Why Public Acceptance Matters in GMO Food Markets?

By

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Abstract

Since 2011 there has been increasing debate with respect to the safety of genetically modified organisms (GMOs) in China. Many genetically modified (GM) crops have exceptional pest and disease resistance, can tolerate environmental stress, increase yields, and contribute to sustainable agriculture. However, Chinese consumers' level of acceptance of GM foods is very low. In September 2014, China's Ministry of Agriculture (MOA) suspended its import approval process for a GM soybean variety—marking the first time that Chinese officials cited public opinion as a reason to delay the approval of GM crops for importation. In 2015, China released its latest No.1 Central Document, which it emphasizes the accelerating of agricultural technological progress while focusing on China's own agricultural modernization.[2] While reviewing the No. 1 Central document thoroughly, author's view is that China's policy is aimed at increasing the public acceptance of its domestic GM crops without necessarily taking any further actions to reduce trade barriers of foreign imports.

This paper (1) links consumers' attitude towards the consumption of GM foods to the latest changes in Chinese agricultural policy as well as the possible economic impacts on China (2) employs technical approaches in determining the effects the GMO debate in China has had and will have on the United States. A general equilibrium model with the GTAP framework is utilized to determine the impact on trade, focusing on export sales, domestic price changes, agricultural productivity changes and welfare effects of changing regulations and public acceptance of GMO crops in China.

The paper examines the prospects of implementing rational agricultural policies on GM soybeans. It finds that Chinese agricultural policies aimed at increasing the public acceptance of GM soybeans as well as policies that promote GM technologies and boost land productivity will improve the economic welfare in both the United States and in China.

Keywords: GMO, public acceptance, soybean, agricultural productivity, GTAP framework, trade, non-tariff barriers, tariff barriers, market price, welfare analysis.

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[2] Chinese key agricultural policy, released in the beginning of each year, by the Central Committee of the Communist Party. The document serves as a direction to future agricultural policies.

1. Introduction

Sales of foreign agricultural products and crop shipments to China containing unauthorized genetically modified traits have largely increased since early 2006. In 2006, Greenpeace claimed that Heinz baby food that was exported to China was found to contain illegal genetically engineered rice that contained proteins (Cry1Ac) that may contribute to allergic immune responses in infants.[3] The following year, Greenpeace announced that unauthorized genetically engineered rice from the U.S. was found on the shelves of supermarkets in Beijing.[4]

Both Chinese public concerns over food safety and advertence of unauthorized foreign shipments have contributed to rising nationalist sentiment in China. In 2013, 148 Beijing avant-garde artists and anti-GMO activists gathered in Beijing to demonstrate the harmful health effects of GMOs. Online survey (Phoenix Television, 2014) shows that among 11,513 nationwide participants, only 6.01% of people believe that GM foods are as safe as regular foods. Another online survey indicates that over 90% of Chinese citizens believe that GM foods are unsafe, and they are against the commercial production of GMOs in China (Jiang, 2013).

Since September 9th, 2013, the "Big Food Fight", Zhouzi Fang vs. Yongyuan Cui, has triggered widespread social concerns over GM foods safety.[5] The move has led countless Chinese to join the controversy, and, yet, there are still no signs of ending the fierce debate. Many Chinese scholars who support GMOs have also joined this increasingly heated discussion. For instance, during 2013, 61 Chinese academicians appealed to promote the commercial cultivation of GMO in China.

In the past, the Chinese government has banned importations of GM crops, but is seemingly favoring domestic producers. In September 2014, China's Ministry of Agriculture suspended its import approval process for a GMO soybean variety due to low public acceptance of GM foods, which was the first time that Chinese officials has cited public opinion as a reason to delay the approval of GM crops for importation. However, China has not stopped issuing licenses to domestic famers to grow commercialized GM crops in mainland China, nor has China officially revealed its safety concerns about GM technology. Further, in 2015, Chinese government released its latest No.1 Central Document which emphasizes the acceleration of agricultural technological progress with focus on China's own agricultural modernization. While reviewing the document thoroughly, author's view is that China's policy is aimed at increasing the public acceptance of its domestic GM crops without necessarily taking any further actions to reduce trade barriers of foreign imports.

[3] Information released by Greenpeace, a non-governmental environmental organization, in 2006

[4] Information released by Greenpeace in 2007

[5] Two Chinese public figures—biochemist Zhouzi Fang and former TV talk show host Yongyuan Cui—debated the safety of GM food for human consumption online, bringing the heated controversial issue into spotlight.

2. Review of the Literatures

2.1 An Introduction to GM Technology

A broad acknowledgement is that—the GM technology—which involves the recombinant DNA (rDNA), is an improvement in breeding technology and nurture of new plant varieties demonstrating greater qualities and outputs (Hino, 2002). Precisely speaking, GM should not be confused with genetic engineering (GE), which is a relatively newer technology that involves transfer of traits that are analogous to precision cross breeding, in particular involves artificial transfer of genetic material from one organism to another (Taylor, 1997). To distinguish GE and GM, one inserts genes from unrelated species strictly through human manipulation and intervention, while the latter one may be referred to that DNA is altered or an organism is produced either through human manipulation or traditional plant breeding methods. However, the term "GMOs" is generally used by public to denote or refer to as GE due to the similar processing in biotechnology.

In agriculture, many of the GM crops have exceptional pest and disease resistance, and can tolerate environmental stress (Hino, 2002). Since 2004, the cultivation of GM crops has been listed as one of the chief scientific developments in China because of bigger yields and the contribution to a more sustainable agriculture. The controversy over GM technology regarding its use in GM food consumption is worldwide. Although no agreement has been reached, the broad scientific consensus is that the GM foods derived from gene transfers do not poses greater risks than those from non-GM foods.[6]

2.2 The Public Acceptance of GMOs in China

As mentioned above, the public acceptance of GMOs in China is very low. Several academic papers focus on the study on consumers' attitudes of GMOs in urban China. One study shows that public acceptance of GM food in China is very low due to the lack of knowledge of productions and the cause to potential risks (Ho *et al.*, 2005). Dr. Akihiro Hino, the head of Gustatory Biology Laboratory at National Food Research Institute in Japan, states that the general public feels uncomfortable and is unfamiliar with rDNA technology because of limited information that is available (Hino, 2002). Furthermore, the discussions of GMOs in China have never been merely limited to the Chinese scientific communities. Rather, Chinese jingoism has been a key role to influence Chinese consumers' attitudes toward GMO crops imported from western countries including the United States. The consumption of GM foods is sometimes theorized by Chinese people as "Western Imperialism Conspiracy Theorists," "Crisis of Brutal Subjugation and Genocide" (Yunbo Luo, 2013) or "The Third Opium War",[7] which is considered by many Chinese young generation to be a potential trigger to subjugation of China through undermining Chinese food security. Chen *et al.*'s

[6] So far, there are very little to no scientific evidences to prove that currently marketed GM foods pose greater risks than non-GM food (American Association for the Advancement of Science). A thorough GMO research lunched by the European Commission also shows that biotechnology is no more risky than traditional technologies ("A decade of EU-funded GMO research", 2001-2010).

[7] It means extreme patriotism or nationalism, often in the form of aggressive foreign policies.

finding using Contingent Valuation Method (CVM) shows that Chinese consumers are generally willing to pay a 33% premium for non-GM vegetable oils, as will be discussed in section 6.

2.3 China's "No. 1 Central Document"–Take Control of its Own Bowl (MOA)

Typically, the policy document is put forward in the very beginning of each year by both State Council of the People's Republic of China and Central Committee of the Communist Party of China, primarily stressing the importance of agriculture, rural areas and farmers. The first Chinese policy document of 2014 was issued on January 19th, 2014. The document emphasizes the significance of Chinese rural reform, the development of Chinese modern agriculture, and keeping agriculture as the basis of Chinese economy. The national food security system is the top priority on the list of 2014 rural reform and over the next few years. The document states that China can utilize international market as a complement and only fill in the gaps of domestic demands due to limitations of the actual available arable land, and general unsuitability of lands for farm use because of pollutions. Nonetheless, the document emphasizes that China should continue to remain dependent on domestic grain production, and suggests that China must take good control of its own bowl, underlining that China should make the best efforts to promote domestic agricultural production by increasing the capacity of agricultural production. Meanwhile, it promotes the technological innovation for the modernization of agriculture by developing China's own molecular plant breeding technology. The latest policy in 2015 is aimed at increasing its own agricultural productivities owing to its concerns about more serious environmental and sustainability issues.

3. Possibilities for China to Create Trade Barriers

3.1 Tariff-Barriers to Trade

It is difficult to clearly predict agricultural trade policies in an emerging market especially like China where negative public opinion against higher productivity growth, land degradation, and environmental stresses are both present. The exact policies that can be further derived from the No.1 Central Document still remain very ambiguous. However, we know that China will set increasing agricultural productivity and self-sufficiency as a main goal for now and succeeding years. In 2014, the No. 1 Central Document explicitly expressed that China will take control of its own bowl, thus further domestic policies may be enacted to produce a higher yield of its own food. In the mid-2014, Chinese military has banned all GM grains and oils (Forbes, 2014). In the meantime, both documents released in 2014 and 2015 have revealed that China would continue to devote large amount of resources to its own GMO research and development (R&D).

These events including rejection and bans of GM crops, along with several key messages that China has conveyed in 2014 and 2015 give an early signal that it seems highly plausible that future Chinese policies could attempt to discourage the importation of GM crops into China, as long as China would maintain its self-sufficiency. While "taking control of its own bowl" is not very clear for Chinese future agricultural policies, one shall also understand that fully banning GM crops and continuously citing public acceptance and safety concerns as a reason will contradict the notion in the latest "No.1 Central Document".[8] This statement is especially true if farm's output in China does not keep pace with an increasing demand for certain crops, such as soybeans and corns.

To the extend allowed by WTO commitments, a natural way, other than restricting or outright banning imports, is to diminish imports of GMO crops through raising the tariff rate of all GM crops or those GM crops imported to China with large quantities, such as soybeans.[9] For instance, soybeans are among the largest imported agricultural crops in China supplied annually by another giant supplier (other than the U.S.)—Brazil that has much more powerful incentives and willingness to provide non-GM soybeans to China.[10]

China has maintained an unchanged low tariff rate on soybean for many years. The import tariffs for whole soybean, soybean meal and soybean oil are ranged 3-9 % (see table 1). The import tariff rate for soybean is still considerably maintained at a low rate. When China is approaching a land productivity level that meets its food and feed needs (along with the uninterrupted supplies from Brazil), it could be a rational way for China to use trade barrier to partially lower the level of imports for GM soybeans while still being able to preserve the level of its aggregate supply for soybeans.

Table 1. The Import Tariffs of Soybean Products in China.

	Whole Soybean	**Soybean Meal**	**Soybean Oil**
Import Tariff	3%	5%	9%

Source: Brazil: Competitive Factors in Brazil Affecting U.S. and Brazilian Agricultural Sales in Selected Third Country Markets (USITC, 2012).

3.2 Non-Tariff Barriers (NTBs) to Trade

3.2.1 Introduction to NTBs

Non-tariff barriers are commonly used as a restriction of foreign imports. Unlike tariff barriers, which are duties imposed on imported goods that result in obstructions to trade, non-tariff barriers consist of numerous types of obstacles to free trade, often deriving from strict safety standards, direct import prohibitions, lengthy administrative and bureaucratic entry procedures, specific market requirements and regulations, immediate expropriation of charges from importing firms, and many more.

The General Agreement on Tariffs and Trade (GATT), and eventually the World Trade Organization (WTO) since 1995, has increasingly strived to make substantial reduction in

[8] The No.1 Central Document, released in 2015, emphasized on strengthening the scientific popularization of GM technology.
[9] This statement does not conclude that our shocked tariff rate is below the bound tariff rate under GATT.
[10] See explanations in "Non-GM Seeds and Traceability in Brazil" in the section 5.1 below.

tariffs by promoting free trade between nations. The negotiated tariff reductions gave rise to the NTBs as an alternative way to restrict trade. Prior studies have showed that the use in non-tariff barriers in the U.S. and other industrialized nations dated back to the World War II era (Ray, 1987)

During the past 15 years, while the number of uses of NTBs showed a sharp rise after the WTO rules led to remove or reduce tariff rates through WTO trade rounds and negotiations, processed multilaterally among nations, there was an increase in the number of disputes brought to the WTO Dispute Settlement Body. The majority of those disputes over NTBs have become attached to trade in agricultural products which heavily associated with GM crops and ingredients (Maskus, 2001).

3.2.2 Efficiency of NTBs on GMOs and Their Economic Effects

Most people usually understand well of how efficient are those tariffs and protective barriers to trade. For instance, in a GTAP working paper, Hertel *et al.* measured that a reduction of 40% of applied tariff and export subsidies in agricultural products would increase $60 billion per year in real global income (Hertel, *et al.*, 2000). However, the NTBs can have sizeable impacts on the economy as well. The lengthy approval process for GMOs in China, as one example of NTBs, has cost U.S. famers billions of dollars in distiller grain and soybean revenue.[11] The American Soybean Association states that U.S. farmers are increasingly suffering from huge revenue losses by complying with Chinese regulations and policies as it was difficult to gain approvals for commercial uses of GM crops in China.[12]

3.2.3 Practice of NTBs on GMOs in European Union (EU)

The EU citizens and politicians are generally much unfriendly to the use of GMOs in Europe. Therefore, a common practice in Europe is to use non-tariff barriers for imports of GMO crops from the United States (Redick *et al.*, 2005). The Directorate General for Health & Consumers of European Commission has worked on a regulatory package on GM that monitors all sectors of GMOs in EU after its commissioner has received mass e-mails from EU citizens concerning safety issues and the legislative initiatives regarding to GMO. The EU also established a traceability system for biotech crops, which gave this giant politico-economic union the strongest legislative powers to track any GM foods and crops that have transgenic contaminations from production to distribution, at every possible stage of commodity commerce. The attendant circumstances and economic dislocation led by non-tariff barriers caused the unfortunate loss of billions of dollars in agricultural export sales in the United States (Redick *et al.*, 2005). Furthermore, a chain of related legal issues arose among United States-based producers as they were striving to track specific GM events and prevent commingling of GMO-tainted crops and other forms of GMO contamination (Redick *et al.*, 2005).

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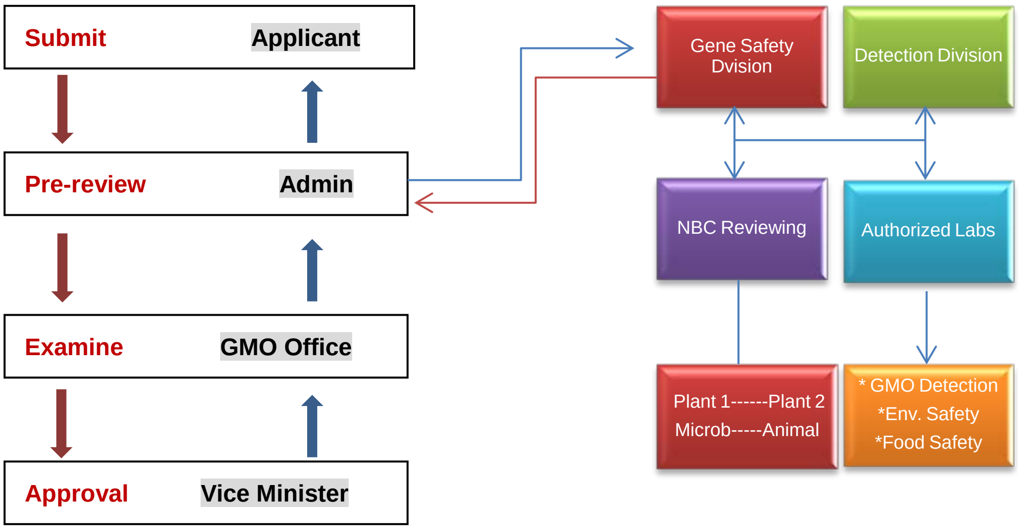
[11] While it does not necessarily represent the view of the U.S. government, the information was released by several major media channels and newspapers in the United States (Bloomberg, The Wall Street Journal, etc.).

