# Commercialization of Herbicide-Tolerant Soybeans in China: Perverse Domestic and International Trade Effects

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China is a key player in global agricultural markets. In the case of soybeans, China is the leading global importer of soybeans in the world and the United States, except for the 2005/06 marketing year, has been the leading exporter. As of 2003, 81 percent of soybeans planted in the United States were of herbicide-tolerant , biotech trait, and that adoption rate reached 89 percent in 2006. During the marketing years of 2002/03 to 2006/07, exports averaged about 36 percent of total U.S. soybean use, or 27.8 million metric tons (mmt) per year. China's share of the total U.S. exports averaged about 36 percent, or nearly 10 mmt a year, valued at over $2 billion. The growth of China's imports of soybeans from the United States has been rapid, increasing from 5.4 mmt in 2000 to 8.2 mmt in 2003, and surpassing 10 mmt a year over 2004-06.

At present, all soybeans grown in China are conventional varieties and concentrated in provinces of Heilongjiang, Jilin, Shandong, Hebei, Inner Mongolia, Henan, and Sichuan (fig. 1). Herbicide-tolerant, biotech soybeans are not grown in China because the government has not granted approval for domestic production of the biotech crop. However, if the government chooses to commercialize this biotech crop, how would the (hypothetical) domestic release affect U.S. soybean exports to China and the competitiveness of U.S. soybeans in the world market?

On January 5, 2002, China's Ministry of Agriculture issued three ministerial decrees that set forth guidelines for biosafety regulation in China, which were scheduled to have taken

Fig. 1. Map of China


effect on March 20, 2002. The requirement of safety certificate for imported biotech products might have caused the delay in soybean imports from the United States initially during April-June of 2002, but had virtually no impact on subsequent imports (Marchant and Song). Decree No. Eight, which addresses measures for safety evaluation and administration of biotech products, has the potential to affect commercialization of biotech soybeans in China. The permit system calls for field trials at various stages, including the initial experimental research, small-scale field trials under controlled environment, medium-scale experiments under natural environments, and large-scale experiments prior to commercialization (Chinese Ministry of Agriculture).

Implementation of China's biotech regulations and biotechnology developments could impact international soybean markets in the world market. Soybeans and other crops, such as biotech rice, are in China's agrobiotech development pipeline. China's commercialization of biotech soybeans with a trait of herbicide tolerance could increase China's soybean production through a potential increase in yields and/or savings in weed control costs (Marchant and Tuan). This expanded production could lead to partial displacement of U.S. exports to China and negatively impact U.S. competitive position in the world market.

On the other hand, research indicates that about 20 percent of consumers in urban cities are not willing to accept soybean products, such as soybean oil made from soybeans imported from the United States and South America (Lin *et al*.). Commercialization of biotech soybeans would reduce acreage of non-biotech soybeans (the only soybean type grown in China today) due to limited arable cropland. Growing population and expanding demand for non-biotech soybean products could create new market opportunities for non-biotech soybean exports from the United States and other countries to China. However, viability of this non-biotech market calls for segregating non-biotech from biotech soybean market segments throughout the supply chain and consumer willingness to pay can more than cover the costs of segregation. In addition, the impacts that the commercialization of biotech soybeans might have on world trade critically depends on the likelihood of farmers' adoption of this biotech crop and consumer acceptance of food products made from imported biotech soybeans, such as soybean oil.

The main purpose of this study is to analyze the impacts of commercializing herbicide-tolerant, biotech soybeans in China on world soybean trade and U.S. competitiveness in the world market. The adoption of the biotech soybeans would shift the supply curve to the right, reflecting any potential yield enhancement and weed control cost savings. The adoption, however, is inversely related to the technology fee charged to adopters. Given consumer acceptance of biotech soybeans and the costs of segregation, results from the ERS China model show the impacts of the commercialization on soybean production by six regions and consumption of soybean products by consumers at the urban and rural areas for soybean oil, and the feed industry for soybean meal. Impacts of the commercialization on production, consumption, and trade in major soybean producing and trading countries will then be presented. Adoption of biotech soybeans in China may provide perverse trade effects, depending on the displacement of non-biotech soybeans by the biotech variety and consumer acceptance of soybean products made from imported biotech soybeans.

