in the US (by 73.7 million metric tons). Unlike soybeans, production of coarse grains has increased in CHIHKG by 383 million metric tons.

Table 3. Crop production in 2011 and 216 (million metric tons)

Region	Paddy Rice	Wheat	Sor-ghum	Other coarse grains	Soy-beans	Palm fruit	Rape-seed	Other Oil-seeds	Sugar Crops	Other crops*
2011										
USA	8.4	54.4	5.4	318.6	84.2	0.0	0.7	2.8	52.9	762.4
EU27	3.1	137.9	0.7	149.1	1.1	0.0	19.2	22.1	124.0	886.8
Brazil	13.5	5.7	1.9	56.5	74.8	1.3	0.1	3.5	734.0	96.2
CHIHKG	201.0	117.4	2.1	198.4	14.5	0.6	13.4	20.3	125.2	954.7
S. America	12.8	20.0	5.7	42.2	61.5	6.7	0.2	5.7	112.6	206.5
Other	484.4	363.9	42.6	343.7	26.3	232.3	29.1	117.1	938.0	2263.6
Total	723.2	699.4	58.4	1108.4	262.4	241.0	62.7	171.5	2086.6	5170.0
2016										
USA	10.2	62.9	12.3	392.3	117.1	0.0	1.4	4.2	63.6	753.6
EU27	3.0	141.8	0.7	148.0	2.2	0.0	19.6	19.8	109.5	873.5
Brazil	10.6	6.8	1.2	65.5	96.3	1.6	0.1	3.3	768.7	85.3
CHIHKG	209.4	131.7	2.4	236.7	12.0	0.7	15.3	21.8	130.4	1075.9
S. America	12.9	21.2	4.4	59.4	74.4	9.8	0.4	5.3	114.5	212.5
Other	491.5	386.9	44.9	393.6	34.1	284.1	32.0	128.6	994.9	2508.2
Total	737.6	751.2	65.8	1295.5	336.0	296.2	68.7	183.0	2181.6	5509.0
% Change in 2011-2016										
USA	21.2	15.5	125.5	23.1	39.1	0.0	102.1	49.2	20.2	-1.2
EU27	-2.2	2.8	-5.5	-0.7	99.8	0.0	2.2	-10.3	-11.7	-1.5
Brazil	-21.2	20.1	-40.2	16.0	28.7	26.6	38.5	-3.7	4.7	-11.3
CHIHKG	4.2	12.2	17.0	19.3	-17.4	3.2	13.8	7.2	4.2	12.7
S. America	1.2	5.6	-22.7	40.5	20.9	46.5	78.7	-7.2	1.7	2.9
Other	1.5	6.3	5.4	14.5	30.0	22.3	9.8	9.8	6.1	10.8
Total	2.0	7.4	12.6	16.9	28.1	22.9	9.6	6.7	4.6	6.6

* Feed crops such as silages, forages, fodders, and cultivated grasses are included.

Note: This data and the data in Tables 4 and 5 is from FAO and may differ in some cases from the USDA data presented earlier.

Table 4 represents harvested area by crop and region for 2011 and 2016. At the global scale, harvested area of palm fruit represents the largest percentage increase among all crop categories. Harvested area of palm fruit has increased from 16.6 million hectares in 2011 to 20 million hectares in 2016, about 20.2% or 3.4 million hectares expansion. Harvested area of soybeans represents the second largest percentage increase among all crop categories. Harvested area of soybeans increased from 103.6 million hectares in 2011 to 121.4 million hectares, about 17.2% (or 17.8 million hectares). In fact, among all crop categories soybeans represents the largest area increase in harvested area in 2011-2016. Most of this expansion occurred in Brazil (by 9.2 million hectares), Other region (by 4.2 million hectares), US (by 3.6 million hectares and), and South America (by 1.7 million hectares. Harvested area of soybeans decreased in CHIHKG by -1.3 million hectares.

After palm fruit and soybean, harvested area of other oilseeds represents the third largest percentage change increases among all crops. Harvested area of this crop category increased from 89.4 million hectares in 2011 to 97 million hectares in 2016. After these crops sorghum represents the fourth largest percentage change increase harvested area, from 42.3 million hectares in 2011 to 44.9 million hectares in 2016.