[12] Brazil: Competitive Factors in Brazil Affecting U.S. and Brazilian Agricultural Sales in Selected Third Country Markets, USITC, 2012.

3.2.4 An Overview of NTBs on GMOs in China

China established its own legal system for agricultural policies and has been amended numerous times since 1990. In the early years, as the safety regulation was evaluated by a case-by-case procedure, there was no general protocol in applying safety regulations to newly added GM products for commercial uses. The role of government to intervene GM regulations on imports and labelling occurred in 2001. The current GM product import process takes two years in average and can be further delayed if the feasibility for the use of pending GM product in China is questioned (see figure 1) (Huang *et. al.*, 2011). While China has already allowed GM approval processes and certificate applications delaying the GM crops to enter Chinese boarder, there are also a few possibilities that other countries like China will establish stricter standards as EU to lessen the GM crops' imports from the United States through NTBs.

Figure 1. The Import Approval Procedures for GM Products in China.



Source: China's Agricultural Biotechnology Regulations—Export and Import Considerations and author's modifications, 2011.

4. Soybean Study

4.1 Object of Study

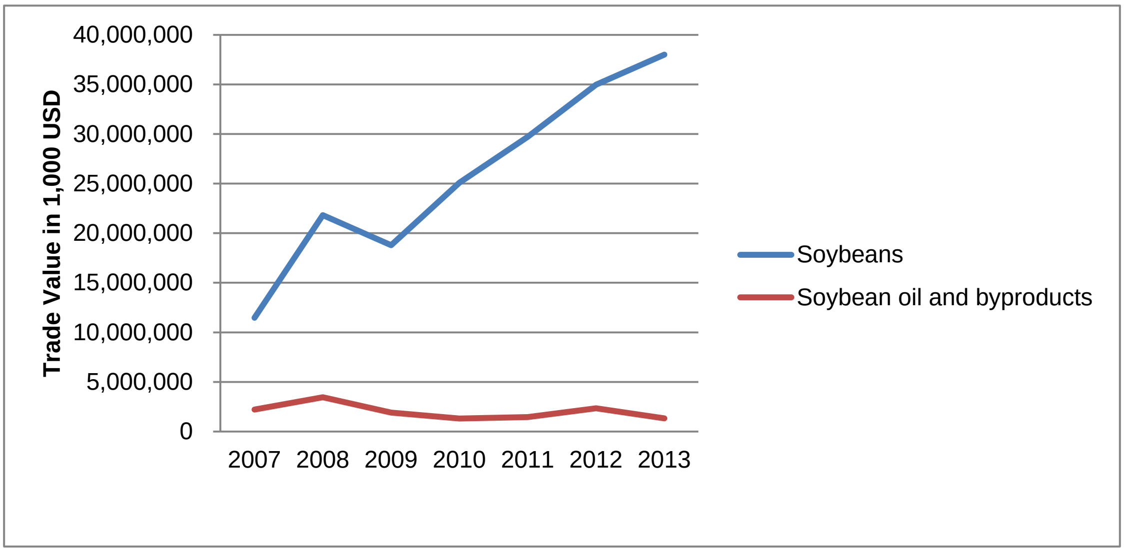
The author chose soybean as the object of this study, because (1) China is the world's largest leading importer of soybean owing to the needs of its large domestic livestock sector and its increasingly higher demand for cooking oil that is not self-sufficient in China's domestic production (USITC, 2011). (2) China's outright rejection of U.S. soybeans has cost U.S. farmers billions of US dollars in 2014. (3) Furthermore, it was the first time that China cited negative public acceptance as the reason to delay GM soybean approval. Furthermore, GM soybeans have the highest GM to non-GM world production ratio among all crops, and more than half of the world's soybean crops (58.6%) are genetically modified (GMO

Compass).[13]

4.2 Descriptive Statistics

The demand for soybean and its by-products has grown rapidly in China, whereas the trade values of exports for soybean oil and their by-products in China have seen the significant drop, declining by 40.20% (see figure 2). This decline may be due to the Chinese policy that encourages importation of whole soybean in order to capture the value-added processing activities.[14] While soybean and by-products in China have remained imported in large quantities, both are primarily sourced from the United States, Brazil and Argentina (see table 2).

Figure 2. China's Imports of Soybean and Soybean Oil and By-Products from the World (2007-2013)



Source: The World Bank, Integrated Trade Solution (WITS) (accessed on January 20th, 2015).

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[13] GMO Compass is an organization based in Europe that aims at educating general public on safety and regulations regarding GMOs, as well as the most recent events, policies and practices.

[14] China's Agricultural Trade: Competitive Conditions and Effects on U.S. Exports, USITC, 2011

Table 2a. China's Imports of Soybean by Top Three Suppliers in 2011

Trade Partner	Trade Value (Million $)	Percent
United States	12,653	42.41%
Brazil	11,792	39.53%
Argentina[15]	4,362	14.62%
Total	29,834	

Table 2b. China's Imports of Soybean Oil by Top Three Suppliers in 2011

Trade Partner	Trade Value (Million $)	Percent
Brazil	593	44.79%
Argentina	471	35.57%
United States	258	19.49%
Total	1,324	

Source: Brazil: Competitive Factors in Brazil Affecting U.S. and Brazilian Agricultural Sales in Selected Third Country Markets (USITC, 2012).

5. Brazil

5.1 Non-GM Seeds and Traceability in Brazil

The geographical traits in Brazil have been playing an important role in agricultural productivities, thus the same high yields and productivity levels with conventional soybeans have been achieved in Brazil as farmers there would have done with GM seeds and transgenic technologies.[16] According to the IBGE 2006 agricultural census data and IOP Publishing, out of 26 states in Brazil,[17] more than half of Brazilian states produced less than 1% of soybean derived from transgenic seeds (Garrett *et al.*, 2013). Although some southern and central western Brazilian states remained favorable to growing GM soybeans, the climate in some states of the Center-West region allows farmers to achieve the same high yield with non-GM seeds, while the rest of Brazilian states have been far less favorable to the use of GM seeds and transgenic technologies. On the cost-saving side, many Brazilian states have been able to offset the higher fungicide and herbicide costs by savings on royalty fees and lower costs for conventional seeds. As far as the legality was concerned, the GM seeds have been approved for U.S. commercial use since 1996 but have remained illegal in Brazil until 2005.[18] In 2008, Brazilian Association of Non Genetically Modified Grain Producers was established to promote the use of non-GM seeds. Economists' studies have shown that the presence of GM foods would result in unfavorable consumer's attitudes towards the product in Brazilian Market (Celso Augusto de Matos *et al.*, 2006), whereas prior economic research has shown that in the United States consumers generally perceived that GM food products were weakly inferior to conventional food products (Huffman, 2010). In addition, U.S. crops have

[15] As of 2007, 98% of soybeans produced in Argentina are Genetically Modified (GMO Compass).
[16] Brazil: Competitive Factors in Brazil Affecting U.S. and Brazilian Agricultural Sales in Selected Third Country Markets (USITC, 2012)
[17] IBGE stands for Brazilian Institute of Geography and Statistics. IOP Publishing is a publishing company that provides publications of scientific researches
[18] Also see footnote 16

processed input traits that significantly reduced famers' production costs, whereas non-GM seeds have benefited Brazilian producers to the extent of all GM-favored geographic weather and climate regions.

5.2 Brazil's competition with the United States in China

As the largest remaining non-GM producer in the world, Brazil has an absolute comparative advantage in product differentiation over the United States in the Chinese market that continuously demand them (USITC, 2012). With the rise of substantial safety concerns of GM foods in China, recent Chinese GM regulations and policies have seen increasingly less favorable to U.S. soybean producers and more favorable to non-GM soybean producers, such as Brazil. With the increasing demand of Chinese market owing to high demand for cooking oil and livestock sector, and with Chinese policies promoting value-added processing activities to crush soybeans within its domestic market, China is very likely to continue to import large quantities of whole soybeans and the importation of soybean oil will likely remain declined. When China decides to establish new international trade policies to cut the importation of GM soybeans, it must take account of the estimates of potential supply to meet its domestic demand. If trade policies are made to favor Brazilian non-GM producers, U.S. GM producers[19] will suffer more from the loss in sales revenue. Since it is not difficult for Brazil to produce non-GM soybeans, farmers in Brazil are expected to suffer less if they are able to produce less GM soybeans.

6. Analytical Framework

As a response to the No.1 Central Document discussed above, we think of several movements that Chinese may step forward to formulate its agricultural trade policies with respect to the rising public concerns over food safety as well as its wear agricultural land stress. First, China's policies could be aimed at increasing land productivity. Second, China could reduce its GM soybeans imports from the United States through different types of non-tariff barrier. Third, we assume that China could impose a higher tariff rate on GM soybeans citing lack of public acceptance as a rational.

6.1 Model and Data

The GTAP general equilibrium model is utilized to determine the impact on trade, focusing on export sales (*qxs*), domestic price changes (*pms*), behavior of farmers with respect to land use (*qfe*), as well as welfare effects (which are measured by equivalent variation, *EV*). The data we used comes from the GTAP 9 data base for the year of 2011.[20] In this regard, we simulate and analyze three hypothetical scenarios.

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[19] As of 2007, 85% of soybeans produced in the U.S. are Genetically Modified (GMO Compass).

[20] The GTAP data used here has four regions (USA, China, EU and Rest of the World) and 23 sectors (paddy rice, wheat, cereal grains nec, vegetables, fruit, nuts, oil seeds, sugar cane, sugar beet, plant-based fibers, crops nec, bovine cattle, sheep and goats, horses, animal products nec, raw milk, wool, silk-worm cocoons, other natural resources, bovine meat products, vegetable oils and fats, dairy products, processed rice, sugar, food products nec, beverage and tobacco products, other manufactures and services).

6.2 Selecting Shock Values

6.2.1 Change in the Power of Tariff on Imports of i from r into s, *tms (i,r,s)*

First, we examine the potential effects of increasing China's tariff rate on U.S. oilseeds to 7%. A 7% tariff rate for oilseeds falls within the range of China's tariffs for soybeans and by-products. This shock value is selected because of China's high demand for soybean and increasing demand sparked off by higher income and consumption of soybean oil. It is very unlikely that China will impose an extremely high tariff on GM Soybeans as non-GM suppliers currently do not have predominant advantage in supplying sufficient quantities of whole soybeans to meet China's needs. Also, it is partly because that China will need to take into account of WTO's interventions. Note that the 7% is the ad valorem (AV) rate. The exogenous variable, *tms*, is bilateral and represents the percent change in the power of an import tax (Hertel and Tsigas, 1997). The actual percent change in the power is calculated by $\frac{\text{tms1}-\text{tms0}}{\text{tms0}}$, where the initial AV rate in 2011 GTAP 9 data base is 2.4166%. Thus the percent change in the power is 4.4752%.

6.2.2 Primary Factor i Augmenting Tech. Change Sector j in r, *afeall (i,j,r)*

Second, we computed the historical data for land productivity growth (agricultural yields per hectare) released by the U.S. Department of Agriculture (USDA). Because our finding from the USDA and GMO compass was that the first GM soybeans were planted in the United States in 1996, we computed the growth rate in average U.S. soybean yields for the periods 1991-95 and 1996-2000 and calculated that the average U.S. soybean yields increased by 5.60% during 1991-1995; while the average U.S. soybean yields increased by 15.69% during 1996-2000. We assumed that yields grew faster during 1996-2000 than 1991-95 because of the introduction of GM technologies. By subtracting these two we got the difference that Δ=10.09%. We applied this number in our simulation to reflect the productivity growth in China. Though it was not very realistic to shock this value, it was appropriate since we could give any values to the shock and the use of this value helps get closer to the realistic world. The author's goal in this study is to find the relationship between the shocked exogenous variables and other key factors in the models.

Table 3. U.S. Historical Soybean Yields from 1991 to 2000

Year Yield	Million planted acres	Bushels per harvested acre	Total Yield (MM.bushels)
1991	34.2	59.18	2023.956
1992	37.6	59.13	2223.288
1993	32.6	60.086	1958.8036
1994	41.4	61.62	2551.068
1995	35.3	62.495	2206.0735
1996	37.6	64.195	2413.732
1997	38.9	70.005	2723.1945
1998	38.9	72.025	2801.7725
1999	36.6	73.73	2698.518
2000	38.1	74.266	2829.5346

Source: Economic Research Service (USDA, 2010) and author's calculations.

6.23 Import i from Region r Augmenting Tech. Change in Region s, *ams (i,r,s)*

Third, our research involved determining a shock value given to import preference shift, *ams (i,r,s)* —import-augmenting technical change in the Armington nest, which represents the negative of the rate of decay on imports of oilseeds from the United States to China. This variable indicates the Δ% of (more or less) oilseeds will become available to Chinese domestic consumers (Hertel *et al.*, 2001).[21] This shock helps simulate the preference shift of GM soybean consumption in China, but is among the hardest to quantify in the real world. Chen *et al.* surveyed a sample of 671 consumers in Beijing and applied a dichotomous choice format contingent valuation method to capture consumer's willingness to pay (WTP) for non-GM vegetable oil. The willingness-to-pay (WTP) study is to estimate the premium that consumers would pay for non-GM oil and that reflects to consumers' attitude towards consumption of GM vegetable oil. Since the increasing demand for imports of soybean in China is much owing to the high demand for cooking oil, we believe that the study of Chinese consumers' willingness to pay for vegetable oils best reflects to the import preference shift in our shock. The probabilistic models used in this study:[22]

$$y_1 = \beta_1' + \varepsilon_1, y_1 = 1, if\, y_1 = 1, \; if\, y_1^* > 0$$

$$y_2 = \beta_2' + \varepsilon_2, y_2 = 1, if\, y_2 = 1, \; if\, y_2^* > 0$$[23]

Where

ε_1 and ε_2 are both error terms

and

$y_1 = 1$ if consumers choose "yes" in the second stage and $y_2 = 1$ if consumers choose "DK" in the first stage.

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21 See GTAP Resource #576 (GTAP Model Version 6.0", by Thomas Hertel, Robert McDougall and Ken Itakura).

22 The WTP study, *Willingness to Pay for Non-Genetically Modified Vegetable Oil in China*, is conducted by Kevin Chen, Shi Min-Jun and Getu Hailu (Journal of Zhejiang University: Humanities and Social Sciences, 2004).

23 The equations for probabilistic models are used to determine whether consumers were willing to respond to the survey in the first stage ($E(\varepsilon_1) = E(\varepsilon_2) = 0$, $Var(\varepsilon_1) = Var(\varepsilon_2)$, $Cov(\varepsilon_1) = Cov(\varepsilon_2) = \rho$).

The WTP equation can be written as (Cameron *et al.* 1987) (Chen *et al.* 2004):

$$WTP = -\eta/\beta_{\text{Price}}$$

Where

β_{Price} is the estimated coefficient of price variable.

and

η is the sum of each estimated coefficient (other than price variables) that multiplies the mean of social-demographic variables.

It is estimated that the survey respondents in China are willing to pay 33% more for non-GM vegetable oils. The computed WTP found that Chinese consumers were generally not favorable to GM vegetable oils. It helps understand the consumer acceptance of GM vegetable oil and how Chinese government will regulate policies with respect to consumer's willingness to pay, as well as how Chinese regulations will respond to the Chinese food market for GM oilseeds and oils (Chen *et al.* 2004). Majority of the Chinese imported soybeans are consumed in government household for crushing for oil and soybean meal. In our simulation, it helps us select a general range of import preference shift for GM soybeans in which Chinese consumers' willingness to pay is present. We chose a shock value of -16% based on our assumption that the import preference shifts will take time and that Chinese government does not necessarily fully regard the public acceptant of GM foods.