## Previous Related Studies

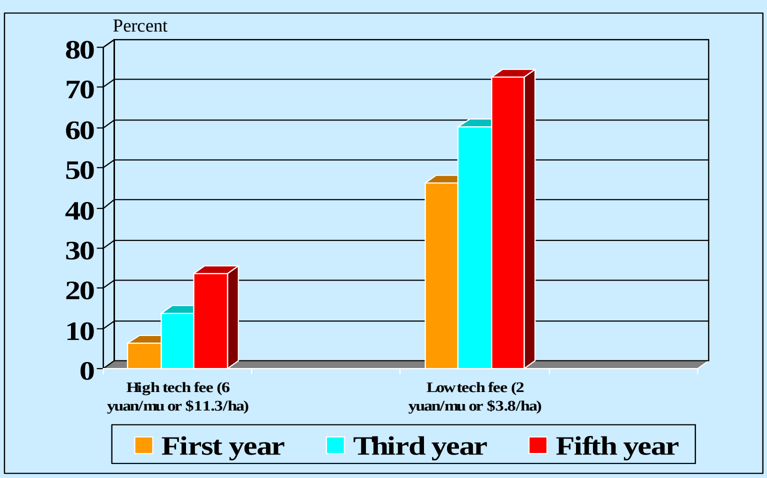
This section briefly reviews previous related studies on the adoption of herbicide-tolerant, biotech soybeans, consumer acceptance of food products made from imported biotech soybeans, and segregation of non-biotech soybeans from the biotech variety. This review focuses on studies that address the above issues in China, although it also touches upon others that address the same issues in other countries, including the United States. Key parameter assumptions on these issues have a significant impact on trade implications of commercializing biotech soybeans in China. In addition, this section also provides a brief review of a few studies that address the impact of commercializing biotech crops on trade in the world grain and oilseed markets.

**Adoption of Herbicide-Tolerant Soybeans**

A survey of soybean producers in Heilongjiang province in 2006 shows that the likelihood of adopting herbicide-tolerant, biotech soybeans is critically contingent upon the technology fee charged to the seeds for adopters. Under a high technology fee scenario (6 yuan/mu, where 15 mu=1 hectare), about 6 percent of soybean producers in the province would likely adopt biotech soybeans in the first year of commercialization, 14 percent in the third, and 24 percent in the fifth (Xu *et al*.; fig. 2). In contrast, biotech soybeans are likely adopted at much faster pace under a low technology fee scenario (2 yuan/mu)—about 46 percent in the first year, 60 percent in the third, and 73 percent in the fifth. Based on survey data, adopters tended to be positively associated with farm size (measured in soybean acreage), yield loss, expenditures of herbicides, and the

Figure 2

**Adoption rate of biotech soybeans in Heilongjiang: low and high tech fees**



proportion of off-farm income source, but negatively related to operator age. Also, producers practicing no-till tended to be more likely to adopt biotech soybeans than those using conventional tillage, although there is also a large share of producers who are uncertain about the adoption. Of course, the above relationships may not be statistically significant in regression analysis once other variables are kept constant.

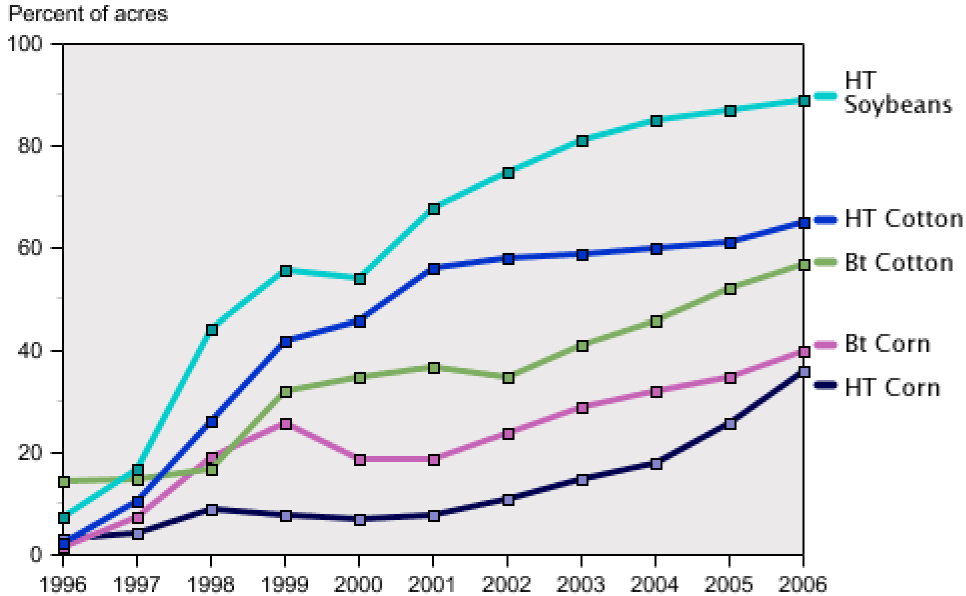
The likelihood of adopting biotech soybeans in Heilongjiang province is slower under the high technology fee scenario than actual adoption of herbicide-tolerant, biotech soybeans in the United States, but faster under the low technology fee scenario (fig. 3). In the United States, adoption of herbicide-tolerant soybeans reflected a minimal yield enhancement (about 3%) and weed control cost savings of 10%, along with the simplicity and flexibility of pest management (Price et al.). The adoption was found through a Tobit model to be positively related to operator experience and the use of marketing or production contracts, but negatively related to the location in marginal production region, risk aversion and “limited-resources” type of farm in the ERS farm typology (Fernandez-Cornejo and McBride). In addition, a simultaneous adoption model found that the use of no-till contributed to a larger adoption rate of herbicide-tolerant soybeans, but the use of herbicide-tolerant seeds is not an important factor affecting no-till practice.