Table 4. Harvested area in 2011 and 2016 (million hectares)

Region	Paddy Rice	Wheat	Sor-ghum	Other coarse grains	Soy-beans	Palm fruit	Rape-seed	Other Oil-seeds	Sugar Crops	Other crops*
2011										
USA	1.1	18.5	1.6	35.6	29.9	0.0	0.4	1.2	0.8	36.8
EU27	0.5	26.1	0.1	29.9	0.4	0.0	6.7	9.6	1.6	37.9
Brazil	2.8	2.1	0.8	13.6	24.0	0.1	0.0	0.7	9.6	14.5
CHIHKG	30.1	24.3	0.5	36.2	7.9	0.0	7.3	6.8	1.9	59.6
S. America	2.4	6.3	1.4	9.1	23.5	0.4	0.1	2.8	1.3	15.6
Other	126.6	143.0	37.9	156.6	18.0	16.0	19.1	68.4	15.2	313.7
Total	163.3	220.3	42.3	281.0	103.6	16.6	33.8	89.4	30.6	478.1
2016										
USA	1.3	17.8	2.5	37.0	33.5	0.0	0.7	1.5	0.8	39.2
EU27	0.4	27.1	0.1	29.5	0.7	0.0	6.5	9.6	1.5	37.9
Brazil	1.9	2.2	0.6	15.5	33.2	0.1	0.0	0.5	10.2	11.9
CHIHKG	30.2	24.3	0.5	41.3	6.6	0.1	7.6	6.5	1.8	61.8
S. America	2.3	6.9	1.1	10.2	25.2	0.6	0.2	2.4	1.4	15.8
Other	124.2	141.6	40.1	160.1	22.1	19.2	18.7	76.4	15.6	334.1
Total	160.4	219.9	44.9	293.6	121.4	20.0	33.7	97.0	31.3	500.8
% Change in 2011-2016										
USA	18.3	-4.0	56.2	4.0	12.1	0.0	64.0	28.7	-2.1	6.4
EU27	-7.7	3.8	-1.9	-1.2	93.1	0.0	-4.2	-0.1	-9.0	0.0
Brazil	-29.4	1.3	-26.3	13.9	38.3	30.4	9.5	-22.9	6.5	-17.7
CHIHKG	0.5	0.3	6.7	14.1	-15.8	5.0	3.6	-3.4	-7.5	3.7
S. America	-1.5	10.1	-22.2	12.2	7.1	33.9	56.1	-13.4	4.3	1.4
Other	-1.9	-1.0	5.8	2.2	23.2	19.8	-2.0	11.7	2.3	6.5
Total	-1.8	-0.2	6.1	4.5	17.2	20.2	-0.2	8.5	2.4	4.7

* Feed crops such as silages, forages, fodders, and cultivated grasses are included.

Table 5 represents the shares of US export in production of wheat, sorghum, corn, and soybeans in 2016. It also shows the shares of China in US exports of these commodities. These shares where used in updating the GTAP-BIO data base for 2016. This table shows big export shares for wheat, sorghum, and soybeans. It also indicates that China has large shares in US exports of sorghum and soybeans. That information will be useful in interpreting some of the percentage change results from the tariff impact analysis.

Table 5. Shares of export in US production and shares of China in US export for targeted crops (figures are in quantity %)

Commodities	Share of export in US production	Share of China in US export
Wheat	45.6	3.8
Sorghum	50.1	78.8
Corn	14.4	0.5
Soybeans	50.6	62.3

Table 6 shows land cover items including forest, pasture, and cropland areas for 2011 and 2015. Land cover items for 2016 were not available when we developed this work. As shown in Table 5, global forest and pasture areas declined by -0.3% (or -13.2 million hectares) and -1.3% (-44.3 million hectares). On the other hand, global area of cropland has increased by 2.1% (or 33.1 million hectares). The sum of changes in forest and pasture is larger than the change in cropland. That could represent land converted to other uses. One can trace changes in the geographical distribution of land cover items over 2011-2015 in Table 5. We used these data items to update the GTAP-BIO land cover items for 2015. To accomplish this task, we assigned the annual growth rate between 2011-2105 to 2016.

Table 6. Areas of land cover in 2011 and 2015 (million hectares)

Region	2011			2015			%change		
	Forest	Pasture	Cropland	Forest	Pasture	Cropland	Forest	Pasture	Cropland
USA	309.0	250.4	154.3	310.1	251.0	154.9	0.4	0.2	0.4
EU27	157.0	65.0	118.1	158.5	63.1	117.4	0.9	-3.1	-0.6
Brazil	497.5	196.0	79.4	493.5	196.0	86.6	-0.8	0.0	9.1
CHIHKG	202.2	392.8	122.5	208.3	392.8	135.8	3.1	0.0	10.8
S. America	344.5	265.9	68.1	340.3	267.1	69.6	-1.2	0.4	2.2
Other	2502.2	2149.6	1018.1	2488.4	2105.5	1029.3	-0.6	-2.0	1.1
Total	4012.4	3319.8	1560.4	3999.1	3275.5	1593.5	-0.3	-1.3	2.1

We also collected data on biofuels produced across the world in 2011 and 2016. Data on biofuel production is obtained from the OECD data base. The results are presented in Table 7. As shown in this table, the US is the leading country in ethanol production, mainly from corn. Brazil is the second largest ethanol producer, mainly from sugar cane. EU27 is the leading region in biodiesel production. At the global scale production of ethanol has increased from 22,115 million gallons in 2011 to 25,988 million gallons in 2016. In this period, production of biodiesel has increased from 4,608 million gallons to 6,004 million gallons.