6.3 Modelling Procedures

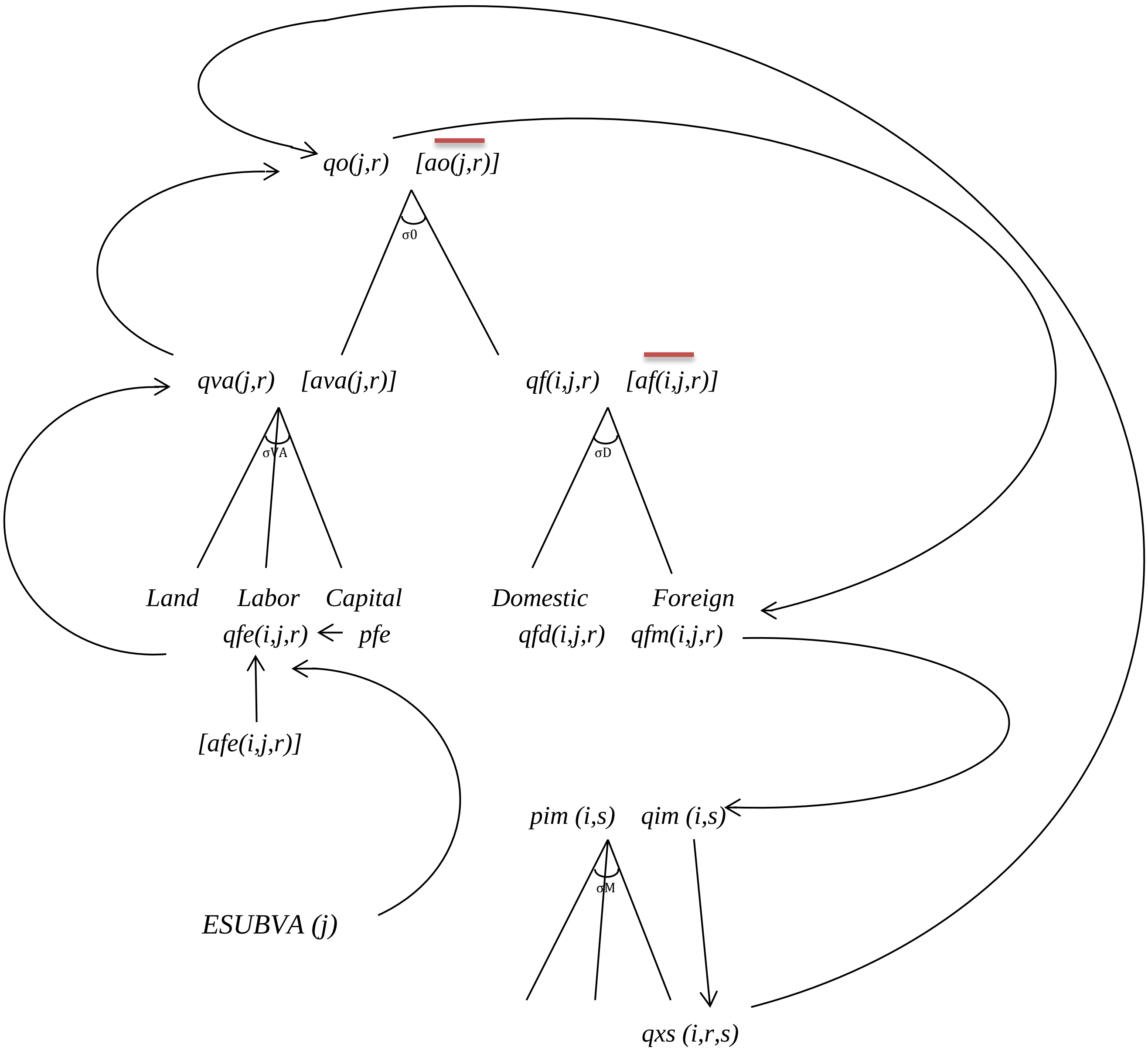
In section 8, we first discuss a comprehensive simulation that includes all three shocks (*tms*, *afeall*, *ams*). Second, in section 9, we would separately discuss the three single-shocked simulations. At the end, we illustrate a comparison with three other policy shocks: (1) *ams + afeall* (2) *ams + tms*, and (3) *tms + afeall*, respectively.

In the comprehensive simulation, we start with the simple expression—domestic price equation that includes price variables (*pcif*, *pfob, pms, pim, etc.*) and from there we study the impacts on export sales (*qxs*), the aggregate imports (*qim*) as well the implication on equivalent variation (*EV*) from the export sales. The next, we move to land productivity (*afeall*), and analyze the shocked impacts under production structure for firms, covered with a thorough decomposition for industry demands for intermediary goods (both domestic and imported). At the end, we return to the implication of equivalent variation and decompose *EV* (regional *EV* computed in alternative way).

In the three single-shocked scenarios, we illustrate the cause to the difference of EV, export sales, market prices, etc., among single-shocked and comprehensive simulations. The section 10 lists the results that have been derived from other policy shocks. These results are compared with our interpreted scenarios in section 8 and section 9. From there, we will able to bring to final conclusions in section 11.

6.4 Model Structure[24]

Figure 3. A graphical representation of the relevant linkages in the GTAP model



Source: Figure 2.6 in Hertel and Tsigas (1997) and author's modifications.

7. Limitations

Our limitations in this research are significant, most of which were present in the stage of choosing shock values for the model. Although we have made efforts to select the best hypothetical values among the reasonable range, there is still room for improvement. For example, we assumed that the Chinese government would impose a higher import tariff rate on GM soybeans. This was based on our assumption that (1) China has enough incentives to

[24] Red bar = endogenous but are composed of un-shocked exogenous variables.

raise the import tariff due to an extremely low public acceptance, while China is self-sufficient in meeting its high demand through other sources, and that (2) China would fulfill its WTO's commitment so a higher-than-bound tariff rate would not be imposed. Second, we analyzed our shocks involved changing the value of land productivity growth per hectare. The value that we chose was based on the historical data of U.S. productivity growth, measured at bushels per harvested acre. The approach can be further refined, because the 5-year productivity growth rates before and after 1996 would not explicitly capture the real growth solely owing to the adoption of GM technology. For instance, there could be many other factors involved in advanced development that have contributed to the land productivity growth in the United States.

Another limitation is that we assumed that the United States was the only supplier of GM soybeans to China. According to GMO Compass, 98% of soybeans produced in 2007 in Argentina were genetically modified. A tariff policy change in China would also affect Argentina, who is responsible for 14.62% of total imports of soybean in China (USITC, 2012).

Furthermore, the most limited resources in our study are the disaggregated data for GM soybeans. Jackson *et al.*'s study used the estimates that were based on Stone *et al.*'s research conducted in 2002. Stone *et al.*'s estimated that 40% of North American coarse grain and about 65% of oilseeds production were genetically modified (Jackson *et al.*, 2003).[25] In our case, we assumed that all imported soybeans to China were genetically modified. Note the fact that though 58.6% of 2007 soybean crops in the world were genetically modified, the United States is responsible for 33% of the world's total GM soybean production in 2007, and produced almost exclusively (over 94%) GM soybeans in 2014 (USDA).[26] The second and third largest soybean exporters to China (Brazil and Argentina) were responsible for 48% of the world's total GM soybean production in 2007 (GMO Compass). We find that the estimates of the share of GM soybeans in recent years more accurately represent the data (than the estimates for coarse grain and oilseeds in 2002) that can be fitted into our GTAP model. In addition, 96.56% of total 2011 soybean imports in China were supplied by United States, Brazil and Argentina.[27] We also assume that the GM technological progress is growing over time. Therefore, we did not further disaggregate our data, although it was desirable.

Our limitation was also that we did not disaggregate the soybeans from oilseeds in GTAP 9 data base for the year of 2011. However, it was relatively a minor limitation. In our simulations we assumed that all "soybeans" were "oilseeds". That is, we used *osd* variable in our soybean study. It was, however, not completely unfounded. USDA estimated that in the MY14/15[28] out of total oilseeds imports of 75.8 million tons, 72 million tons would be reached (USDA, 2014).[29] This indicated that about 95% of Chinese imported oilseeds were

[25] About 95% of Chinese imported oilseeds were soybeans (USDA, 2014).
[26] Economic Research Service, USDA (http://www.ers.usda.gov/data-products).
[27] See Descriptive Statistics in section 4.2.
[28] Model Year from 2014 to 2015
[29] The report was assessed and prepared by staffs in the USDA Foreign Agricultural Service.

soybeans, which would not be excessively deviated from our assumption.

8. Modelling in Comprehensive Simulation[30]

In our comprehensive simulation, we assume that China will impose a 7% import tariff rate on oilseeds, while the region specific average rate of primary factor "land" augmenting technical change sector "oilseeds" (oilseeds productivity growth of agricultural yields per hectare) in China is 10.09%. Simultaneously, we assume that there is a negative import preference shift and that *ams (i,r,s)*—import-augmenting "technical change" in the Armington nest is shocked by -16%, which represents the negative of the rate of decay on imports of oilseeds from the United States to China. It also means that 16% less of oilseeds will become available to Chinese domestic consumers.[31] Including the "*ams*" variable is useful to help necessarily understand and quantify the preference shift of GM soybean consumption in China. For clarifications with regard to variable names please see table 4:

Table 4. Selected key variables and definitions

Variable Name	Definition
EV*	Equivalent Variation, US$ million
qxs(i, r, s)	Export sales of i from the r to s
pcif (i,r,s)	CIF** price of i supplied from the r to s
pms (i,r,s)	Domestic price for i supplied from the r to s
pim (i,s)	Market price of composite import i in s
qim (i,s)	Aggregate imports of i in region s
pp(i,s)	Private Consumption Price for i in s
osd	oilseeds
vol	Vegetable oils
qfe (i,j,r)	Demand for endowment i for use in j in region r
qva(j,r)	Value added in industry j of r

*The EV (equivalent variation) measures the difference between the initial expenditure and the new expenditure resulting from the policy shocks.

**CIF=Cost, Insurance and Freight

[30] The simulations are solved and analyzed using GEMPACK; AnalyseGE is used to assist in the analysis of simulation results.

[31] See GTAP Resource #576 (GTAP Model Version 6.0", by Thomas Hertel, Robert McDougall and Ken Itakura).

Table 9. Selected Results for *comprehensive* shock

Variables	USA	China	EU_28	ROW
EV	-1281.63	-1898.3	-15.57	1633.23
qxs (osd,USA,*)	**	-40.43	9.83	7.54
qxs (vol,USA,*)	**	6.19	7.64	7.3
pms (osd,USA,*)	**	2.87	-1.83	-1.53
pms (vol,USA,*)	**	-0.93	-1.04	-0.97
pcif(osd,USA,*)	**	-1.54	-1.83	-1.53
pcif(vol,USA,*)	**	-0.93	-1.04	-0.97
pim (osd,*)	0.45	6.97	0.05	-0.43
pim (vol,*)	0.16	0.14	0.08	0.06
qim (osd,*)	-3.32	-2.89	0.06	1.84
qim (vol,*)	-1.8	-1.08	-0.09	0.19
qo (osd,*)	-9.97	5.63	0.14	2.63
pp (osd,*)	-1.53	5.51	0.03	0.43
pp (vol,*)	-0.26	-0.2	0.04	0.14
qfe (land,osd,*)	-7.69	-1.8	0.1	2.1
qfe (land,vol,*)	4.08	0.29	0.03	-0.56
qfe (UnSkLAb,osd,*)	-10.81	4.67	0.15	2.87
qfe (SkLab,osd,*)	-10.81	4.67	0.15	2.87
qfe (Capital,osd,*)	-10.81	4.67	0.15	2.87
qfe (sum,osd,*)	-40.15	12.24	0.53	10.71
qfm (osd,osd,*)	-14.88	4.32	0.09	5.14
qfm (osd,vol,*)	-1.92	-16.42	0.13	1.71
qfm (osd,sum,*)	-98.17	-21.52	-0.03	44.96
qfm (vol,sum,*)	-65.47	-21.49	-1.73	6.25
qva (osd,*)	-9.97	5.63	0.14	2.63
qva (vol,*)	3.45	0.21	0.16	-0.45

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

**ams (i,r,s)=-16, afeall (i,r,s)*=10.09 and *tms (i,r,s)*=4.4752 (shock to 7%)

Source: GTAP 9 data base for the year of 2011.

8.1 Domestic Price and CIF World Price of Soybeans Supplied from the U.S.

First, we look at our domestic price linkage equation – the equation that links to the domestic and world prices. This can be written as:

$$pms\ (i,r,s) = tm\ (i,s) + tms\ (i,r,s) + pcif\ (i,r,s)$$

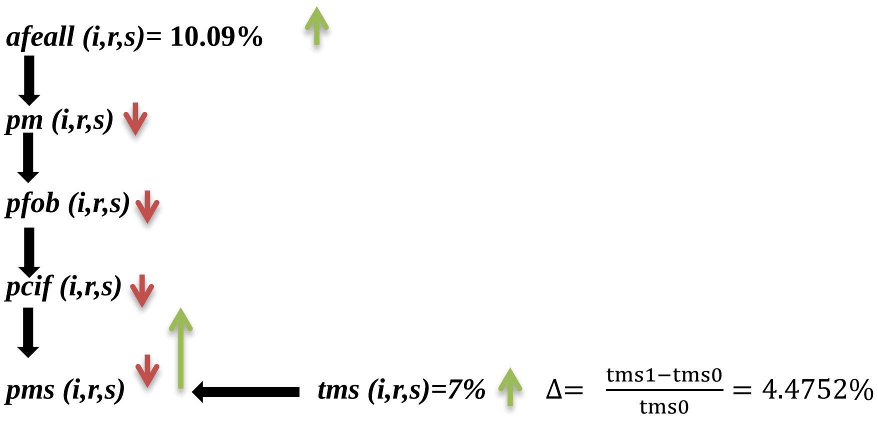
The next, we look at the right hand side (RHS) of the expression in the market price equation. Note that the *source-general change in tax on imports of oilseeds*, *tm*, into China is an unchanged (exogenous) variable because we assume that China does not impose a higher tariff rate on non-GM soybeans supplied from other countries (assume that China is supplied of non-GM soybeans from other countries). The domestic price for oilseeds supplied from the U.S. to China, *pms*, is increased by 2.87%. As mentioned above, the power of import taxes on GM soybeans supplied from the United States is increased by 4.4752%, owing to an increase in tax on imports of oilseeds from the United States into China. This, intuitively, indicates that Chinese new import tariff policy in raising the price of imported oilseeds plays a dominant role in elevating domestic price level for oilseeds supplied from the United States. In the meantime, we must take into account the CIF world price of oilseeds supplied from the U.S. to China. It is also important to underline that the absolute value of change in CIF world price must not be greater than that of change in power of import taxes. In this regard, we must resolve in the equation that links FOB (free on board) and CIF prices for oilseeds shipped from the U.S. to China:

$$pcif\ (i,r,s) = FOBSHR\ (i,r,s) * pfob\ (i,r,s) + TRNSHR\ (i,r,s) * ptrans\ (i,r,s)$$

The United States has a large positive FOB share in value of imports (VIW) of oilseeds as well as a moderately large transport share in VIW in China.[32] The price of transportation, *ptrans (i,r,s)* is approximately increased by 0.008% (and has a much smaller share of in VIW), while the FOB price of oilseeds supplied from the U.S. to China is declined by -1.88%, and is therefore very dominant. Thus the total FOB costs of oilseeds supplied from the United States to China is decreased, leading to a decline in the world CIF price of oilseeds supplied from the U.S. to China. This can be linked to the change in domestic market price, which will also decline. We find that the decline in domestic price is also partly due to the land productivity growth,[33] which will cause a price reduction in overall oilseeds market, *pm*. A decline in Chinese soybean market will lead to a reduction in the FOB price of soybean imported from the United States. Thus, increasing productivity growth level in China will also reduce the domestic price for GM soybeans supplied from the United States. However, the magnitude of the change in world CIF price is not as large as the change in power of import taxes on GM soybeans. When *tms* is shocked to a greater value, the domestic price for oilseeds supplied from the U.S. to China will be sufficiently influenced by the Chinese policy aimed at increasing the import tariff rate on GM soybeans supplied from the United State. See figure 4 for illustration:

[32] To understand mechanisms in which the FOB and transport shares are computed, see "*Sets and Variables: Shares*" (https://www.gtap.agecon.purdue.edu/models/setsVariables.asp).
[33] See details in section 8.4 (technological Progress for GM Soybean Farming in China)

Figure 4.



*The length of arrows is not strictly drawn to scale, but they do generally illustrate the scale of magnitudes for differences or changes (in terms of smaller or larger change) in percentage.