**Consumer Acceptance**

Previous surveys suggested that the majority of Chinese consumers have favorable opinions about the use of biotechnology in crop production, livestock and poultry products fed with biotech feed grains, and the use of biotech ingredients in processed

Figure 3

**Adoption of genetically engineered crops grows steadily in the U.S.**




Data for each crop category include varieties with both HT and Bt (stacked) traits.
Source: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-06 are available in the ERS data product, Adoption of Genetically Engineered Crops in the U.S., tables 1-3.

Source: ERS website: Biotechnology briefing room—data products (Jorge Fernandez-Cornejo).

food production (Gale et al.; Li et al.). Based on a large-scale survey in 11 cities (including Beijing and Shanghai), a study in fall 2002 found that a majority of China's urban consumers were supportive of biotech foods (Bai). This pro-biotech group of consumers accounted for 46 to 67 percent of all respondents, depending on the kind of biotech foods. In the case of soybean oil, the acceptance rate was 53.6 percent, although nearly 30 percent of respondents were neutral and 13 percent were opposed to soybean oil made from biotech soybeans (fig. 4).

In the context of the price differential, the survey found that a majority of Chinese urban consumers—58.3-74.1 percent—were willing to purchase biotech foods if food prices were the same as non-biotech foods, depending on the kind of biotech foods. An even

Figure 4. Consumer attitudes toward biotech soybean oil in China

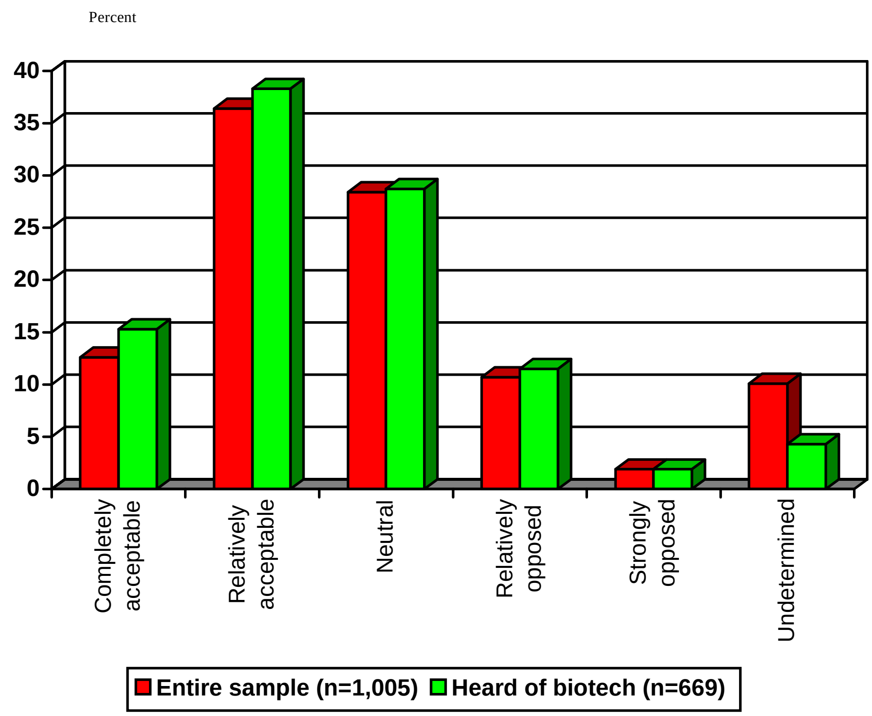
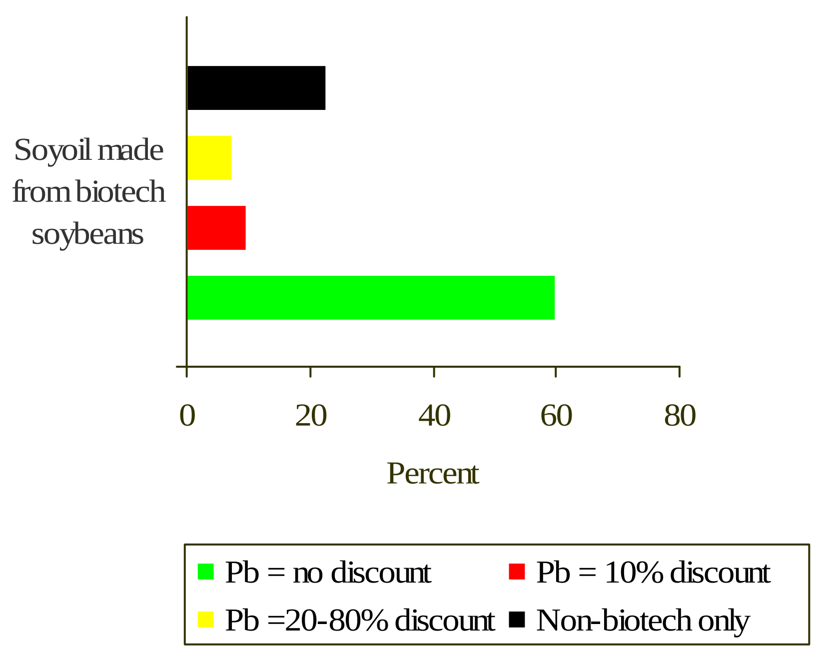