Table 7. Biofuel production in 2011 and 2016 (million gallons)

Region	Ethanol*			Biodiesel**		
	2011	2016	%Change	2011	2016	%Change
USA	14089	15297	8.6	569	964	69.6
EU27	561	757	35.1	2499	2931	17.3
Brazil	5123	7025	37.1	604	835	38.2
CHIHKG	1597	1725	8.0	0	0	0.0
S. America	255	471	84.5	835	944	13.0
Other	490	614	25.2	100	330	230.0
Total	22115	25889	17.1	4608	6004	30.3

* Includes all types of ethanol produced from grains or sugar crops

** includes all types of biodiesel produced from oilseeds

Simulation Cases

Using the updated data base we conducted four simulations. One simulation examines impacts of Chinese tariff only on soybeans imported from US. Then the domain of Chinese tariff is extended to wheat, sorghum, corn, soybeans, and beef imported from US. These simulations were developed using the standard GTAP trade elasticities. Since the magnitudes of trade elasticities affect the simulation results, we repeated these simulations with a set of large trade elasticities for soybeans as explained below.

Many international trade models, especially computable general equilibrium models like GTAP-BIO, use what is called an Armington structure (named after the economist who developed the concept) [4] to handle the choice between domestically produced or imported commodities and also to model trade relationships among trade partners across the world. This structure was developed based on the notion that substitution among products produced in different countries is not perfectly elastic and that there is some degree of differentiation by country of origin. An Armington structure uses trade elasticities to govern these choices. In general, Armington elasticities measure the degree of substitution between home and imported goods and also differentiation by exporting country. The other modeling alternative is termed a homogeneous goods model in which goods produced in different countries are assumed to be perfectly homogeneous, with no country of origin differentiation. In a model with a homogeneous goods assumption, the trade responses are rapid with respect to price changes. However, the Armington structure, in a sense, buffers the trade responses. Previously, we had done a test of sensitivity of Armington elasticities for estimating biofuels induced land use changes [5]. In that analysis we concluded that with higher Armington elasticities (approaching the homogenous goods model), the induced land use emissions for US corn ethanol increase by 30 percent, compared to the base case with the GTAP standard Armington elasticities.

In GTAP, there are two Armington elasticities for each commodity: (1) ESUBD represents the ease of substitution between domestic and imported goods; and (2) ESUBM, represents the degree of substitution among different countries of origin for imports. In GTAP, ESUBM is always set to twice ESUBD. Table 8 contains the two Armington base elasticities of ESUBD and ESUBM for major agricultural and food commodities.

Recent research done at Purdue by Yao et al. [6] suggests that for soybeans Armington elasticities higher than the default values in GTAP may be appropriate . Earlier work by Hillberry et al. also supports higher Armington elasticities [7]. Consequently for the higher trade elasticity cases, we used Armington elasticities of ESUBD=10 and ESUBM=20 for soybeans. These high values correspond to the case for which the market for soybeans is closer to the homogenous good model with stronger reaction to price changes.

Hence, in this research we developed the following four simulation cases:

Case 1: A 25% increase in Chinese tariff on soybeans imported form US with the standard GTAP trade elasticities.

Case 2: A 25% increase in Chinese tariff on soybeans imported from US with the elevated trade elasticities for Soybeans.

Case 3: A 25% increase in Chinese tariff on wheat, sorghum, corn, soybeans, and beef imported form US with the standard GTAP trade elasticities.

Case 4: A 25% increase in Chinese tariff on wheat, sorghum, corn, soybeans, and beef imported from US with the elevated trade elasticities for Soybeans.

Table 8. Original GTAP Armington Elasticities for food industries

Sector	ESUBD	ESUBM	Sector	ESUBD	ESUBM
Paddy Rice	5.05	10.10	Dairy	3.65	7.30
Wheat	4.45	8.90	Ruminant	3.33	6.66
Sorghum	1.30	2.60	Non-Ruminant	1.30	2.60
Other coarse grains	1.30	2.60	Proc. Dairy	3.65	7.30
Soybeans	2.45	4.90	Proc. Ruminant	3.85	7.70
Palm fruit	2.45	4.90	Proc. Non-Rum.	4.40	8.80
Rapeseed	2.45	4.90	Bev. & Sug.	1.42	2.84
Other Oilseeds	2.45	4.90	Proc. Rice	2.60	5.20
Sugar crops	2.70	5.40	Proc. Food	2.00	4.00
Other crops	2.46	4.93	Proc. Feed	3.00	6.00
Forestry	2.50	5.00			

Simulation Results

We will present simulation results for changes in trade, production, producer prices, and welfare (economic well-being). It is important to recall for all results that GTAP-BIO is a medium-term model, which means that the implicit assumption is that the tariffs would go into effect and remain in effect for at least 4-5 years. These are not short-run impacts. After presenting the detailed results, we will provide a summary of the overall impacts.