8.2 Export Sales from the U.S. and Market Price of Composite Import

Now, we may look back into the export sales of oilseeds from the U.S. to China, *qxs (i,r,s)*. The export sales are responsible by the demand for disaggregated imported soybeans, which may be decomposed in the import demand equation as:

$$qxs\ (i,r,s) = -ams\ (i,r,s) + qim\ (i,s) - ESUBM\ (i) * [pms(i,r,s) - ams\ (i,r,s) - pim\ (i,s)]$$

Where

ESUBM (i) = region-generic elasticity of substitution among imports of oilseeds

Note that the import of oilseeds from the United States augmenting technical change in China (import preference shifts), *ams (i,r,s)*, is exogenous. This is shocked by -16% in our comprehensive simulation. We find that the aggregate imports of oilseeds in China are only decreased by 2.89% and that the market price of composite imports of oilseeds in China is increased by 6.96%. The price of composite imports can be further decomposed as:

$$pim\ (i,s) = \sum(k, REG, MSHRS(i,k,s) * [pms\ (i,k,s) - ams\ (i,k,s)])$$

where

MSHRS (i,k,s) = share of imports from the United States in import bill of China at market prices.

Since a relatively large negative shock (-16%) is given to the variable, *ams (i, k,s)*, thus the difference between the $+\Delta\%$ in market price and $-\Delta\%$ in import preference shift is always positive, so long as we know that the market price will increase by 2.87%. Therefore, the market price of composite import oilseeds in China, *pim (i,s)*, will increase, and by 6.97%. This is mainly dominated by the negative shock value that we set up for the preference shift in imports of oilseeds supplied from the United States to China. Note that if a much larger U.S. import share of oilseeds in import bill of China at market prices is present, or if we assign a very large positive value to the variable, *ams (i, k,s)*, the result from the export sales of oilseeds from the U.S. to China, qxs (i,r,s), may be changed. That is, intuitively, if we give a very large positive shock (i.e. 85%) to the variable *ams (i, k,s)* , we will obtain a much larger value of the Δ% in market price of composite import oilseeds in China, leading to a positive change in export sales of oilseeds from the U.S. to China.

For the sake of finding the dominant factor in affecting the change of export sales in China, we ran a separate simulation in which we only changed the shock value in the variable *ams (i, k,s)* from -16% to 85% while all other variables in our primary comprehensive simulation are held constant, we found that the change in export sales of oilseeds from the U.S. to China is 55.92%, making a sharp contrast to -40.70%. Although a decline in the import preference will add to the effect in increasing the export sales, one must note that the change in *pim (i,s)* is evaluated on a share-basis (where *MSHRS* <1). Therefore, the magnitude of an increase in market price of composite import is always increasingly smaller than the decline in the import preference, leading to a larger reduction in export sales.

Interestingly, we ran a series of simulations to find the break-event point (zero net change) in the export sales of oilseeds imported from the United States to China (given tariff rate is increased to 7% and “land” augmenting technical change is 10.09%). In order to offset the negative effects of export sales originally shocked by the increases in tariff rate and “land” augmenting technical change, the preference shift variable, *ams (i, k,s)* has to be exactly set as 7.425% (see table 5). Within the shock range from -16% to 85%, both export sales of oilseeds and vegetable oils from the U.S. to China are “linear” with respect to the changes in preference of imports in oilseeds. However, as the Δ% of import preference increases, there is a positive Δ% in export sales of oilseeds from the U.S. to China, as well as a small negative Δ% in export sales of vegetable oils from the U.S. to China (see figure 5). This implies that as the import preference level for soybeans increases, the export sales of soybeans from the United States to China will also raise but the exports of vegetables will slightly decline.

Our finding also indicates that if the import preference for soybean in China is at a negative level, the vegetable oil sectors in the U.S. will be slightly better off. Furthermore, we also find that vegetable oils and GM soybeans in China that complement each other have a negative cross elasticity of demand (see figure 5). This is because that a large quantity of imported GM soybeans are used to crush for vegetable oils, and that as the domestic market price of soybean increases, much less of vegetable oils will be demanded in Chinese market. Thus, the shifts in import preference away from GM soybean may also potentially have an adverse effect on future profitability of vegetable oil industry in the U.S., and will likely contradict the increasing demand for cooking oil consumption in China.

Table 5. Δ% in Export Sales and Equivalent Variation associated with Δ% in import preferences (productivity growth, *afeall*=10.09%).

ams	**qxs_osd**[a]	**qxs_vol**[b]	**EV (USA)**[c]	**EV (China)**[d]
%-change	*%-change*	*%-change*	*$ US million*	*$ US million*
-16	-40.43	6.19	-1281.63	-1898.30
-10	-29.67	3.89	-967.87	-1061.58
-5	-20.78	1.97	-701.58	-317.76
0	-12.13	0.08	-436.29	460.97
7.425	0	-2.628	-53.982	1667.533
7.45	0.040	-2.637	-52.73	1671.68
7.5	0.118	-2.655	-50.229	1679.968
7.65	0.352	-2.708	-42.731	1704.848
7.728	0.474	-2.735	-38.836	1717.793
7.729	0.475	-2.736	-38.786	1717.958
7.73	0.477	-2.736	-38.736	1718.125
7.735	0.485	-2.738	-38.487	1718.955
7.75	0.508	-2.743	-37.738	1721.445
8	0.896	-2.831	-25.276	1762.960
10	3.956	-3.530	73.318	2096.762
12	6.929	-4.215	169.819	2433.134
15	11.216	-5.217	310.250	2941.773
20	17.883	-6.815	531.524	3797.722
30	29.362	-9.726	920.186	5524.360
50	45.21	-14.467	1468	8938.166
70	53.344	-18.041	1743.437	12173.938
85	55.918	-20.185	1818.661	14434.813

qxs_osd[a] = export sales of oilseeds from the U.S. to China.

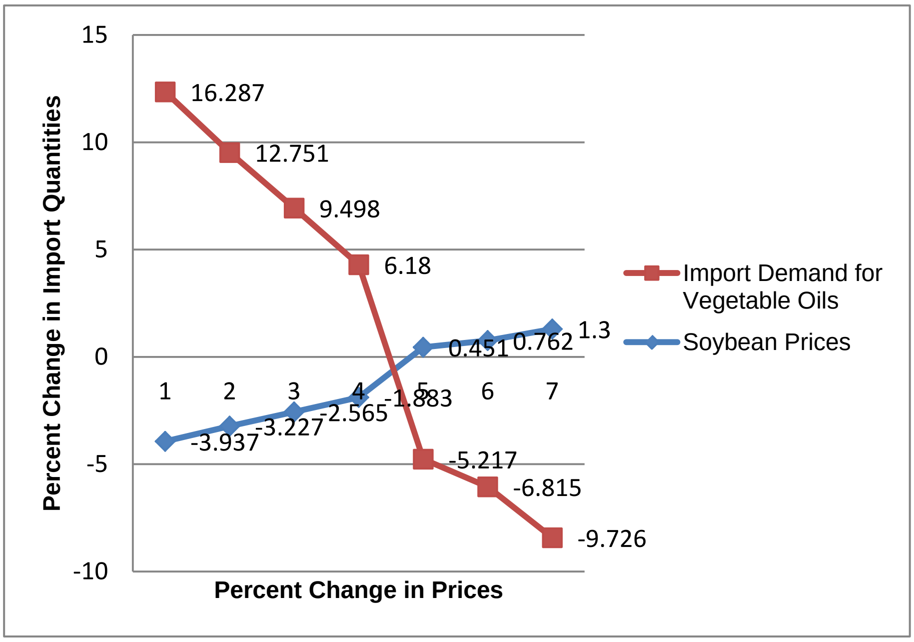
qxs_osd[b] = export sales of vegetable oils from the U.S. to China.

EV (USA)[c] = equivalent variation in the U.S.

EV (USA)[d] = equivalent variation in China.

Source: GTAP 9 data base for the year of 2011.

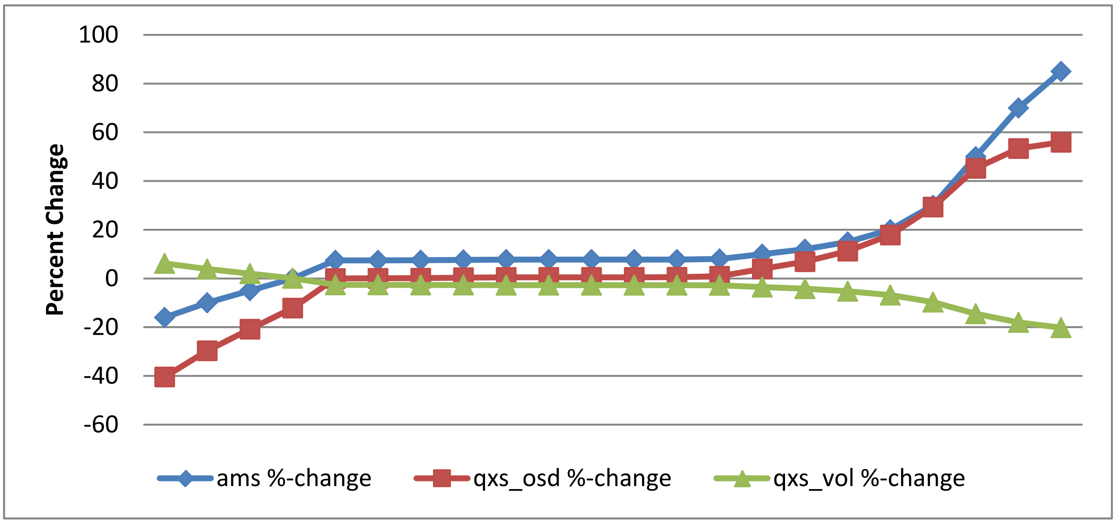
Figure 5. Import Demand for Vegetable Oils vs. Soybean Prices



Source: GTAP 9 data base for the year of 2011.

8.3 Implications of Gaining Economic Welfare from Export Sales[34]

Figure 6. Change in Export Sales Associated with the Change in Preference of Imports (productivity growth, *afeall*=**10.09%**).



ams—import preference, *qxs_osd*—export sales of oilseeds, *qxs_vol*—export sales of vegetable oils

Source: GTAP 9 data base for the year of 2011.

Our results also show that, while holding other shocks constant, as Chinese productivity level for soybean increases the equivalent variation will increase in China but will decline in the United States. For instance, if we raise about 60% of our shocked productivity growth level from 10.09% to 16.32%, there will be a similar climbing trend in export sales and

[34] Decomposition of change in welfare will be introduced in section 8.5.

equivalent variation for both countries due to the elevation in import preference in China (see figure 7). However, at the same level of import preference, the United States will be better off (and China will be worse off) when China has a slower land productivity growth for soybean (see table 7). At our shocked value—10.09% land productivity growth level, the economic benefits to China (measured by equivalent variation) will become substantially larger from -1.9 billion to positive +3.15 billion as the import preference for soybean imported from the United States increases from -16% to 15% (see table 7). Note that Chinese crushing capacity has risen rapidly in the past 15 years, increasing almost sevenfold from 8.4 million MT in 1997 to 55.1 million MT in 2011,[35] thus an increase in export sales will allow Chinese processing sectors to add and capture more value in processing activities, continuously improving the economic welfare in China.

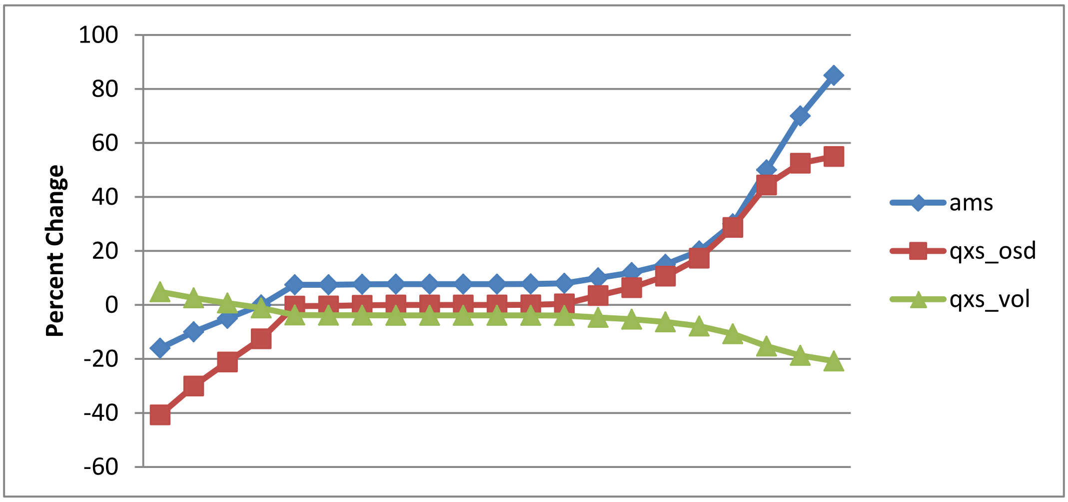
Table 6. Δ% in Export Sales and Equivalent Variation associated with Δ% in import preferences (productivity growth, *afeall*=16.32%).

ams	**qxs_osd**	**qxs_vol**	**EV (USA)**	**EV (China)**
%-change	*%-change*	*%-change*	*$ US million*	*$ US million*
-16	-40.7	4.85	-1317.26	-1669.5
-10	-30	2.6	-1005.18	-836.02
-5	-21.14	0.73	-740.36	-95.05
0	-12.53	-1.11	-476.59	680.73
7.45	-0.43	-3.7622	-95.32	1886.85
7.5	-0.35	-3.78	-92.83	1895.11
7.65	-0.12	-3.83	-85.38	1919.9
7.728	0	-3.858	-81.51	1932.79
7.729	0.01	-3.86	-81.46	1932.96
7.73	0.015	-3.86	-81.41	1933.12
7.735	0.016	-3.86	-81.16	1933.95
7.75	0.04	-3.87	-80.42	1936.43
8	0.43	-3.95	-68.04	1977.8
10	3.47	-4.63	29.94	2310.32
12	6.43	-5.3	125.82	2645.42
15	10.69	-6.28	265.33	3152.12
20	17.32	-7.83	485.09	4004.79
30	28.72	-10.66	870.87	5742.7
50	44.44	-15.27	1413.82	9124.53
70	52.48	-18.72	1686.05	12345.93
85	55	-20.79	1760	14596.03

Source: GTAP 9 data base for the year of 2011.

[35] USDA Foreign Agriculture Service, China Oilseeds and Products Annual Report, 2011

Figure 7. Δ% in Export Sales Associated with the Δ% in Import Preferences (productivity growth, *afeall*=**16.32%**).



ams—import preference, *qxs_osd*—export sales of oilseeds, *qxs_vol*—export sales of vegetable oils

Source: GTAP 9 data base for the year of 2011.