Figure 5. Price discounts needed to induce Chinese consumers to purchase biotech soybean oil



greater majority—67.0-80.9 percent—were willing to purchase biotech foods if a 10-percent price discount was offered to them. In the case of biotech soybean oil, 60 percent of respondents were willing to purchase the product if there was no price discount and the percentage increased to 69.7 percent if a 10-percent discount was offered (fig.5). However, 22.7 percent of respondents were willing to purchase only soybean oil made from non-biotech soybeans.

Results of a Probit model, based on the instrumental variable approach, show that consumer acceptance of biotech soybean oil was positively related to unemployment status, residence in the small city, awareness of biotech foods for no more than three years, and trust in the accuracy of media information, but negatively related to the choice of not consuming soybean oil in the household (Lin et al.$_a$). In addition, a study of consumers' willingness to pay for biotech foods using the contingent valuation approach suggests that price premiums that respondents were willing to pay for non-biotech foods averaged 23-53 percent for non-biotech soybean oil (Lin et al.$_b$). The lower bound WTP comes closer to the true value in light of hypothetical bias associated with the contingent valuation method.

**Segregation of Non-biotech Soybeans**

In addition to the adoption of herbicide-tolerant soybeans and consumer acceptance, segregation of non-biotech soybeans from the biotech variety and the associated costs of segregation is another key parameter that could have an important economic impact of commercializing biotech soybeans on trade in the world soybean market (Johnson, Lin and Vocke). Once herbicide-tolerant soybeans were commercialized, locally grown non-biotech soybeans can only be maintained its identity through identity preservation, which would add costs.

An examination the costs of segregation for non-biotech crops, based on a survey of U.S. grain elevators and specialty grain firms conducted by the University of Illinois (Bender et al.) indicates that, on average, segregation could add $0.18/bu (4% of the soybean farm price) to the costs of handling non-biotech soybeans from country elevators to export elevators if segregation follows the same handling process used for high oil corn (Lin). The costs of segregation include additional expenses for handling, storage, risk management, analysis and testing, marketing, as well as hidden costs—opportunity costs associated with the loss of efficiency during handling, storage, and hauling non-biotech soybeans (Maltsbarger and Kalaitzandonakes). Segregation often requires changes in infrastructure during the handling-storage-marketing process. For example, farmers often need multiple, separate farm bins to store non-biotech soybeans so that they do not commingle with biotech soybeans.

**Trade Impacts of Commercializing Biotech Crops**

The introduction of U.S. biotech crops in 1996 was found to have the potential to alter the trade flows for U.S. corn and soybeans, but its trade impact appeared to be limited. During 1995-98, U.S. corn exports declined from 60.1 mmt to 41.1 mmt. Most of the drop in U.S. corn exports from 1995 to 1998 is attributable to a fall in shipments to "other East Asian countries," including China (Ballenger, Bohman, and Gehlhar). The plunge stemmed largely from increased global supplies and weak demand when China, a net importer in 1995, became a net exporter in 1998. EU purchases in 1998/99 represent less than 1 percent of U.S. corn exports, a decline from 4 percent prior to biotech-related problems.

The same study also found that price competition and established bilateral trade ties are the main driving forces behind the changes in observed bilateral trade patterns for soybeans (Ballenger, Bohman and Gehlhar). During 1997-98, U.S. soybean exports declined from 26.1 mmt to 20.3 mmt across-the-board, which led to expanding foreign sales for other competitors and most importing countries switching some purchase to non-U.S. soybeans. The biotech issue appeared not to be the major factor in the decline of U.S. soybeans to the EU, from 9.0 mmt to 6.8 mmt, because of three reasons: 1) Roundup Ready soybeans grown in the United States are EU-approved, and 2) only a tiny fraction of soybeans imported into the EU is used for food, although some consumers did not want to consume oil produced from biotech soybeans, and 3) Brazil is quite competitive in exporting soybeans to EU.

Barkley developed a partial-equilibrium trade model of the United States, the EU, and the rest of the world (ROW) and measured the economic consequences of introducing agricultural biotechnology. Commercial adoption of biotech grain seed shifts the supply curve of the adopting nation by the amount of research-induced cost reduction attributable to the technological change. Results of the model simulation demonstrated that producer adoption of biotechnology results in an increase in the supply of corn and soybeans, price reductions and increases in domestic demand and exports. For example, in a simulation analysis where the U.S. adoption rate in 2002—32 percent for corn and 74 percent for soybeans is assumed, the introduction of agricultural biotechnology changes trade flows only slightly, and domestic consumption increases by 0.34 percent for corn and 0.36 percent for soybeans. Changes in world prices are relatively minor—a decrease of 0.63 percent for corn and 0.64 percent for soybeans.