Trade impacts

The changes in soybean trade for the 25% tariff only on soybean with the standard and higher trade elasticities (cases 1 and 2) are presented in Tables 9 and 10. In these tables rows represent major exporters and columns represent main importers. These tables represent percentage changes in quantities of traded soybeans. Therefore, it is important to recall that the bases are quite different for each region. A high percentage change on a small base may not be as important as a small percentage change on a large base. In general, one can make the following major conclusions from the results presented in Tables 9 and 10:

1) Chinese imports of US soybeans fall substantially under both cases, but the changes are much larger for the elevated elasticities. The range is a reduction of 48-91%.
2) Total US soybean exports globally also fall in both cases. The total export decrease is not as large as the decline in Chinese imports as exports increase to some other regions. In

other words, there is what is called trade diversion. For example, in Table 9, Chinese imports from the US fall 48%, but US global exports fall 24%. Exports to other countries make up about half of the loss in Chinese exports. Brazil and other exporters capture more of the Chinese market, and the US takes some of the markets the other exporters give up.

3) Global soybean imports decrease by a small percentage as well in both cases.
4) Brazilian exports to China increase 18% and 36% in the base and elevated elasticity cases. Chinese imports from Brazil and other South American countries increase in both cases.
5) The biggest change from the previous study is that the percent changes in EU imports from US are smaller in this analysis, largely because of the changes made in the export data from US to EU in the base data.

The changes in soybean trade for the 25% tariff on all targeted items with the standard and higher trade elasticities (cases 3 and 4) are not very different from the results provided in Tables 9 and 10. That is because China has small shares in US exports of wheat, corn and beef. For the case of sorghum, China has a large share in US exports (about 78.8%), but this crop has a tiny share in US total harvested area.

Table 9. Trade changes for tariff on soybeans alone (base trade elasticities)

Region	EU27	CHIHKG	Rest of the World*	Global
USA	12.97	-47.83	15.07	-24.20
BRAZIL	-16.83	18.05	-13.05	14.82
S. America	-13.91	22.42	-9.81	15.83
Global	7.32	-5.30	4.64	-2.50

*Rest of world in this table represents the sum of Brazil, South America, and Other.

Table 10. Trade changes for soybeans alone (elevated trade elasticities)

Region	EU27	CHIHKG	Rest of the world*	Global
USA	38.26	-90.71	63.63	-34.40
BRAZIL	-79.89	36.19	-73.14	24.88
S. America	-76.43	62.32	-64.09	36.57
Global	15.13	-5.30	13.21	-0.20

*Rest of world in this table represents the sum of Brazil, South America, and Other.

Table 11 presents changes in US exports of targeted crops to China under all examined cases. This table shows that when the tariff is imposed only on soybeans, that reduces US soybeans exports to china by -17 MMT. With the high trade elasticity, the US exports of soybeans to China drop by -33 MMT. That is because, in this case, China switches more rapidly to imports from other regions, in particular from Brazil. In the first two cases where only soybeans are subject to the tariff, US exports of wheat, sorghum, and corn go up slightly. That is because in these two cases, production of soybeans goes down in US, while supplies of other crops go up.

Table 11 also shows that imposing the tariff on all targeted items does not affect the model results for the changes in US soybean exports to China. This argument applies to both cases with the standard and high trade elasticities. However, the US exports of wheat, sorghum, and corn to China drop when tariff imposed on all targeted items. The magnitudes of the reductions in exports of these commodities are very similar for the standard and high trade elasticities for soybeans. When all items are subject to tariff, the US exports of wheat, sorghum, and corn to China drop by -0.74 MMT, -0.78 MMT, and -0.11 MMT, regardless of the sizes of trade elasticities for soybeans. No changes were made in the Armington elasticities for the other commodities.

To further clarify the changes in US soybean exports, the quantitative changes in US exports to the EU, China, and rest of world are delineated in Table 12 for the four examined cases. Exports to China decline in all cases, and they increase in all cases to the EU and rest of world. The total change also represents a decline in all cases.

Finally, it is important to note that the imposed tariff on US beef exports to China could drop the export of this commodity to China by 77%. However, it does not affect the total exports of US for this item, as China has a small share in US beef exports.