Table 7. Welfare effects of Land Productivity Growth and Import Preference for Soybean

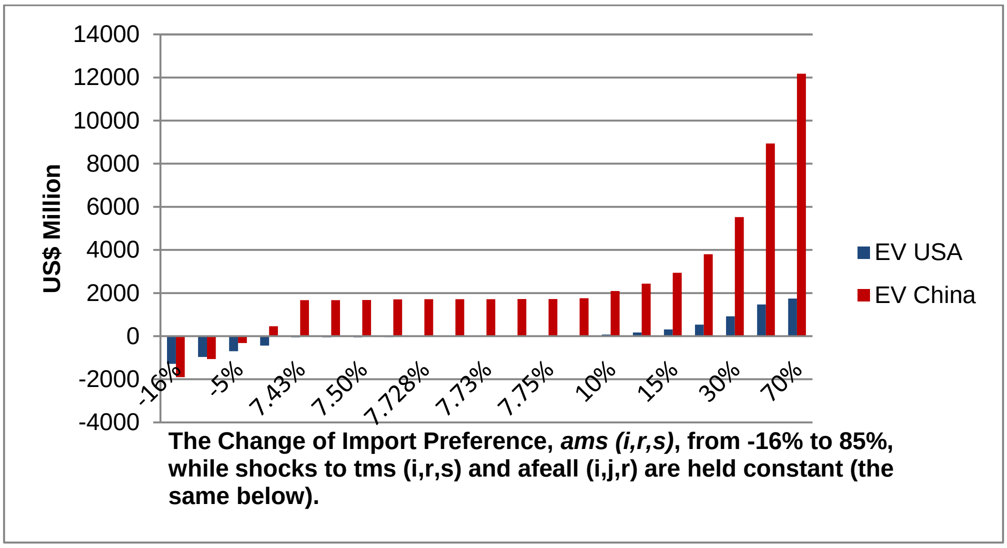
afeall	**10.09%***	**16.32%****	**10.09%***	**16.32%****
ams	**EV (USA)**	**EV (USA)**	**EV (China)**	**EV (China)**
% change	$ US million	$ US million	$ US million	$ US million
-16	-1281.63	-1317.26	-1898.3	-1669.5
-10	-967.87	-1005.18	-1061.58	-836.02
-5	-701.58	-740.36	-317.76	-95.05
0	-53.982	-476.59	1667.533	680.73
7.45	-52.73	-95.32	1671.68	1886.85
7.5	-50.229	-92.83	1679.968	1895.11
7.65	-42.731	-85.38	1704.848	1919.9
7.728	-38.836	-81.51	1717.793	1932.79
7.729	-38.786	-81.46	1717.958	1932.96
7.73	-38.736	-81.41	1718.125	1933.12
7.735	-38.487	-81.16	1718.955	1933.95
7.75	-37.738	-80.42	1721.445	1936.43
8	-25.276	-68.04	1762.96	1977.8
10	73.318	29.94	2096.762	2310.32
12	169.819	125.82	2433.134	2645.42
15	310.25	265.33	2941.773	3152.12
20	531.524	485.09	3797.722	4004.79
30	920.186	870.87	5524.36	5742.7
50	1468	1413.82	8938.166	9124.53
70	1743.437	1686.05	12173.938	12345.93
85	1818.661	1760	14434.813	14596.03

*afeall (“land”, “osd”, “China”) =10.09; **afeall (“land”, “osd”, “China”) =16.32.

Source: GTAP 9 data base for the year of 2011.

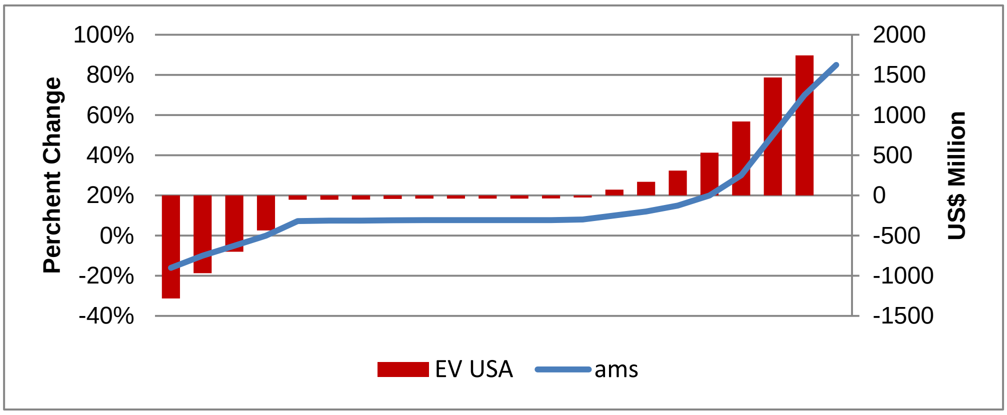
Referring back to table 6 we see that, with the $\Delta\%$ in import preferences, the economic welfares (measured by equivalent variation), both in the United States and China will change as well. As the import preference approach to approximately 8%, the relationship with EV is much more than linear in the United States (see figure 8), indicating that the economic welfare in the United States has close ties with the import preference for soybeans supplied to China (see figure 9). In our comprehensive simulation, *tms ("i","r","s") = 4.4752 afeall ("j","i","s") = 10.09* and *ams ("i","r","s") = -16*, the EV for China and for the U.S. will decline by US$1.28 billion and US$1.89 billion, respectively. This implies that at lower level of land productivity, China's policy aimed at increasing the size of imports of GM soybeans from the United States will contribute more to increasing the economic welfare in China than in the United States. This is more intuitive that, when the import preference for U.S. soybeans is very low, there will be an urgent need for policy makers in China to implement policies aimed at increasing the public acceptance of GM soybeans and promoting more imports from the United States.

Figure 8. A Comparison in Equivalent Variation (EV) for the U.S. and China



Source: GTAP 9 data base for the year of 2011.

Figure 9. EV for the U.S. with respect to the Change of Import Preferences



Source: GTAP 9 data base for the year of 2011.

8.4 Land Productivity Growth for GM Soybean Farming in China

Referring back to the import demand equation:

qxs (i,r,s)
= -ams (i,r,s) + qim (i,s)
*- ESUBM (i) * [pms (i,r,s) – ams (i,r,s) – pim (i,s)]*

The reason that we now bring back this equation is that, as we decompose the exports sales (*qxs*), market price of composite import (*pim*), domestic price (*pms*) and CIF world price (*pcif*) in earlier sections, we did not "physically" see where our shock for "land" augmenting technical change (*afe*) comes to places. In our comprehensive simulation, our empirical evidence shows that the domestic price for oilseeds, *pms (i,r,s)*, supplied from the United States to China, CIF world price of oilseeds supplied from the United States to China, *pcif (i,r,s)*, as well as the market price of composite import of oilseeds in China, *qim (i,s)*, will be slightly affected by the productivity growth associated with the "land" augmenting technical change of oilseeds in China (refer to figure 3). Considering how productivity growth of agricultural yields per hectare affect the $\Delta\%$ in export sales, one must also determine the change in aggregate import, *qim (i,s)*, which can be written as a function of imports of oilseeds used by agricultural sectors and by private and government households in China:

qim (i,r)
$= \sum(j, PROD\_COMM\ , SHRIFM\ (i,j,r) * qfm\ (i,j,r))$
*+ SHRIPM (i,r) * qpm (i,r)*
*+ SHRIGM (i,r) * qgm (i,r);*

where

SHRIFM (i,j,r) = share of import oilseeds by sector j in China
qfm (i,j,r) = demand for oilseeds by industry j in China
SHRIPM (i,j,r) = share of import oilseeds used by private households in China
qpm (i,j,r) = private households demand for imports of oilseeds in China
SHRIGM (i,j,r) = share of import oilseeds used by government households in China
qgm (i,j,r) = government households demand for imports of oilseeds in China

and

The demand for imported oilseeds (intermediate inputs) by industry j can be defined as:

*qfm (i,j,s) = qf (i,j,s) - ESUBD(i) * [pfm (i,j,s) – pf (i,j,s)]*

where

qf (i,j,s) = demand for oilseeds (as intermediate inputs) for use by j in China
pfm (i,j,s) = price index for imports of oilseeds by j in China
pf (i,j,s) = firms' price for oilseeds for use by j in China

The industry demand function for intermediary inputs is written as:

$$qf\,(i,j,r) = -\,af(i,j,r) + qo\,(j,r) - ao(j,r) - ESUBT(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r) - ao(j,r)]$$

Note that af (i,j,r) = *afcom*(i) + *afsec*(j) + *afreg*(r) + *afall*(i,j,r)=0; output augmenting technical change *ao (j,r)*=0; the elasticity of substitution among composite intermediate inputs *ESUBT(j)=0.* For purpose of simplification, now rearrange the industry demand equation to isolate the demand for intermediate outputs on the left hand side (LHS):

$$qf\,(i,j,r) = qo\,(j,r) - ESUBT(j) * [pf\,(i,j,r) - ps\,(j,r)] = qo\,(j,r)$$

where

ps (j,r) = supply price of oilseeds in China

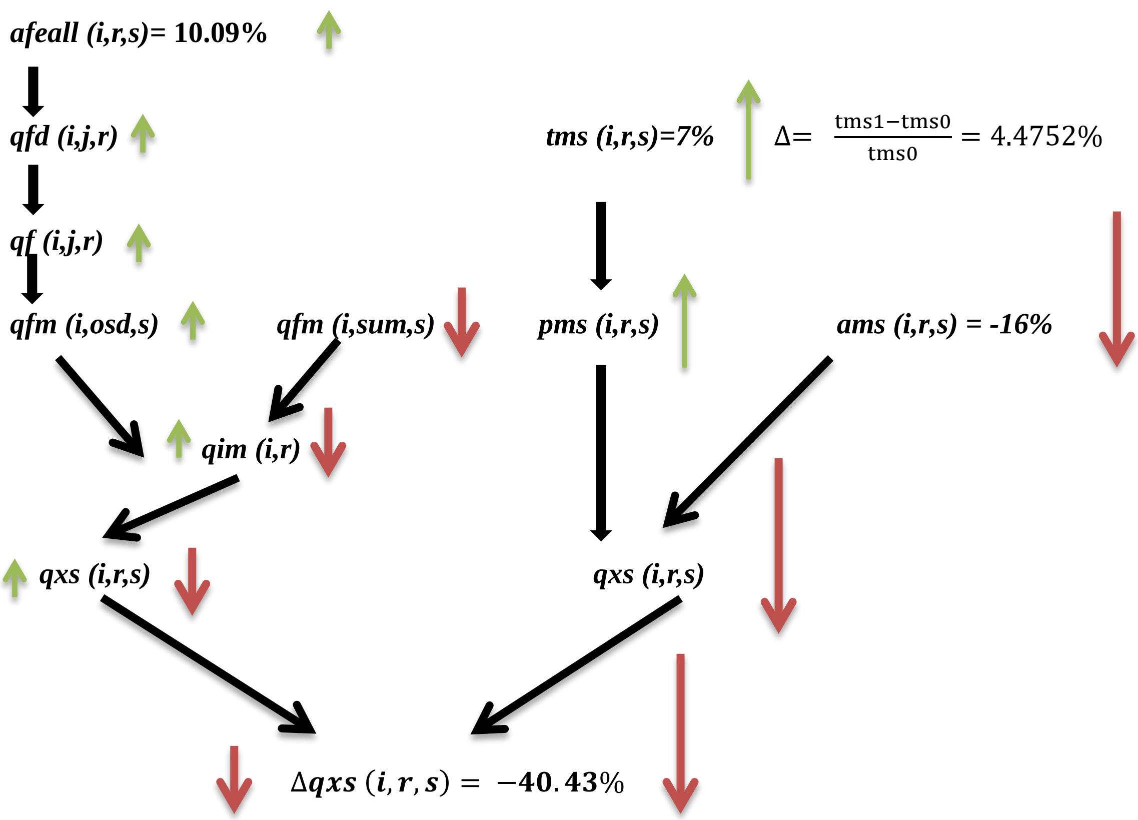
From here, we can see that the productivity growth, *afe (i,r,s)*, is strictly related to the aggregate imports of oilseeds in China, *qim (i,s)*, which will also affect export sales supplied from the United States to China. This is because that *qo (i,r)*, as an independent variable in the RHS of the industry demand equation, is also an interactive term in the firm production structure of GTAP framework. As a result of an increasing domestic land productivity in which a higher yield will occur, Chinese firms will accordingly have a higher demand for domestically yielded oilseeds, *qfd (i,r,s)*, which will result in an increase in domestic sales of oilseeds (*qds*) in China. Therefore, the industry output *(qo)* will increase. This can be expressed in the following equations:

$$qds\,(i,r) = \sum(j, PROD\_COMM, SHRDFM(i,j,r) * qfd\,(i,j,r)) + SHRDPM(i,r) * qpd(i,r) + SHRDGM(i,r) * qgd(i,r)$$

$$qo\,(i,r) = SHRDM(i,r) * qds(i,r) + sum(s,REG, SHRXMD(i,r,s) * qxs(i,r,s)) + tradslack(i,r)$$

A domestic development of productivity growth (*afeall*) will increase the domestic industry output (*qo*) thus the demand for intermediary inputs for oilseeds *(qfm)* produced in the United States will also increase because the aggregate demand for intermediate goods (as intermediary inputs for oilseeds) purchased by Chinese firms (*qf*) will increase. Therefore, the aggregate imports of soybean *(qim)* as well as the export sales of soybean from United States to China *(qxs)* will *slightly* increase due to the increase in demand for oilseeds used by *oilseeds sectors*, but the total export sales will decline (see figure 10). Note that intermediate inputs are "sourced" from particular exporters, *qxs (i,r,s)* (Hertel and Tsigas, 2000), but the aggregate import, *qim (i,r)*, accounts for total imports of oilseeds entering Chinese boarder regardless of whether they are imported from the United States. The computation for aggregate imports involves taking account of the sum of oilseeds demanded by each agricultural industry, which will decline (see figure 10).

Figure 10.



*The length of arrows is not strictly drawn to scale, but they do generally illustrate the scale of magnitudes for differences or changes (in terms of smaller or larger change) in percentage.

Referring to the figure above, there are several interpretations to clarify why the land productivity growth for oilseeds has a much smaller effect in export sales. A profound one is that, as mentioned above, although the land productivity growth for oilseeds will lead to an increase in demand for oilseeds by its own sector, the aggregate demand, *qfm (i,j,s)*, for oilseeds for other agricultural sectors in China will generally fall. Furthermore, the aggregate imports of oilseeds in China, *qim (i,r)*, as a demand-responsive element, do not only reflect to the change in the demand for Chinese oilseeds industry but will also respond to the change in aggregate demand in all agricultural sectors in China. Our results show that as the relative return to land used in producing oilseeds rises the aggregate demand for oilseeds used by total agricultural industries will decline (see table 8), which is dominantly caused by the greater decreases in the demand for oilseeds used by vegetable oil sectors, *qfm (osd, vol, China)* (see figure 11). Note that we have mentioned earlier that the productivity growth will have slight effects on the market price, *pm*. This is also mainly due to a decline in firm's price for vegetable oil, *pf (i,j,r)* resulting in a fall in price index for domestic purchases of oilseeds, *pfd (i,j,r)*, which can be further connected to the market price (*pm*).[36] However, the decline in the aggregate demand for oilseeds for the rest of agricultural sectors will not affect much of the aggregate imports of oilseeds in China as there are very small shares, *SHRIFM (i,j,r)*, of oilseeds imports that is used by each agricultural sector in China. We also found that majority of the imported oilseeds in China go to processing (29.5%) and other manufacturing sectors (25%), and vegetable oil industries (17.25%). The simulation translates to that as Chinese land productivity for oilseeds grows much less of oilseed products (as intermediate inputs) imported from the United States will be demanded by agricultural industries in China. This may be further interpreted as that an increase in land productivity for oilseeds in China will shift away the demand for oilseeds imported from the United States.[37] However, there is no large effect of reduced export sales for oilseeds because majority of Chinese agricultural sectors does not depend on imports of oilseeds (as intermediate products) from the United States and other foreign countries.

[36] Equation links domestic market and firm prices: *pfd (i,j,r) = tfd (i,j,r) + pm (i,r)*, where *tfd (i,j,r)* is exogenous.

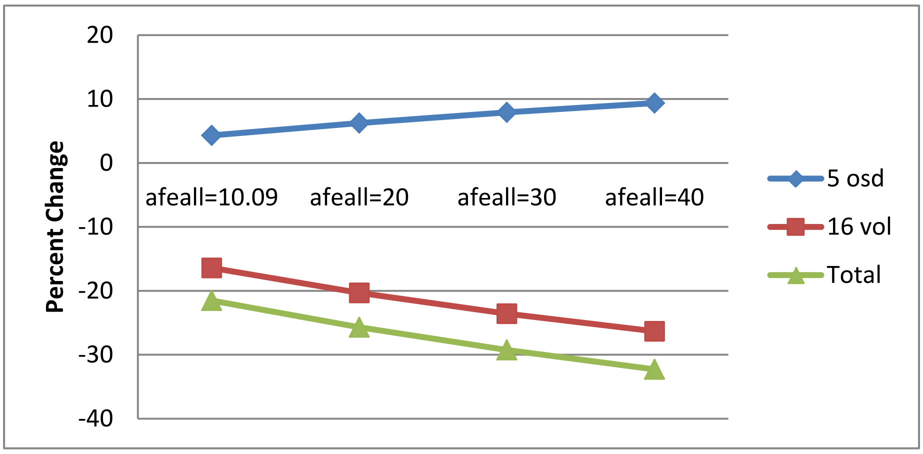
[37] The whole soybeans are among the intermediate products for vegetable oils. Moreover, the increasing demand of Chinese market for soybean is owing to high demand for cooking oil and livestock sector. Much of the whole soybeans imported from the United States are used for crushing for vegetable oils (USITC, 2011).