Extending the adoption of agricultural biotechnology to all nations of the world, including the United States, the EU and ROW, would enlarge the decreases in world prices—a decline of 0.82 percent for corn and 0.85 percent for soybeans (Barkley). These price changes result in an additional increase in U.S. corn domestic demand, but exports to the EU and ROW fall, resulting from productivity enhancement in these countries. Similar results of model simulation apply to soybeans. The major economic implication of global adoption of biotechnology is that the economic impacts are roughly similar to the case of adoption in the United States alone.

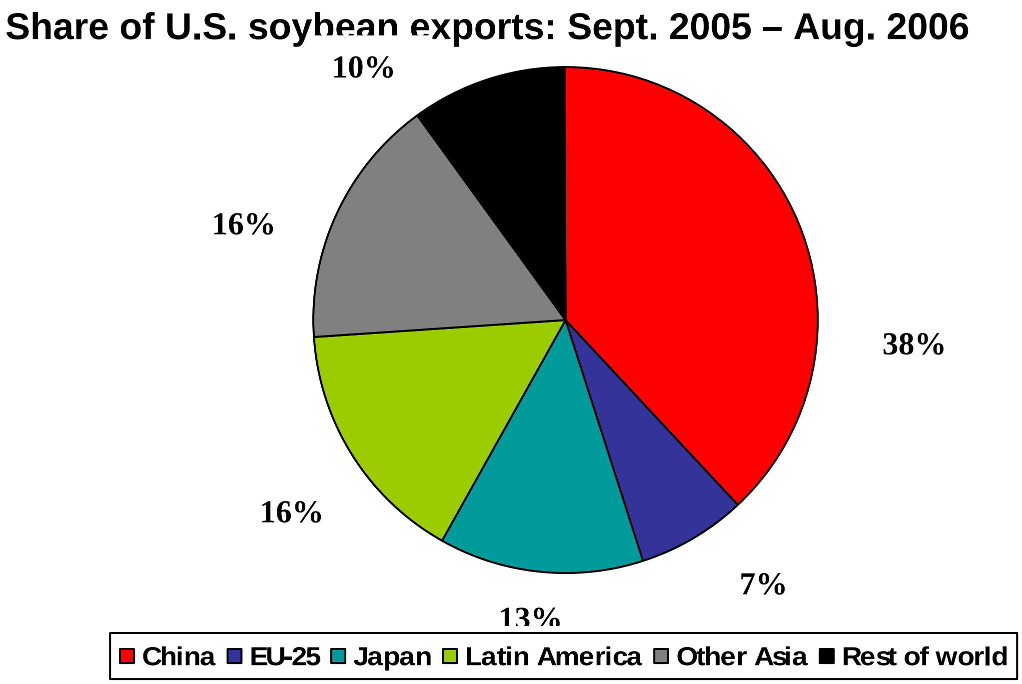
In a study of the economic and welfare impacts of commercializing a herbicide-tolerant, biotech wheat, Johnson, Lin and Vocke developed a model of the U.S. wheat sector that incorporates market segmentation, substitution in demand between different wheat classes (hard red spring vs. hard red winter), cost savings for producers of biotech wheat, and costs of segregation. Extra handling costs are assumed to apply in the non-biotech market segment, reflecting costs of segregation and identity-preservation (IP). Model results are critically dependent on the farm-level effects from the adoption of the biotech crop, consumer acceptance, and the costs of segregation and IP.

## World Soybean Trade

Soybean and soybean products dominate world trade of protein-rich oilseeds and meals. Over the last three years (2003/04-2005/06), world soybean production averaged about 207 mmt. However, more than 80 percent of the production and over 90 percent of exports come from three Western Hemisphere countries: the United States, Brazil, and Argentina. In 2005/06, soybean exports from Brazil reached 25.9 mmt, slightly surpassing the exports of 25.8 mmt from the United States. However, the United States is projected to regain its leading exporter status for 2006/07. The volume of soybean exports is projected to reach 29.4 mmt, surpassing the 26.1 mmt projected for Brazil. China also produces a significant amount of soybeans—averaging 16.4 mmt or about 8 percent of world production during these three years, but imports more soybeans than it produces—averaging 23.7 mmt. In fact, China is the most important importer of soybeans in the world market, averaging 39.1 percent of world imports over these years. During September 2005 – August 2006, China's soybean imports totaled 28.4 mmt, of which the top three suppliers were: Brazil, 11.4 mmt; the United States, 9.5 mmt; and Argentina, 7.2 mmt. Uruguay and Canada were two other suppliers, but each of them accounting for a very small amount. The EU-25 ranks second in world soybean imports, averaging 14.3 mmt or 23.7 percent of world imports over the last three years. China and the EU-25 together accounted for 63 percent of world soybean imports during this period.