Table 11. Changes in US exports to China for targeted crops (metric tons)

Description	25% tariff only on soybeans		25% tariff on all targeted crops and beef	
	Standard trade elasticities	High soybean trade elasticities	Standard trade elasticities	High soybean trade elasticities
Wheat	48,538	62,570	-740,444	-737,694
Sorghum	27,405	42,627	-679,312	-675,361
Corn	5,793	8,235	-113,709	-112,299
Soybeans	-17,204,549	-32,629,093	-17,167,804	-32,604,612

Table 12. Changes is US soybean exports (metric tons)

Cases	EU27	4 China	Rest of the world*	Total
Case 1	634,655	-17,204,549	2,538,797	-14,031,097
Case 2	1,872,918	-32,629,093	10,722,878	-20,033,298
Case 3	645,174	-17,167,804	2,575,375	-13,947,256
Case 4	1,888,454	-32,604,612	10,794,575	-19,921,583

*Rest of world in this table represents the sum of Brazil, South America, and Other.

Production impacts

Tables 13-16 present the impacts for the four examined cases on US agricultural commodity production. The results represent percentage changes in the quantities of outputs of crop and livestock sectors. Table 13 is for the soybean only case with base elasticities (case1), and Table 14 is for the elevated soybean trade elasticities (case 2). Tables 15 and 16 represent the results for cases 3 and 4 with protection applied for the targeted agricultural commodities. Note again that these are medium term impacts after global changes in production have had time to materialize.

The results all follow the patterns that would be expected:

1) Soybean production declines for the US range from 11 to 15 percent.
2) Soybean production increases in Brazil range from 9 to 15 percent.
3) Soybean production increases in China range from 3 to 5 percent.
4) Rapeseed production increases in the US and China and declines in Brazil.
5) Production of other oilseeds also increases in the US and China, and remains constant or falls in Brazil.
6) Declines are higher with the elevated Armington elasticities than with the base GTAP elasticities.
7) When the tariffs are on the set of all targeted commodities, US production of wheat, and corn still increase, but sorghum and beef production fall. The reductions in sorghum are significant in these cases, as China has a large share in US sorghum export. Production of all the other commodities falls in Brazil. In essence, the US takes a bit of the market for the other commodities from Brazil.

Table 13. Impacts on US Commodity Production of Chinese Protection of US Soybeans (Case 1: Base Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	2.78	0.09	-0.91	-0.03	-0.31	-0.01	-0.01
Wheat	2.52	-0.22	-5.31	0.08	-1.55	-0.07	0.06
Sorghum	0.88	-0.02	-1.67	-0.23	-0.96	-0.09	0.10
Other Coarse gains	1.26	-0.05	-1.72	-0.47	-1.02	-0.17	-0.06
Soybeans	-10.74	-0.15	9.33	3.14	3.24	0.09	-0.51
Palm fruit	0.81	1.99	1.55	2.12	1.70	0.03	0.07
Rapeseed	6.46	0.47	-2.47	2.07	0.29	0.89	1.46
Other Oilseeds	6.23	1.08	-0.64	2.21	1.93	0.40	1.03
Sugar crops	0.09	0.00	-0.59	-0.04	-0.06	0.02	-0.17
Other crops	2.21	0.02	-2.82	-0.07	-0.63	-0.02	0.00
Forestry	0.09	0.00	-0.19	-0.01	-0.09	-0.01	0.00
Dairy	0.10	0.00	-0.11	-0.09	-0.10	0.00	0.00
Ruminant	0.23	0.00	-0.44	-0.01	-0.09	0.01	0.00
None Ruminant	0.25	0.01	-0.59	-0.09	-0.07	0.01	-0.03

Table 14. Impacts on US Commodity Production of Chinese Protection of US Soybeans (Case 2: Elevated Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	3.76	0.20	-1.57	-0.06	-0.62	0.00	-0.02
Wheat	3.48	-0.31	-8.92	0.04	-2.99	-0.04	0.05
Sorghum	1.31	0.03	-2.84	-0.20	-1.73	-0.07	0.18
Other Coarse gains	1.76	-0.01	-2.95	-0.53	-1.85	-0.15	-0.07
Soybeans	-14.82	-15.84	15.46	5.45	6.57	-1.80	0.03
Palm fruit	0.98	3.58	-0.62	2.53	1.91	0.06	0.09
Rapeseed	7.13	0.40	-5.98	2.07	-1.44	0.63	1.34
Other Oilseeds	6.83	1.17	-3.86	2.18	0.54	0.22	0.78
Sugar crops	0.13	0.00	-1.02	-0.04	-0.11	0.03	-0.28
Other crops	3.04	0.10	-4.85	-0.10	-1.21	0.02	-0.01
Forestry	0.12	-0.01	-0.32	-0.01	-0.17	0.00	-0.01
Dairy	0.14	-0.01	-0.19	-0.10	-0.20	0.00	0.00
Ruminant	0.32	0.02	-0.76	-0.01	-0.20	0.01	-0.01
None Ruminant	0.35	0.02	-1.00	-0.09	-0.17	0.02	-0.04