Table 8. The Demand for oilseeds by Agricultural Sectors in China (*qfm*) shifts as land productivity for oilseeds increases.

qfm (i,j,s)	afeall=10.09	afeall=20	afeall=30	afeall=40	SHRIFM (i,j,r)
1 pdr	-0.015759	0.024426	0.059251	0.089421	0.001358
2 wht	-0.011357	0.014729	0.037538	0.057446	0.000651
3 gro	-0.024093	0.030344	0.077381	0.118025	0.000633
4 v_f	-0.017994	0.022311	0.057282	0.087612	0.00934
5 osd	4.324887	6.244852	7.915149	9.368889	0.002801
6 c_b	-0.224432	-0.196605	-0.172087	-0.150549	0.000074
7 pfb	-0.010587	-0.014696	-0.017868	-0.020345	0.000407
8 ocr	0.237986	0.354292	0.457319	0.548225	0.000199
9 ctl	-1.948783	-2.531093	-3.05022	-3.511222	0.000509
10 oap	-2.208736	-2.857032	-3.434519	-3.946971	0.008542
11 rmk	-2.17929	-2.804728	-3.362348	-3.857547	0.000136
12 wol	-2.051163	-2.670324	-3.221855	-3.711328	0.000421
13 OthNatRes	-0.028029	-0.04619	-0.062145	-0.076147	0.00989
14 cmt	-0.043078	-0.049407	-0.055084	-0.060162	0.000543
15 omt	-0.043327	-0.025793	-0.010567	0.002638	0.001618
16 vol	-16.418417	-20.314369	-23.574945	-26.31525	0.172529
17 mil	-0.052351	-0.031292	-0.013136	0.002516	0.002182
18 pcr	-0.067791	-0.04076	-0.017153	0.003442	0.055118
19 sgr	-0.23834	-0.214638	-0.193828	-0.175605	0.019487
20 ofd	-0.09245	-0.061998	-0.035562	-0.012629	0.294892
21 b_t	-0.028055	-0.025407	-0.023082	-0.021046	0.056374
22 OthManuf	-0.022945	-0.045904	-0.065914	-0.083354	0.25042
23 Services	-0.037798	-0.046411	-0.054138	-0.061043	0.111661
24 CGDS	-0.319809	-0.412055	-0.495026	-0.569292	0
Total	-21.521711	-25.697749	-29.255557	-32.294278	0.999785

Source: GTAP 9 data base for the year of 2011.

Figure 11. The Dominant Role of Vegetable Oils in Reduced Level of Aggregate Demand for Oilseeds for Total Agricultural Sectors in China.



Source: GTAP 9 data base for the year of 2011.

To build more intuition on the $\Delta\%$ in industry output of oilseeds in China, we may refer back to figure 2 and start from the bottom of the firm production structure. The equation for primary factor i augmenting technical change by j of r can be written as:

afe (i,j,r) = afecom (i) + afesec (j) + afereg (r) + afeall (i,j,r);

Where

afe (i,j,r) = "land" augmenting technical change by j of China.
afecom (i) = factor input technical change of input "land", worldwide.
afesec (j) = factor input technical change of oilseeds, worldwide.
afereg (r) = factor input technical change in China.
afeall (i,r,j) = "land" augmenting technical change of oilseeds in China.

Note that *afecom*(i), *afesec*(j), *afereg*(r) and afeall (i,j,r) are exogenous. Recall that we have given a shock value of 10.09% to *afeall (i,j,r)*, thus *afe(i,j,r) = afeall (i,j,r) = 10.09%*. Again, it is unrealistic to expect that there will be no world development made to primary factors and sectors. In the real world, productivity growth rate in foreign countries is very less than likely to remain stable, and the GM's technological progress in the rest of the world is expected to grow over time. However, our purpose in this section is to discover the relationship among productivity growth and other variables that we have evaluated in earlier sections, and its influence made to those variables in the GTAP framework. To decompose, the equation for endowment demand is written as the following:

qfe (i,j,r)
= - afe (i,j,r) + qva (j,r)
*- ESUBVA(j) * [pfe(i,j,r) - afe(i,j,r) - pva(j,r)];*

This can be rewritten as:

*qva (j,r) = qfe (i,j,r) + afe (i,j,r) + ESUBVA(j) * [pfe(i,j,r) - afe(i,j,r) - pva(j,r)];*

where

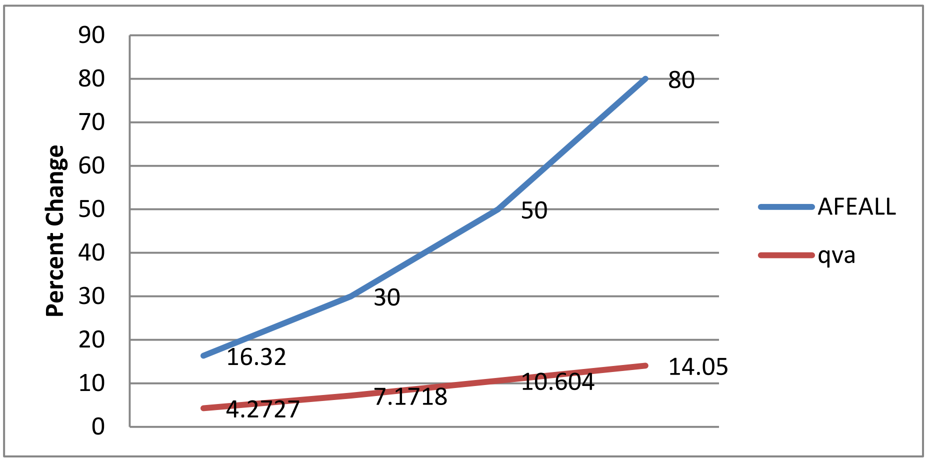
qfe (i,j,r) = demand for endowment "land" for use in oilseeds industry in region China.
qva(j,r) = value added in oilseeds industry of China.
ESUBVA (j) = elasticity of substitution between primary factors of value added in oilseeds (σVA).
pfe(i,j,r)= firms' price for endowment commodity "land" in oilseeds industry of China.
pva(j,r)= firms' price of value added in oilseeds industry of China.

First, we can see that the rapid growth of land productivity of oilseeds will improve its economic value added in oilseed indsutry as well as lower the firm's price for the endowment commodity land in which the technological progress is growing. Firm's price for land will decrease as increasingly growing land productivity will lower the market price of sluggish endowment land used by oilseeds sectors in China.[38] Also note that as productivity growth *afeall (i, j,r)* increases, the value added in oilseeds products will also be expanded, but is increased by a relatively much flatter slope of the value-added line: $\partial \Delta \text{qva}\,(\text{i}, \text{r}, \text{j}) < \partial \Delta \text{afeall}(\text{j}, \text{r}) \rightarrow \partial \Delta \text{qva}\,(\text{i}, \text{r}, \text{j}) < \partial \Delta \text{afe}(\text{j}, \text{r})$, and because the productivity growth line is more linear than the value-added line, therefore $-\Delta \text{afeall}(\text{j}, \text{r}) + \Delta \text{qva}\,(\text{i}, \text{r}, \text{j}) < 0$, or it can be expressed as (see figure 12):

$$\lim_{\text{afeall(i,r,j)}\rightarrow\infty} (\Delta qva(i, r, j) - \Delta afeall) = -\infty$$

Second, although - *ESUBVA (j) * [pfe (i,j,r) – afe (i,j,r) – pva (j,r)]* is positive because *pfe(i,j,r) - afe(i,j,r) - pva(j,r)* (the terms in brackets [.] are denoted as "k" below) will decrease as productivity growth continues to increase, the growth rate of the downward slope of Δk $(\partial \Delta k)$ will decline. As productivity growth increases, *k*[- ESUBVA (j)]* will also increase, but will have a very sluggish growth rate of change of k. Also note that *qva* is a price-responsive element, thus the *elasticity of sub. land in production of value added in oilseeds, ESUBVA (j)* $(\sigma VA^{osd} \approx 0.274)$,[39] also plays a major part in lessening the impact on increasing the demand for endowment land for use in oilseed sectors. That is, because Chinese farmers are much inelastic of substituting primary factors in prodcution in value added in oilseeds sectors, increasing productiviy of agricultural land will not have a much higher increase in demand for the endowment land than those commodities have smaller elasticities of substitution (i.e. vegetable oils: $\sigma VA^{vol} \approx 1.120$).

Figure 12. Flatter slope of qva than AFEALL

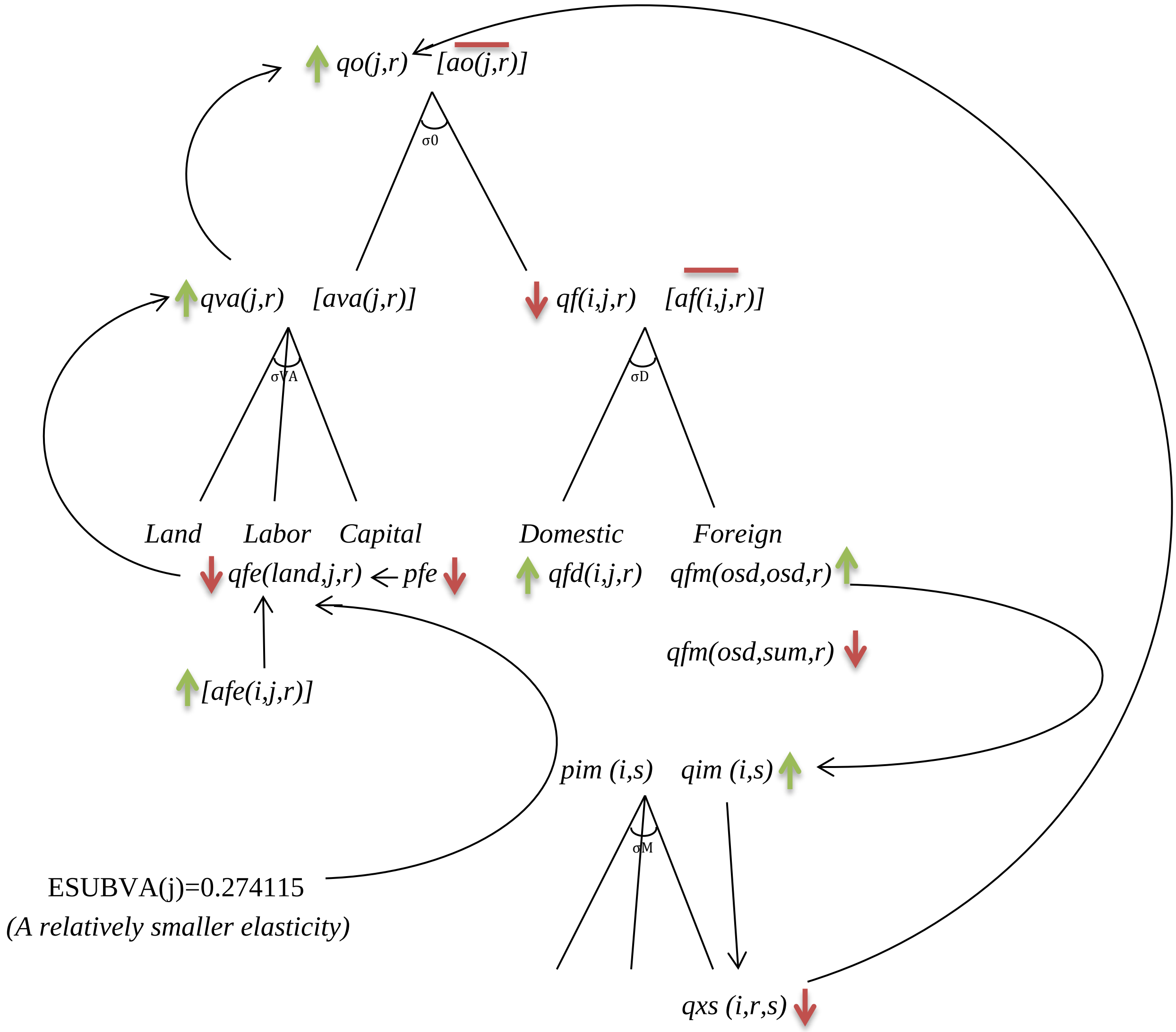


Source: GTAP 9 data base for the year of 2011.

[38] The equation that links domestic and firm demand prices is *pfe (i,j,r) = tf (i,j,r) + pmes (i,j,r)*, where *tf* is exogenous.

[39] See how Behavioral parameters in the GTAP model in Chapter 19 (https://www.gtap.agecon.purdue.edu/resources/download/289.pdf).

Figure 13. A summary of the world linkages and the direction of changes in quantities



Source: Figure 2.6 in Hertel and Tsigas (1997) and author's modification.

8.5 Decomposition of Equivalent Variation (EV)

In section 8.3, we mentioned several implications of gaining economic welfare from export sales, but the actual decomposition of economic welfare involves mathematically complicated computations. While Huff and Hertel has developed a thorough decomposition of the welfare change using GTAP model (Huff and Hertel, 2000),[40] we will briefly break down several key equations involved in the equation for decomposition of welfare:

EV_ALT(r)

$$= -[\frac{1}{100} * UTILELASEV(r) * INCOMEEV(r)]$$

[40] GTAP technical paper 5 is among the most complete and authoritative papers to explain welfare decomposition in GTAP model (https://www.gtap.agecon.purdue.edu/resources/download/2365.pdf).

* [DPARPRIV(r) * loge(UTILPRIVEV(r) / UTILPRIV(r)) * dppriv(r)
+ DPARGOV(r) * loge(UTILGOVEV(r) / UTILGOV(r)) * dpgov(r)
+ DPARSAVE(r) * loge(UTILSAVEEV(r) / UTILSAVE(r)) * dpsave(r)]

+ [$\frac{1}{100}$ * EVSCALFACT(r)]

* [$\sum(i, NSAV\_COMM, PTAX(i,r) * [qo(i,r) - pop(r)])$
+ $\sum(i, ENDW\_COMM, \sum(j, PROD\_COMM,$
ETAX(i,j,r) * [qfe(i,j,r) - pop(r)]))
+ $\sum(i, TRAD\_COMM, \sum(j, PROD\_COMM,$
IFTAX(i,j,r) * [qfm(i,j,r) - pop(r)]))
+ $\sum(i, TRAD\_COMM, \sum(j, PROD\_COMM,$
DFTAX(i,j,r) * [qfd(i,j,r) - pop(r)]))
+ $\sum(i, TRAD\_COMM, IPTAX(i,r) * [qpm(i,r) - pop(r)])$
+ $\sum(i, TRAD\_COMM, DPTAX(i,r) * [qpd(i,r) - pop(r)])$
+ $\sum(i, TRAD\_COMM, IGTAX(i,r) * [qgm(i,r) - pop(r)])$
+ $\sum(i, TRAD\_COMM, DGTAX(i,r) * [qgd(i,r) - pop(r)])$
+ $\sum(i, TRAD\_COMM, \sum(s, REG,$
XTAXD (i,r,s) * [qxs(i,r,s) - pop(r)]))
+ $\sum(i, TRAD\_COMM, \sum(s, REG,$
MTAX (i,s,r) * [qxs(i,s,r) - pop(r)]))
+ $\sum(i, ENDW\_COMM, VOA(i,r) * [qo(i,r) - pop(r)])$
- VDEP(r) * [kb(r) - pop(r)]
+ $\sum(i, PROD\_COMM, VOA(i,r) * ao(i,r))$
+ $\sum(j, PROD\_COMM, VVA(j,r) * ava(j,r))$
+ $\sum(j, PROD\_COMM, \sum(i, ENDW\_COMM,$
VFA (i,j,r) * afe(i,j,r)))
+ $\sum(j, PROD\_COMM, \sum(i, TRAD\_COMM,$
VFA(i,j,r) * af(i,j,r)))
+ $\sum(m, MARG\_COMM, \sum(i, TRAD\_COMM, \sum(s, REG,$
VTMFSD(m,i,s,r) * atmfsd(m,i,s,r))))
+ $\sum(i, TRAD\_COMM, \sum(s, REG, VIMS(i,s,r) * ams(i,s,r)))$
+ $\sum(i, TRAD\_COMM, \sum(s, REG, VXWD(i,r,s) * pfob(i,r,s)))$
+ $\sum(m, MARG\_COMM, VST(m,r) * pm(m,r))$
+ NETINV(r) * pcgds(r)
- $\sum(i, TRAD\_COMM, \sum(s, REG, VXWD(i,s,r) * pfob(i,s,r)))$
- $\sum(m, MARG\_COMM, VTMD(m,r) * pt(m))$
- SAVE(r) * psave(r)]