In 2005/06, the United States exported nearly 26 mmt of soybeans to foreign countries, accounting for about a third of total use. China is also the largest importer of U.S. soybeans, accounting for 38 percent of total exports in September 2005- August 2006 (fig. 6). Latin America and Japan comprised 16 percent and 13 percent of total U.S. soybean exports, and “other Asia” had 16 percent share. The EU-25 recorded a 7-percent share while rest of the world posted a 10-percent share.

Figure 6




Source: USDA Foreign Agricultural Service; ERS FATUS database.

## Scenarios

The impacts of commercializing herbicide-tolerant biotech soybeans in China are analyzed under two scenarios of the adoption rate in response to the level of technology fees charged to the producers. Adoption of biotech soybeans impacts China’s production, consumption, global trade, competitiveness and world prices. The results of these changes in China’s production, consumption (including urban and rural), trade, and prices are presented and discussed. The impact on production, consumption and trade in major soybean producing and trading countries are also presented.

The two scenarios correspond to high and low technology fee assumptions. We divide cultivated area into non-biotech and biotech soybeans to model adoption scenarios. Consumers are differentiated into urban and rural. The urban consumers' preferences are differentiated by per capita consumption of biotech and non-biotech soybeans. We assumed that 20 percent of urban consumers would not consume biotech soybean products, based on our previous research studies. In contrast, rural consumers are assumed to be indifferent between biotech and non-biotech soybeans.

Scenario 1 is a high technology fee for adoption of biotech soybeans. This scenario is evaluated by increasing area harvested of biotech soybeans in crop year 2008 to 5 percent of total soybeans harvested, continues to increase to 20 percent by 2010, and then increases slowly throughout the remaining projection period, to 2015. Biotech soybeans yields are greater than non-biotech soybeans by less than 5 percent. Most of the increase in biotech soybeans area comes from non-biotech area. Price response will affect production and consumption of both biotech and non-biotech soybeans and alternative commodities throughout the projection period. Total revenue is slightly greater for biotech soybeans as it reduces production costs by 6 yuan/mu, ( mu = 1/15 of hectare). The technology fee is partially passed through as higher prices to urban consumers of non-biotech soybean oil and soybeans for direct food consumption.

Scenario 2 assumes a low technology fee which leads to more rapid adoption of biotech soybeans. This scenario is unlikely to occur because of China's government biotech policies. Harvested area for biotech soybeans under this scenario is increased to 40 percent of total soybeans harvested area in 2008, continues to increase to 70 percent by 2010, and then gradually increases throughout the remaining projection period to 2015. Again, most of the increase in biotech area will come from non-biotech area. Price response will affect production and consumption of both biotech and non-biotech soybeans and alternative commodities throughout the projection period. Total revenue is only slightly greater for biotech soybeans. The technology fee is partially passed through as higher prices to urban consumers of non-biotech soybean oil and soybeans for direct food consumption.

## Model and Data

The study uses the Country-Commodity Linked System (CCLS), the USDA-ERS China model and the ERS Food and Agricultural Policy Simulator (FAPSIM) model of U.S. agriculture. This modeling system contains 42 countries and regional models. The country models account for policies and institutional behavior such as tariffs, government subsidies, and trade restrictions. A rest-of-world model handles any missing country-commodity coverage. In general, production, consumption, imports, and exports in the models depend on world prices, which are solved within the modeling system. Domestic and trade policies are determined within the modeling system and are exogenous, depending upon individual country policies. Macroeconomic assumptions and projections are exogenous.

This modeling system also incorporates USDA's country and commodity analysts' expertise from different agencies. The system reaches simultaneous equilibrium in prices and quantities for 24 world commodity markets for each of the 8 projected years in the analysis. The 24 commodity markets include coarse grains (corn, sorghum, barley, and other coarse grains), food grains (wheat and rice), oilseeds (soybeans, rapeseed, sunflower seed, and other oilseeds and their corresponding meals and oils), other crops (cotton and sugar), and animal products (beef and veal, pork, poultry and eggs). The primary data sources are USDA's PS&D (USDA, November 2006). The US model uses data collected by the National Agricultural Statistical Service (NASS). Additional data for individual country models come from individual country data sources and from the United Nations Food and Agricultural Organization.

The USDA-ERS China model is used to address the impacts of commercializing biotech soybeans in China. The China model used in this analysis incorporates behavior of state trading enterprises (STE's) and WTO commitments (such as tariff-rate quotas) into import and export equations for the relevant commodities. The model is solved at the national level for this analysis. The models production can be solved at the national level or by six different regions. The biotech scenarios are conducted at the national level because most soybean production are the north and northeast regions and closely represents the national model. World price signals enter the domestic market through import and export equations. China's domestic prices adjust until supply and demand are in equilibrium in all commodity markets.