Table 15. Impacts on US Commodity Production of Chinese Protection of the Entire Set of Agricultural Commodities (Case 3: Base Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	2.95	0.08	-0.91	-0.03	-0.31	-0.01	-0.01
Wheat	1.91	-0.25	-5.35	0.22	-1.61	-0.06	0.05
Sorghum	-4.29	0.22	-1.68	-0.82	-0.86	0.05	-1.16
Other Coarse gains	1.22	-0.03	-1.70	-0.28	-1.04	-0.18	-0.03
Soybeans	-10.64	-0.19	9.27	3.05	3.23	0.07	-0.50
Palm fruit	0.86	1.98	1.62	2.18	1.73	0.05	0.09
Rapeseed	6.71	0.44	-2.51	2.02	0.29	0.86	1.45
Other Oilseeds	6.46	1.05	-0.69	2.13	1.92	0.38	1.01
Sugar crops	0.09	0.00	-0.60	-0.04	-0.05	0.02	-0.17
Other crops	2.37	0.02	-2.83	-0.09	-0.64	-0.02	0.00
Forestry	0.10	-0.01	-0.19	-0.01	-0.09	-0.01	0.00
Dairy	0.14	-0.01	-0.12	-0.23	-0.11	0.00	-0.01
Ruminant	-0.50	0.20	-0.31	0.11	-0.01	0.10	0.00
None Ruminant	0.28	0.01	-0.60	-0.10	-0.07	0.02	-0.04

Table 16. Impacts on US Commodity Production of Chinese Protection of the Entire Set of Agricultural Commodities (Case 4: Elevated Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	3.92	0.20	-1.56	-0.05	-0.62	0.00	-0.02
Wheat	2.85	-0.34	-8.95	0.18	-3.05	-0.03	0.05
Sorghum	-3.97	0.27	-2.85	-0.92	-1.63	0.07	-1.11
Other Coarse gains	1.72	0.01	-2.93	-0.34	-1.87	-0.16	-0.04
Soybeans	-14.70	-16.10	15.40	5.36	6.56	-1.85	0.04
Palm fruit	1.03	3.57	-0.55	2.59	1.93	0.07	0.11
Rapeseed	7.38	0.38	-6.01	2.02	-1.44	0.60	1.33
Other Oilseeds	7.06	1.13	-3.91	2.10	0.53	0.21	0.77
Sugar crops	0.13	0.00	-1.02	-0.04	-0.11	0.03	-0.28
Other crops	3.20	0.10	-4.85	-0.12	-1.21	0.02	-0.01
Forestry	0.12	-0.01	-0.32	-0.01	-0.17	0.00	-0.01
Dairy	0.18	-0.01	-0.19	-0.24	-0.22	0.00	-0.01
Ruminant	-0.42	0.22	-0.63	0.11	-0.12	0.10	-0.01
None Ruminant	0.37	0.02	-1.01	-0.11	-0.17	0.03	-0.04

Price impacts

As is commonly the case in computable general equilibrium (CGE) models like GTAP, price impacts are smaller in percentage terms than the changes in other variables or than changes one would get with a partial equilibrium (PE) model. This is because there are many more substitution possibilities on both the production and consumption sides in a CGE model than in PE models. For example, the domestic consumption of soybeans and soybean products would increase in the US with the drops in exports of these products to China. Also CGE results represent medium to long run price impacts, while PE models concentrate on short run impacts. Tables 17-20 contain the percentage changes in price for agricultural commodities for each of the four cases. The patterns in estimated price changes are as follows:

1) The price changes are larger with elevated Armington elasticities than with base GTAP elasticities, but the differences are not as large as for trade or production. Part of the reason the differences are smaller is that the overall percentage price change are smaller.
2) The price of soybeans drops 4 to 5 percent in the US, increases 4 to 6 percent in Brazil, and increases 3 to 5 percent in China. Soybean prices increase in South America as well.
3) The price changes for most other commodities in the US and China are small. However, all agricultural commodity prices increase in Brazil, some by relatively large percentages.
4) When the tariff is applied to the set of all targeted commodities (Tables 19 and 20), the price of all the commodities fall around 1 to 2 percent in the US, and they increase more in Brazil. The price increases in China are lower.