+ $\frac{1}{100}$ * INCOMEEV(r) * pop(r);

The first one to note is the regional income for EV calculation, which equals level of expenditure and NET income in China, and can be written as a function of the sum of the regional expenditures and the expenditures on NET savings (valued at agent's prices), i.e. *PRIVEXP(r) + GOVEXP(r) + SAVE(r).* Since we have three exogenous parameters involved computing at this first step, thus:[41]

- [$\frac{1}{100}$ * *UTILELASEV(r) * INCOMEEV(r)]*

** [DPARPRIV(r) * loge(UTILPRIVEV(r) / UTILPRIV(r)) * dppriv(r)*
*+ DPARGOV(r) * loge(UTILGOVEV(r) / UTILGOV(r)) * dpgov(r)*
*+ DPARSAVE(r) * loge(UTILSAVEEV(r) / UTILSAVE(r)) * dpsave(r)]*

= - [$\frac{1}{100}$ * *UTILELASEV(r) * INCOMEEV(r)]*

** [DPARPRIV(r) * loge (UTILPRIVEV(r) / UTILPRIV(r)) * 0*
*+ DPARGOV(r) * loge (UTILGOVEV(r) / UTILGOV(r)) * 0*
*+ DPARSAVE(r) * loge (UTILSAVEEV(r) / UTILSAVE(r)) * 0*

= 0

One can see that there are two augmenting technical change terms that are not used in the calculation. One is the output augmenting technical change variable, *ao (i,r)*, the other is the value added augmenting technical change variable, *ava(j,r)*. Therefore, the $\sum\left(i, PROD_{COMM}, VOA(i,r) * \ ao\ (i,r)\right) + \sum(j, PROD\_COMM, VVA\ (j,r)\ * \ ava(j,r))$ also becomes zero. Note that there are two output terms (*qo*) that are included in the RHS of the expression. One measures the output that derives from agricultural industries in China, the other one measures the output that derives from the endowment commodity with no respect to individual agricultural sectors. The latter one has no intervention in our computation thus $\sum(i, ENDW\_COMM, VOA(i,r)\ *\ [qo(i,r)\ -\ pop(r)]) = 0$ .We also delete the expression involved non-interactive beginning-of-period capital stock variable *kb (r)* thus - *VDEP(r) * [kb(r) - pop(r)* is taken as zero. Note there are other three sets that are derived from added regional dimensions: *REG, TRAD_COMM, and MARG_COMM* have no intervention in the expression used with the two four-dimensional terms,[42] *VTMFSD (m,i,s,r)* and *atmfsd (m,i,s,r)*. For clarification purpose, these two terms are international margin usage, by margin, freight, source, and destination, and tech change in m's shipping of i from region r to s, respectively. We can now slightly simplify the equation and rewrite as:

EV_ALT(r)=

[$\frac{1}{100}$ * *EVSCALFACT(r)]*

* [$\sum(i, NSAV\_COMM, PTAX(i,r)\ *\ [qo(i,r)\ -\ pop(r)])$
+$\sum(i, ENDW\_COMM, sum(j, PROD\_COMM,$
*ETAX(i,j,r) * [qfe(i,j,r) - pop(r)]))*
+ $\sum(i, TRAD\_COMM, sum(j, PROD\_COMM,$
*IFTAX(i,j,r) * [qfm(i,j,r) - pop(r)]))*
+ $\sum(i, TRAD\_COMM, \sum(j, PROD\_COMM\ ,$
*DFTAX(i,j,r) * [qfd(i,j,r) - pop(r)]))*

[41] dppriv(r) = private consumption distribution paramete, dpgov(r) = government consumption distribution parameter, dpsave(r) = saving distribution parameter.
[42] Regions, traded commodities, and margins commodities,

$+ \sum(i, TRAD\_COMM, IPTAX(i,r) * [qpm(i,r) - pop(r)])$
$+ \sum(i, TRAD\_COMM, DPTAX(i,r) * [qpd(i,r) - pop(r)])$
$+ \sum(i, TRAD\_COMM, IGTAX(i,r) * [qgm(i,r) - pop(r)])$
$+ \sum(i, TRAD\_COMM, DGTAX(i,r) * [qgd(i,r) - pop(r)])$
$+ \sum(i, TRAD\_COMM, \sum(s, REG, XTAXD(i,r,s)$
** [qxs(i,r,s) - pop(r)]))*
$+ \sum(i, TRAD\_COMM, \sum(s, REG, MTAX(i,s,r)$
** [qxs(i,s,r) - pop(r)]))*
$+ \sum(i, ENDW\_COMM, VOA(i,r) * [qo(i,r) - pop(r)])$
$+ \sum(j, PROD\_COMM, \sum(i, ENDW\_COMM,$
*VFA(i,j,r) * afe(i,j,r)))*
$+ \sum(j, PROD\_COMM, \sum(i, TRAD\_COMM,$
*VFA(i,j,r) * af(i,j,r)))*
$+ \sum(i, TRAD\_COMM, \sum(s, REG,$
*VIMS(i,s,r) * ams(i,s,r)))*
$+ \sum(i, TRAD\_COMM, \sum(s, REG, VXWD(i,r,s) * pfob(i,r,s)))$
$+ \sum(m, MARG\_COMM, VST(m,r) * pm(m,r))$
*+ NETINV(r) * pcgds(r)*
$- \sum(i, TRAD\_COMM, \sum(s, REG, VXWD(i,s,r) * pfob(i,s,r)))$
$- \sum(m, MARG\_COMM, VTMD(m,r) * pt(m))$
*- SAVE(r) * psave(r)]*

$+ \frac{1}{100} * INCOMEEV(r) * pop(r);$

We can further compute the actual change in equivalent variation due to our shock. In order to quantify the change in equivalent varition due to the import preference shift, we multiply the interacted variable by the equivalent variation scaling factor and 0.01:

$$\sum(i, TRAD_{COMM}, \sum(s, REG, VIMS(i,s,r) * ams(i,s,r)) * [\frac{1}{100} * EVSCALFACT(r)]$$

We obtain that the difference that diametrically caused by a -16% import preference shift is -$2518.29 million. Similary, we can compute the difference of EV that is derivated from adding land prodcutiviy growth rate by the equation below:

$$\sum(j, PROD\_COMM, \sum(i, ENDW\_COMM, VFA(i,j,r) * afe(i,j,r))) * [\frac{1}{100} * EVSCALFACT(r)]$$

Thus a 10.09% primary factor land augmenting technical change in oilseeds sectors will increase the EV by $577.17 million. From these modified equations above, one can see that a negative shock to *ams (i,r,s)* variable is the most dominant factor in affecting the change in equivalent variation. When a significant negative import preference is present, there will be a large reduction in equivalent variation of China. The second dominant factor in affecting the change in equivalent variation is the productivity growth. As the land productivity (*afeall*) in China grows, China is better off by gaining a positive change in equivalent variation. From the equations above, one must also see that there are several other terms that will affect the change in welfare.

Both changes in import preference and productivity growth rate will also indirectly affect the equivalent variation in many ways. For instance, the FOB world price, *fob (i,r,s)*, will affect measured value of exports at world prices, which will add to the contribution of change in welfare within the regional terms affected by trade. When the FOB world price is decreased, it will lower the total export revenues (valued at FOB world prices) from shipping tradable commodities to the world. The decline in FOB world prices will also reduce the FOB export sales from importing tradable goods from foreign countries. The latter one is a subtracting fraction from calculating the change on welfare. Note that the values of exports are measured at different FOB world prices. The *fob (i,r,s)* represents the percentage change in the *fob* which captures the percentage change in domestic market price, *pm (i,r)* of commodity i, or oilseeds.[43] The latter term *fob (i,s,r)* represents the percentage change of *fob* in foreign countries, which reflects to a percentage change of commodity price in foreign markets.

In our simulations, we find that *fob (i,r,s)* and *fob (i,s,r)* are closely related to the market price for vegetable oils. That is, when we give our shocks to oilseeds, the market price (*pm*) for vegetable oils falls at a greater percentage than other commodities, leading to a larger negative change in FOB world prices. Recall that when the market price, *pms (i,r,s)*, increases, the market price of composite import, *pim*, will also increase, thus the price index for imports, *pfm (i,j,r)*, will increase. This can be translated to that as our shocked import tariff rate is increased to 7%, the demand for oilseeds imported from the United States, *qfm (i,j,s)*,will decline because the price index for imports of oilseeds (*pfm*) increases.[44] The intuition is that the percentage change in *tms* will ultimately affect the change in welfare, i.e. $\sum(i, TRAD\_COMM, sum(j, PROD\_COMM, IFTAX(i,j,r) * [qfm(i,j,r) - pop(r)]))$.

The magnitude of change in welfare will be affected by both change in export sales, qxs (i,r,s) and FOB prices, pfob (i,r,s). That is, each of these two terms is a multiplying fraction in computing the exports of commodity which also faces constraints under the demand for imports (see figure 14). Note that the qxs (i,r,s) accounts for the total export sales and VXWD (i,r,s) = VXMD (i,r,s) + XTAX (i,r,s). This is calculated as:

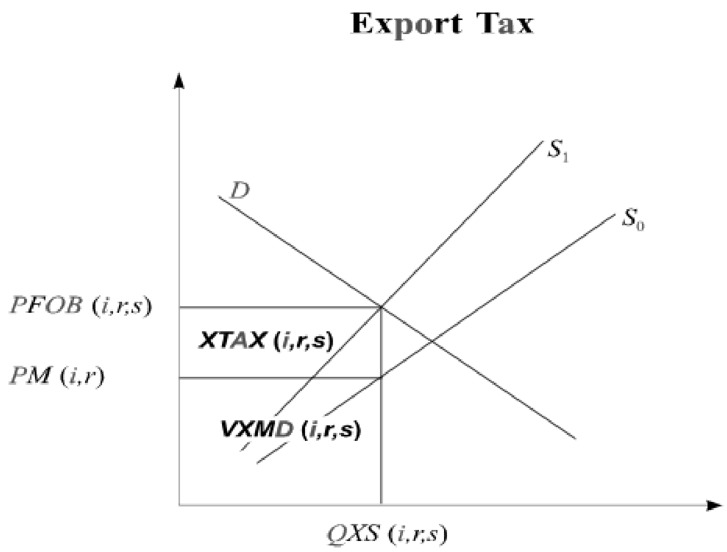
$$\sum(i, TRAD\_COMM, \sum(s, REG, VXWD(i,r,s) * pfob(i,r,s))) * [\frac{1}{100} * EVSCALFACT(r)]$$

The welfare affected by the increased value of exports (at FOB price) is $97.86 million.

Figure 14. Value of Exports (at FOB World Price) in Welfare Decomposition.

[43] Equation links agent's and world prices: *pfob (i,r,s) = pm (i,r) – tx (i,r) – txs (i,r,s)*, where *tx (i,r)* and txs *(i,r,s)* are both exogenous.

[44] This can be referred to the equations: pim (i,s) = sum (k,REG, MSHRS (i,k,s) * [pms (i,k,s) – ams (i,k,s)]); pfm (i,j,r) = tfm (i,j,r) + pim (i,r) and qfm (i,j,s) = qf (i,j,s) - ESUBD(i) * [pfm (i,j,s) – pf (i,j,s)].



D=Demand for imports of commodity i supplied from region r by region s

S_0=Pretax net supply of commodity i from region r in region s

S_1=Taxed net supply of commodity i from region r in region s

Source: Structure of GTAP (Hertel and Tsigas, 1997)

9. Single-shocked simulations

9.1 Import Tariff Rate Shock

Table 9. Selected Results for *tms* shock

Variables	USA	China	EU_28	ROW
EV	-361.63	45.94	9.8	392.47
qxs (osd,USA,*)	**	-11.35	2.7	2.13
qxs (vol,USA,*)	**	2.33	2.1	1.99
pms (osd,USA,*)	**	4.01	-0.52	-0.44
pms (vol,USA,*)	**	-0.27	-0.3	-0.28
pcif(osd,USA,*)	**	-0.44	-0.53	-0.44
pcif(vol,USA,*)	**	-0.27	-0.3	-0.28
pim (osd,*)	0.12	1.59	0.01	-0.1
pim (vol,*)	0.04	0.03	0.02	0.01
qim (osd,*)	-0.95	-0.5	0.01	0.41
qim (vol,*)	-0.5	0.35	-0.02	0.05
qo (osd,*)	-2.8	0.66	0.03	0.58
pp (osd,*)	-0.44	1.39	0.01	0.09
pp (vol,*)	-0.08	0.14	0.01	0.03
qfe (land,osd,*)	-2.13	0.55	0.02	0.47
qfe (land,vol,*)	1.16	-0.06	0.01	-0.11
qfe (UnSkLAb,osd,*)	-3.06	0.7	0.03	0.63
qfe (SkLab,osd,*)	-3.06	0.7	0.03	0.63
qfe (Capital,osd,*)	-3.06	0.7	0.03	0.63
qfe (sum,osd,*)	-11.32	2.66	0.12	2.37
qfm (osd,osd,*)	-4.32	0.48	0.02	1.12
qfm (osd,vol,*)	-0.54	-2.79	0.02	0.39
qfm (osd,sum,*)	-28.11	-3.91	-0.07	9.76
qfm (vol,sum,*)	-18.44	9.53	-0.37	1.51
qva (osd,*)	-2.8	0.66	0.03	0.58
qva (vol,*)	0.96	-0.1	0.03	-0.08

*tms (i,r,s)=4.4752 (shock to 7%).

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

Source: GTAP 9 data base for the year of 2011.

In the *tms* shock, we only assume that China raised the import tariff rate to 7%. At this stage, since we are not running a comprehensive simulation and therefore the *ams* and *afeall* are both zeros. The export sales of oilseeds from the United States to China will decline by 11.35% (see table 3b) due to a decline in the price of imports, *pms (i,r,s)*.[45] The EV will decline by $351.63 million in the United States and will increase by $45.94 million in China (see table 9). We may refer to section 8.2 in the comprehensive section. Since we assume

[45] Recall that qxs (i,r,s)= -ams (i,r,s) + qim (i,s)- ESUBM (i) * [pms (i,r,s) – ams (i,r,s) – pim (i,s)].

there is a zero land productivity growth, thus there is no diminishing effect on *pms* and the domestic price for oilseeds supplied from the United States (+4.01%) will be higher than in the comprehensive simulation. Also note that the *ams=0*, and therefore the market price of composite import (*pim*) will be lower. We refer to figure 9, because there is no productivity growth, therefore both aggregate demand for oilseeds (*qfm*) and aggregate import (*qim*) will be much less affected. The change of shock leads to a distinct difference in the value of export sales of oilseeds from the United States to China. Because there is no change in import preference, there will not be significant changes in welfare. Since there is no land productivity growth, we will expect to see much improvement in economic welfare.