**China Soybean Model – Overview**

The soybean sector of the China model has three major components: 1) soybean production, consumption, and trade; 2) soybean meal and; 3) soybean oil. Production of soybeans is an identity, calculated as area harvested times soybean yield. Area harvested and yield are determined by expected returns from soybeans and its substitute crops. Research expenditures to increase soybean yield growth are expressed as a time trend. Soybean food demand is modeled as rural and urban per capita consumption equation. The per capita consumption equation is a function of own soybean consumer price, other foods, and income. Soybean crush demand is a function of soybean meal and oil demand and consumer prices of soybeans, meal and oil. Soybean feed demand is a function of total protein feed demand and soybean producer price. Soybean import demand is a function of soybean world price and domestic consumer price. The soybean ending stocks are a function of soybean consumer prices. Producer or farm prices are solved to close the model for equilibrium in supply and demand. China's soybean production, consumption, and domestic prices are affected by the soybean international price through the soybean import demand function.

Soybean meal and soybean oil are determined by supply of soybeans used for crushing times their respective crushing yields. Soybean meal feed demand is a function of derived feed demand based on quantity of pork and poultry produced in the commercial and specialized livestock sectors. Soybean meal import and export demand are a function of consumer prices and import and export prices respectively. Consumer prices are solved to close the model for equilibrium in supply and demand for the soybean meal sector. Soybean oil demand is modeled as urban and rural per capita consumption equations. Per capita consumption equations are a function of own consumer price, other foods, and income. Consumer soybean oil prices are solved to close the model for equilibrium in supply and demand for the soybean oil sector.

**Modeling China's Soybean Biotech Adoption**

To model China's adoption of biotech soybeans additional supply, consumption and prices are developed for biotech and non-biotech soybeans. Production, area harvested and yield equations are modeled separately for both biotech and non-biotech soybeans. The likely adoption rate of biotech soybeans is determined *a priori* and incorporated into biotech and non-biotech area harvested equations through dummy shift variables. Adoption of biotech soybeans shifts out the supply of biotech soybeans through the area harvested equation. The non-biotech soybean area harvested is shifted inward, which reduces the supply of non-biotech soybean. It is assumed that biotech soybean producers are more price responsive and adopt new technology. The supply response for biotech and non-biotech soybean producers are 0.33 and 0.25 respectively. China has limited area, so initial increased production of biotech soybeans is by substitution away from non-biotech area to biotech. Area harvest and consumption adjusts as new commodity price equilibrium is solved for in the model. Yields for biotech soybeans are modeled about four to five percent greater than non-biotech soybeans throughout the projection period.

Demand is specified as two distinct market segments, biotech and non-biotech for soybean oil consumption by urban consumers.  All soybean food demand remains non-biotech soybeans.  A per capita consumption demand equation for urban non-biotech soybean oil demand is developed to capture urban non-biotech consumers preference. Approximately 20 percent of urban consumers will only consume non-biotech soybean oil.  Non-biotech urban consumers are not very responsive to price of soybean oil.  It is assumed that all rural consumers are indifferent between biotech and non-biotech soybean oil consumption, but are very price responsive.  Own price elasticities for non-biotech urban and biotech urban and rural consumers are respectively -0.05, –0.90, and –1.25.  Income elasticities are 0.70, 0.70, and 1.0 respectively. Current data shows that urban per capita soybean oil consumption is about 50 percent greater than rural per capita consumption.  Extra handling costs (percent of the soybean farm price) in the non-biotech segment, reflect the costs of segregation and identity preservation, are passed on to consumers in higher prices.  The price premium for non-biotech soybeans is assumed to be about 10 percent, which is the price urban non-biotech soybean oil consumers pay. Trade data for non-biotech soybean was not available, which prevents us from modeling international trade and international prices of non-biotech soybean.  The trade equations for soybeans are not separated into biotech and non-biotech soybeans.  We are still able to approximate the amount of non-biotech soybeans which China needs to import under the two scenarios of biotech adoption.  Non-biotech soybean imports are equal to soybean food demand ( all non-biotech) plus the non-biotech soybeans required for urban non-biotech soybean oil consumption minus the total non-biotech soybeans produced under the scenarios.

## Results

The results from scenario 1 (high technology fee) and scenario 2 (low technology fee) are provided in the tables 1 - 3. Only scenario 1 will be discussed since this is the most likely policy if Chinese government commercializes biotech soybeans production and exhibits realistic results as modeled. Scenario 2 provides insights into the modeling system and needs for further model development, which includes the development of a non-biotech international market to solve for equilibrium prices for non-biotech global demand and supply.

### Production

Under scenario 1, producers' adoption of biotech soybeans is expressed in area harvested equation. In 2008, producers increase area harvested of biotech soybeans from zero to 458 ,000 hectare. At the end of the projection period in 2015, biotech area is 2.37 million hectare and accounts for 23.8 percent of total soybean area harvested. In 2008 non-biotech area decreases from the base by 421,000 hectare (-4.7 %) and in 2015 area by 2.18 million hectare (-21.8 %). China's total harvested soybean area does not increase in the initial year, but by 2015 total area harvested increases by 117,000 hectare (1.17 %) from the base of 9.99 million hectare.