Table 17. Estimated commodity price changes due to Chinese protection of US Soybeans (Case 1: Base Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	-0.92	0.07	2.10	0.16	0.55	0.01	0.09
Wheat	-0.64	0.05	1.06	0.21	0.40	-0.02	0.03
Sorghum	-0.92	0.09	1.96	-0.13	0.52	-0.02	-0.21
Other Coarse gains	-1.09	0.09	1.99	-0.23	0.50	-0.06	-0.16
Soybeans	-3.67	-0.01	3.24	2.99	2.31	0.05	0.17
Palm fruit	0.00	0.06	1.77	2.02	1.11	0.05	0.08
Rapeseed	0.13	0.12	1.45	1.99	1.13	0.45	0.70
Other Oilseeds	0.20	0.18	1.62	2.10	1.61	0.23	0.55
Sugar crops	-1.48	0.08	1.66	0.12	0.64	0.02	0.47
Other crops	-0.90	0.09	1.65	0.11	0.35	0.00	0.04
Forestry	-0.12	0.01	1.84	0.00	0.32	0.00	0.04
Dairy	-0.27	0.04	1.10	0.10	0.34	0.01	0.03
Ruminant	-0.28	0.05	1.11	0.05	0.31	0.02	0.07
None Ruminant	-0.28	0.04	0.56	0.21	0.18	0.01	0.11

Table 18. Estimated commodity price changes due to Chinese protection of US soybeans (Case 2: Elevated Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	-1.23	0.10	3.82	0.17	1.11	-0.03	0.09
Wheat	-0.86	0.07	1.89	0.22	0.84	-0.04	0.03
Sorghum	-1.22	0.13	3.54	-0.09	1.12	-0.05	-0.26
Other Coarse gains	-1.44	0.13	3.60	-0.23	1.07	-0.08	-0.12
Soybeans	-4.87	-1.16	5.99	5.17	4.86	-1.22	0.85
Palm fruit	-0.01	0.09	2.72	2.44	1.66	0.03	0.08
Rapeseed	-0.18	0.14	2.33	2.02	1.49	0.29	0.64
Other Oilseeds	-0.09	0.21	2.48	2.11	1.92	0.10	0.49
Sugar crops	-1.98	0.11	2.99	0.14	1.27	-0.02	0.85
Other crops	-1.21	0.14	2.96	0.12	0.71	-0.02	0.07
Forestry	-0.17	0.01	3.26	-0.01	0.62	-0.02	0.07
Dairy	-0.39	0.05	1.92	0.08	0.66	-0.02	0.03
Ruminant	-0.39	0.06	1.93	0.03	0.59	-0.01	0.10
None Ruminant	-0.40	0.04	0.95	0.19	0.36	-0.02	0.10

Table 19. Estimated commodity price changes due to Chinese protection on the Set of US Commodities (Case 3: Base Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	-0.99	0.07	2.10	0.21	0.54	0.01	0.11
Wheat	-0.88	0.05	1.06	0.37	0.36	-0.01	0.06
Sorghum	-1.86	0.11	1.95	1.96	0.55	0.03	-0.36
Other Coarse gains	-1.19	0.09	1.99	-0.01	0.48	-0.06	-0.13
Soybeans	-3.75	-0.01	3.23	2.98	2.29	0.04	0.13
Palm fruit	0.00	0.07	1.78	2.14	1.12	0.06	0.09
Rapeseed	0.05	0.11	1.44	1.99	1.11	0.44	0.69
Other Oilseeds	0.12	0.17	1.61	2.09	1.59	0.22	0.54
Sugar crops	-1.61	0.08	1.66	0.15	0.63	0.02	0.46
Other crops	-0.99	0.09	1.65	0.15	0.34	0.00	0.04
Forestry	-0.13	0.01	1.85	0.00	0.32	0.00	0.04
Dairy	-0.41	0.07	1.14	0.48	0.39	0.03	0.06
Ruminant	-0.46	0.07	1.15	0.49	0.38	0.03	0.18
None Ruminant	-0.31	0.04	0.57	0.24	0.17	0.00	0.12

Table 20. Estimated commodity price changes due to Chinese protection on the Set of US Commodities (Case 4: Elevated Elasticities)

Commodity	USA	EU27	BRAZIL	CHINA	S. America	Other	Total
Paddy Rice	-1.29	0.10	3.81	0.22	1.10	-0.03	0.12
Wheat	-1.10	0.07	1.88	0.38	0.80	-0.04	0.06
Sorghum	-2.15	0.15	3.53	1.90	1.15	0.00	-0.41
Other Coarse gains	-1.53	0.13	3.60	-0.01	1.05	-0.09	-0.10
Soybeans	-4.94	-1.18	5.97	5.16	4.84	-1.25	0.81
Palm fruit	-0.01	0.10	2.73	2.56	1.66	0.04	0.09
Rapeseed	-0.25	0.14	2.32	2.02	1.48	0.28	0.63
Other Oilseeds	-0.16	0.21	2.47	2.11	1.90	0.09	0.48
Sugar crops	-2.11	0.11	2.98	0.17	1.26	-0.02	0.84
Other crops	-1.29	0.14	2.95	0.16	0.70	-0.02	0.07
Forestry	-0.18	0.01	3.27	0.00	0.63	-0.02	0.07
Dairy	-0.53	0.07	1.96	0.46	0.72	0.00	0.06
Ruminant	-0.57	0.07	1.97	0.48	0.66	0.00	0.21
None Ruminant	-0.43	0.04	0.96	0.22	0.35	-0.02	0.11