9.2 Import Preference Shock

Table 10. Selected Results for *ams* shock

	USA	China	EU_28	ROW
EV	-936.48	-2336.73	-61.05	1201.21
qxs (osd,USA,*)	**	-30.37	7.56	6.36
qxs (vol,USA,*)	**	-3.73	0.57	-1.49
pms (osd,USA,*)	**	-1.13	-1.34	-1.13
pms (vol,USA,*)	**	-0.68	-0.76	-0.7
pcif(osd,USA,*)	**	-1.13	-1.34	-1.13
pcif(vol,USA,*)	**	-0.68	-0.76	-0.7
pim (osd,*)	0.51	5.88	0.14	-0.13
pim (vol,*)	0.17	0.15	0.1	0.1
qim (osd,*)	-2.69	-1.74	-0.02	1.28
qim (vol,*)	-1.4	1.07	-0.09	0.15
qo (osd,*)	-7.31	2.41	0.29	2.42
pp (osd,*)	-1.09	5.1	0.07	0.45
pp (vol,*)	-0.15	0.51	0.07	0.16
qfe (land,osd,*)	-5.62	1.99	0.21	1.92
qfe (land,vol,*)	3.03	-0.21	-0.01	-0.46
qfe (UnSkLAb,osd,*)	-7.94	2.58	0.31	2.64
qfe (SkLab,osd,*)	-7.94	2.58	0.31	2.64
qfe (Capital,osd,*)	-7.94	2.58	0.31	2.64
qfe (sum,osd,*)	-29.46	9.75	1.14	9.86
qfm (osd,osd,*)	-11.41	1.73	0.12	4.11
qfm (osd,vol,*)	-1.63	-9.79	0.04	1.22
qfm (osd,sum,*)	-79.4	-13.81	-1.78	30.81
qfm (vol,sum,*)	-50.22	30.3	-1.28	5.25
qva (osd,*)	-7.31	2.41	0.29	2.42
qva (vol,*)	2.7	-0.32	0.17	-0.24

*ams (i,r,s,)=-16.

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

Source: GTAP 9 data base for the year of 2011.

In our single-shocked *ams* simulation, we only assume that China shifts away from the imports of oilseeds from the United States. From the import demand equation which has been mentioned a number of times above, one can see that when *ams (i,r,s)*=-16, the market price of composite imports of oilseeds, *pim (i,r,s)*, will increase, but will have a smaller magnitude than the change in *ams (i,r,s)*. This is because that *pim (i,r,s)* is calculated based on the share of imports from r in import bill of s at market prices (*MSHRS*) multiplied by a negative *ams* fraction. Since the region-generic elasticity of substitution among imports of i ($\sigma M = 4.9$) is large, we will expect to see a large reduction in export sales of oilseeds from the United States (-30.37%). Since *ams* is dominant factor in affecting the change in welfare, a -16% of change in import preference shift will cause approximately -$2518.29 million in the change of equivalent variation. The total equivalent variation is reduced by -$2336.73 (see table 10) partly because that a negative import preference leads to a large increase (56.78%) of export sales from the rest of the world. The export sales of oilseeds imported from *EU28* will increase by 29.78%, along with an increase in export sales by 27% from the *ROW*, leading China to gain more tax revenues on imports.

9.3 Productivity Shock

Table 11. Selected Results for *afeall* shock

Variables	USA	China	EU_28	ROW
EV	-78.79	417.48	39.41	115.69
qxs (osd,USA,*)	**	-0.88	0.01	-0.53
qxs (vol,USA,*)	**	-2.16	0.15	0.02
pms (osd,USA,*)	**	-0.07	-0.08	-0.07
pms (vol,USA,*)	**	-0.05	-0.05	-0.05
pcif(osd,USA,*)	**	-0.07	-0.08	-0.07
pcif(vol,USA,*)	**	-0.05	-0.05	-0.05
pim (osd,*)	-0.15	-0.06	-0.1	-0.22
pim (vol,*)	-0.04	-0.04	-0.03	-0.04
qim (osd,*)	0.1	-0.91	0.07	0.22
qim (vol,*)	-0.01	-2.22	0.01	-0.002
qo (osd,*)	-0.4	2.76	-0.18	-0.26
pp (osd,*)	-0.09	-0.5	-0.04	-0.1
pp (vol,*)	-0.05	-0.76	-0.03	-0.04
qfe (land,osd,*)	-0.29	-4.01	-0.13	-0.2
qfe (land,vol,*)	0.12	0.51	0.03	-0.005
qfe (UnSkLAb,osd,*)	-0.44	1.65	-0.19	-0.29
qfe (SkLab,osd,*)	-0.44	1.65	-0.19	-0.29
qfe (Capital,osd,*)	-0.44	1.65	-0.19	-0.29
qfe (sum,osd,*)	-1.31	4.96	-0.56	-0.87
qfm (osd,osd,*)	-0.24	2.35	-0.04	0.09
qfm (osd,vol,*)	0.13	-0.53	0.06	0.18
qfm (osd,sum,*)	2.77	-5.26	1.76	6
qfm (vol,sum,*)	-1.04	-54	-0.15	-0.24
qva (osd,*)	0.4	2.76	-0.18	-0.26
qva (vol,*)	-0.01	0.56	-0.04	-0.13

*afeall (i,r,s)=10.09.

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

Source: GTAP 9 data base for the year of 2011.

The *afeall* shock (*afeall=10.09*) is a better option (among single-shocked simulations) in terms of relatively increasing economic welfares. The equivalent variation is increased by $417.48 million in China, and is *only* reduced by -$78.79 million dollars in the United States. This is mainly due to an increase in land productivity growth rate. For instance, one can find that in the expression for productivity growth that affected the change in welfare:

$$\sum(j, PROD\_COMM, \ \sum(i, ENDW\_COMM, VFA(i,j,r) \ * \ afe(i,j,r)))$$

Multiplying by $[\frac{1}{100}$* EVSCALFACT(r)], we get that the change in welfare (measured by EV) of China is $577 million, which is a bit close to $417.48 (see figure 11). For other immediate effects in the positive welfare change, one can also refer to the expression for FOB world price (*pfob*) that affected the change in welfare:

$$\sum(i, TRAD\_COMM, \sum(s, REG, VXWD(i,r,s) * pfob(i,r,s)))$$

We find that the EV in China will increase by $123.39 due to an increased value of exports at FOB world prices owing to a significant increase in export sales (valued at FOB price) of *OthManuf.*

Part of the welfare loss is due to that the demand for endowment i for use in industry j in region r, *VFM (i,j,r),* exceeds the producer expenditure on i by j in r valued at agent's prices *VFA (I,j,r)*, resulting in a significant loss in tax revenue on use of endowment good i by industry j in region r, *ETAX (i,j,r)*. The excessive demand for endowment i (land) causes the reduction in change of welfare by $79.15 million. Another part of the welfare loss ($89.06 million) is due to a decrease in demand for domestic oilseeds, *qfd (i,j,s)*, which lowers tax revenue charged on use of domestic intermediate goods I by j in r, DFTAX *(i,j,r)*.

Another reduction in equivalent variation is due to the loss in both taxes on import and export of good i from source r to destination s, MTAX (i,s,r) and XTAXD (i,r,s), respectively. This can be calculated from:

$$[\sum(i, TRAD\_COMM, sum(s, REG, XTAXD(i,r,s) * [qxs(i,r,s) - pop(r)]))$$

$$+$$

$$\sum sum(i, TRAD\_COMM, sum(s, REG, MTAX(i,s,r) * [qxs(i,s,r) - pop(r)]))]$$

$$*$$

$$[\frac{1}{100} * \text{EVSCALFACT(r)}]$$

Thus the loss in equivalent variation due to reductions in both taxes on import and exports is $63.36 million. Therefore, an increase in land productivity will simultaneously have negative impacts in diminishing the demand and thus reducing the equivalent variation.

10. A Simulation Comparison with Other Policy Shocks.

10.1 Change of Import Preference and Land Productivity

Table 11. Selected Results for *ams* + *afeall* shock

Variables	USA	China	EU_28	ROW
EV	-1005.19	-1903.14	-21.55	1303.66
qxs (osd,USA,*)	**	-30.98	7.5	5.74
qxs (vol,USA,*)	**	4.32	5.85	5.62
pms (osd,USA,*)	**	-1.18	-1.41	-1.18
pms (vol,USA,*)	**	-0.72	-0.8	-0.75
pcif(osd,USA,*)	**	-2.28	0.02	0.45
pcif(vol,USA,*)	**	-0.33	0.02	0.15
pim (osd,*)	0.35	5.82	0.04	-0.35
pim (vol,*)	0.13	0.11	0.07	0.06
qim (osd,*)	-2.57	-2.59	0.05	1.49
qim (vol,*)	-1.4	-1.27	-0.07	0.15
qo (osd,*)	-7.65	5.19	0.11	2.14
pp (osd,*)	-1.18	4.53	0.03	0.35
pp (vol,*)	-0.19	-0.29	0.04	0.12
qfe (land,osd,*)	-5.87	-2.14	0.08	1.71
qfe (land,vol,*)	3.13	0.32	0.02	-0.47
qfe (UnSkLAb,osd,*)	-8.31	4.21	0.12	2.34
qfe (SkLab,osd,*)	-8.3	4.21	0.12	2.34
qfe (Capital,osd,*)	-8.3	4.21	0.12	2.34
qfe (sum,osd,*)	-30.82	10.5	0.44	8.73
qfm (osd,osd,*)	-11.55	4.03	0.07	4.18
qfm (osd,vol,*)	-1.48	-14.73	0.11	1.38
qfm (osd,sum,*)	-76.01	-18.94	-0.02	36.59
qfm (vol,sum,*)	-5.54	5.04	0.43	4.63
qva (osd,*)	-7.65	5.19	0.11	2.14
qva (vol,*)	2.65	0.26	0.14	-0.38

*ams (i,r,s,)=-16 and afeall (i,r,s)=10.09

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

Source: GTAP 9 data base for the year of 2011.

10.2 Change of Import Preference and Import Tariff Rate

Table 12. Selected Results for *ams+ tms* shock

	USA	**China**	**EU_28**	**ROW**
EV	-1215.83	-2330.6	-54.88	1534.38
qxs (osd,USA,*)	**	-39.9	9.91	8.81
qxs (vol,USA,*)	**	-4.57	-0.81	-1.92
pms (osd,USA,*)	**	0.48	0.04	0.62
pms (vol,USA,*)	**	0.64	0.05	0.22
pcif(osd,USA,*)	**	-1.48	-1.77	-1.48
pcif(vol,USA,*)	**	0.64	0.05	0.22
pim (osd,*)	0.61	7.03	0.15	-0.22
pim (vol,*)	0.2	0.18	0.12	0.11
qim (osd,*)	-3.45	-2.06	-0.01	1.63
qim (vol,*)	-1.8	1.29	-0.1	0.2
qo (osd,*)	-9.65	2.85	0.32	2.91
pp (osd,*)	-1.45	6.08	0.08	0.53
pp (vol,*)	-0.21	0.61	0.07	0.19
qfe (land,osd,*)	-7.45	2.36	0.22	2.31
qfe (land,vol,*)	3.99	-0.25	0	-0.56
qfe (UnSkLAb,osd,*)	-10.46	3.05	0.33	3.18
qfe (SkLab,osd,*)	-10.36	3.05	0.33	3.18
qfe (Capital,osd,*)	-10.36	3.05	0.33	3.18
qfe (sum,osd,*)	-38.86	11.52	1.23	11.86
qfm (osd,osd,*)	-14.75	2.03	0.13	5.08
qfm (osd,vol,*)	-2.06	-11.55	0.06	1.55
qfm (osd,sum,*)	-101.71	-16.41	-1.78	39.25
qfm (vol,sum,*)	-65	36.31	-1.59	6.54
qva (osd,*)	-9.65	2.85	0.32	2.91
qva (vol,*)	3.51	-0.38	0.2	-0.31

*ams (i,r,s,)=-16 and tms (i,r,s)=4.4752 (shock to 7%)

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

Source: GTAP 9 data base for the year of 2011.

10.3 Change of Land Productivity Growth Rate and Import Tariff Rate

Table 13. Selected Results for *afeall*+ *tms* shock

	USA	China	EU_28	ROW
EV	-436.29	460.97	48.94	503.71
qxs (osd,USA,*)	**	-12.13	2.68	1.57
qxs (vol,USA,*)	**	0.08	2.23	2
pms (osd,USA,*)	**	3.95	-0.6	-0.51
pms (vol,USA,*)	**	-0.31	-0.35	-0.33
pcif(osd,USA,*)	**	-0.51	-0.6	-0.51
pcif(vol,USA,*)	**	-0.31	-0.35	-0.33
pim (osd,*)	-0.03	1.53	-0.08	-0.32
pim (vol,*)	-0.01	-0.01	-0.02	-0.03
qim (osd,*)	-0.84	-1.39	0.09	0.63
qim (vol,*)	-0.51	-1.91	-0.005	0.05
qo (osd,*)	-3.18	3.42	-0.14	0.31
pp (osd,*)	-0.53	0.87	-0.04	-0.005
pp (vol,*)	-0.12	-0.63	-0.02	-0.01
qfe (land,osd,*)	-2.41	-3.5	-0.1	0.26
qfe (land,vol,*)	1.27	0.46	0.04	-0.03
qfe (UnSkLAb,osd,*)	-3.47	2.35	-0.15	0.34
qfe (SkLab,osd,*)	-3.47	2.35	-0.15	0.34
qfe (Capital,osd,*)	-3.47	2.35	-0.15	0.34
qfe (sum,osd,*)	-12.83	3.56	-0.56	1.28
qfm (osd,osd,*)	-4.53	2.82	-0.03	1.2
qfm (osd,vol,*)	-0.41	-7.99	0.09	0.57
qfm (osd,sum,*)	-25.12	-9.14	1.68	15.68
qfm (vol,sum,*)	-19.31	-45.44	-0.52	1.26
qva (osd,*)	-3.18	3.42	-0.41	0.31
qva (vol,*)	0.93	0.47	-0.003	-0.21

* *afeall (i,r,s)*=10.09 and *tms (i,r,s)*=4.4752 (shock to 7%)

*EV-Change in US$ Million; the Rest-% Change.

** No results because the United States does not engage in international trade with itself.

Source: GTAP 9 data base for the year of 2011.

11. Conclusions

The author concludes that Chinese policies aimed at promoting genetically modified technologies and GMOs and increasing public acceptance will improve the economic welfare (as measured by equivalent variation) in both the United States and China. (1) An outright ban of GM soybeans or a straight reduction in imports of GM soybeans from the United States will reduce the equivalent variation in income to a great extent. (2) Chinese tariff policies that allow raising effective import tariff rate on GM soybean from the United States will efficiently reduce the export sales of GM soybeans from the United States but will generally have no significant positive impacts on economic welfare in China. (3) The economic welfare will be gained from agricultural policies aimed at actively increasing productivity of land use and/or improving agricultural technologies that can significantly increase the soybean yields. (4) The reduction in import of GM soybeans generally plays a more dominant role in changing the magnitude of equivalent variation than a positive shock to land productivity growth. However, when the negative import preference of GM soybeans imported from the United States is present, China's "second-best" strategy will be aimed at improving the land productivity.

The author finds that vegetable oils and GM soybeans in China that complement each other have a negative cross elasticity of demand,[46] thus the shifts in import preference away from GM soybean may also potentially have an adverse effect on future profitability of vegetable oil industries in the United States. When the market price for vegetable oils falls, it will lead to a larger negative change in FOB world prices (for EV calculation), thus further reducing the regional equivalent variation in income. Therefore, along with the export sales of GM soybeans from the United States, the market price for vegetable oils in China may be served as an additional indicator for change in economic welfare for both United States and China.

The results show that, according to author's review on the latest 2015 No.1 Central Document, Chinese Central Government has generally a well understanding in how the government should behave to avoid future negative economic impacts generated by irrational public opinions about GM foods.[47]

12. Policy Recommendations

Policies that reduce obstacles to imports of GM soybeans from the United States will generally improve the welfare in both United States and China. It is recommended that (1) China continues to put efforts on popularizing scientific knowledge of GM technologies through formal science education and media channels. (2) Trade policies may be established to reduce or eliminate non-tariff barriers to trade for GM soybeans or other GM products that have larger import shares by U.S. exporters, such as vegetables, fruits and food products. (3) China's best long-term goal would be focus on improving agricultural productivity and encouraging scientific research on both GMO safety and GM technologies.

[46] See explanations in section 8.2 (i.e. $\frac{\alpha Q^{vol}\downarrow\uparrow}{\alpha P^{osd}\uparrow\downarrow} < 0 \rightarrow \varepsilon_{osd,vol} < 0$).

[47] Although author's view is that further actions are required to reduce trade barriers of foreign imports.

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