Economic welfare

The changes in economic welfare are provided in Table 21. Economic welfare is a concept economists use to characterize changes in economic well-being of a country or region. The following general conclusions can be drawn from the welfare analysis:

1) US economic welfare falls in all cases. The range of the drop for the tariff on soybeans only is $1.9 - $2.6 billion/year, and the drop for tariffs on the set of commodities is $2.2 - $2.9 billion/year.
2) Welfare also falls for China for all cases. For the tariff on soybeans alone, it is $1.6 to $3.2 billion/year. For tariffs on the set of commodities, it is $1.7 - $3.4 billion/year. Interestingly, Chinese economic well-being falls more than US in the elevated elasticity cases.
3) Economic well-being increases in Brazil ranging from $1.5 to $2.8 billion/year.
4) South America has an increase in economic well-being ranging between $0.7 to $1.4 billion/year depending on the case. Other South American countries also export soybeans.
5) The rest of world (Other) has a gain in economic well-being, but it is in all cases less than $1 billion/year.
6) Global economic welfare also falls in all cases. The range is -$0.9 to -$1.8 billion/year depending on the case.
7) The welfare gains or losses are higher with the elevated Armington elasticities than with the base case GTAP values.
8) The economic welfare changes generally are slightly smaller than those reported in the previous study because of the change in commodity export data.

Table 21. Economic welfare Changes for the 25% Tariff Cases (million $)

Region	EV-soy-base	EV-soy-elev.	EV-all-base	EV-all-elev.
USA	-1,901.5	-2,604.4	-2,206.0	-2,903.6
EU27	-59.9	-196.1	15.9	-119.4
BRAZIL	1,525.4	2,753.2	1,531.9	2,756.6
China	-1,552.1	-3,167.0	-1,744.5	-3,363.5
S. America	670.9	1,374.9	671.9	1,375.5
Other	439.4	303.7	575.4	440.4
Total	-877.7	-1,535.8	-1,155.4	-1,814.1

Summary of Results

Generally, the results of this analysis conform to prior expectations. One of the big uncertainties is the magnitude of the Armington elasticity. The results are much more severe in the Armington cases than for the base values. Recent evidence supports a larger Armington elasticity for the soybean market. Also, in general higher Armington elasticities may be appropriate for commodities that are sourced from multiple countries. Prior literature suggests the Armington structure is more appropriate than the homogeneous goods approach in general. Given the uncertainty in appropriate magnitude of the Armington elasticities, in Table 22, we report the average of the results from the standard GTAP Armington elasticities and the higher values for soybeans. Table 22 provides the changes in soybean exports to China and globally, changes in US soybean production, US producer prices, and reduction in US economic well-being. Changes in economic well-being for China and Brazil also are included. These results differ a bit from our previous study for two main reasons: 1) Previously we examined tariff rates of 10 and 30 percent instead of the 25 percent used here, and 2) we used the USDA FAS data to update the exports of targeted crops for 2016 by country in our database. These results show that the proposed tariff is a lose-lose proposition for both China and the US. The loss in economic well-being is about the same in both countries. Brazil sees a significant gain in economic well-being.

Table 22. Summary Impacts of a 25% Chinese tariff on US imports

Variable	Tariff on soybeans (cases 1 and 2)	Tariff on all targeted Commodities (Cases 3 and 4)
Change in quantity of China's soybean imports from US (%)	-69	-69
Change in quantity of total US soybean exports (%)	-29	-29
Change in quantity of US soybean production (%)	-13	-13
Change in US soybean producer price (%)	-4	-4
Change in US economic welfare ($ billion)	-2.3	-2.6
Change in China economic welfare ($ billion)	-2.4	-2.6
Change in Brazil economic welfare ($ billion)	+2.2	+2.2

There are important caveats to consider in interpreting these results. First, the numerical results all depend on the multitude of assumptions, data sets, and parameters that are included in the model. Also, CGE models, which usually evaluate medium to long run market responses to the changes in economic variables often implicitly assume a good deal of flexibility in substitution among goods and services in production, consumption and trade. In the short rum markets may react sharply to the changes in economic conditions. CGE models may not capture these short run impacts. The main point is that the results of this research represent the changes one would expect after the markets reached their medium to long run equilibriums.

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