Total area planted to soybeans changes very little throughout the projection period. The results indicate increased revenue from lower costs (6 yuan/mu) and increased yield was not sufficient to warrant major changes in types of crops planted in China's soybean producing region.  Most of the increase in biotech soybean area is from existing non-biotech soybean area.  Corn exhibited a very small change in area harvested.

China's production of biotech soybeans increases to 880,000 metric tons (5.31% share of total production), from zero in the first year of adoption.   By the end of the projection period, (2015), biotech soybean production increases to 4.99 million metric tons (25% share of total production).  Non-biotech soybean production decrease by 772,000 metric tons (-4.65 %) in year 2008.  By 2015, non-biotech production decreased by 4.37 million metric tons, (-22 %). China's total soybean production increases by 108,000 metric tons (0.65%) in 2008.  In 2015, total soybean production increased by 635,000 metric tons, (3.13%). The slight increase in production was from higher yields in planting biotech soybeans and slight area harvest expansion.

**Consumption**

Under scenario 1, China's total soybean consumption increases by 0.03 percent, or 15,000 metric tons, in 2008.   By the end of the projection period consumption increases by 0.1 percent, or 73,000 metric tons.  Soybean food consumption increases by 0.12 percent, or 10,000 metric tons in 2008.  By 2015, soybean food consumption increased by 0.45 percent, or 35,000 metric tons. China's total soybean oil consumption increases by 0.01 percent, or 1,000 metric tons in 2008.  In 2015, total soybean oil consumption increased by 0.05 percent, or 7,000 metric tons. Increased consumption results from slightly lower prices as soybean production increases.

Consumption of non-biotech and bio-tech soybean oil differs according to consumer preference and price responsiveness. Based on previous studies and review of literature the price elasticities for soybean oil are assumed at -0.05 for non-biotech consumers, -0.9 for biotech urban consumers, and –1.25 for rural consumers.

Consumption of soybean oil is affected by change in soybean oil prices, increased domestic production and the cost of segregation of biotech and non-biotech soybeans is passed on to consumers of non-biotech soybean oil. A majority of the population consumes biotech soybean oil - all rural consumers and 80 percent of urban consumers. Biotech soybean oil consumers purchase at a slightly lower price because of increased domestic production of soybeans and a slightly lower cost of production. Soybean oil prices are lower by less than a 1 percents throughout the projection period.

**Trade and Prices**

The trade effects from China's adoption of biotech soybeans are relatively small and exhibits a small impact on global markets. Table 3 presents the scenario 1 trade effects for China, United States, Brazil, EU-25 and the World.

China's adoption of biotech soybeans results in increased production, but consumption of soybean oil is almost unchanged since prices are lower for biotech soybean oil and flat for non-biotech soybean oil. China's imports decrease by 92,000 metric tons (-0.24 %) in 2008 and continue throughout the projection period, so by 2015 imports decreases by

551,000 metric tons (-1%). China's decreased import demand leads to lower international prices by about 0.4 percent.

China's decreased import demand leads to lower global trade and prices and lower exports by the major soybean exporting countries, United States and Brazil. The United States decreases exports by 30,000 metric tons (-0.11%) in 2008 and by 2015 exports decrease by 207,000 metric tons (-0.87%). Brazil decreases exports in 2008 by 26,000 metric tons (-0.07%). By 2015, Brazil exports decreases by 190,000 metric tons (-0.32%). Total world trade is decreased by 59,000 metric tons (-0.08%) in 2008 and by 417,000 metric tons (-0.42%) by 2015.

Because of slightly lower international prices some countries will increase imports. EU-25 increases imports by 2,900 metric tons (0.02%). International prices and United States average farm price are lowered by 0.11 percent in 2008, and by 0.4 percent in 2015.

The international price effect is less than one percent. The small international price response are due to two factors. The first is the relatively small decrease in import demand by China relative to total world trade, at a decrease of 92,000 metric tons relative to world trade at 77.5 million metric tons in 2008, and a decrease of 551,000 metric tons by China in 2015 with world trade at 99.5 million metric tons. The second factor is that individual country models are quite responsive to changes in global demand and supply conditions through the changing international reference prices for numerous commodities. Equilibrium among individual country producers and consumers, and global exporters and importers is quickly obtained. The international reference price decreases by 0.11 percent in 2008, from $269 per metric ton to $268.7 .  By 2015, the international reference price decreases by 0.39 percent.

**Non-biotech Trade and Consumption**

The potential import of non-biotech soybeans by China is presented in Table 2 for both low and high technological fee scenarios and discussed below.

Under the high technology fee, scenario 1, total non-biotech soybeans consumed (which includes soybeans for food and oil) exceeds China's non-biotech production by 1.1 million metric tons in 2010 and increases to 2.6 million tons by 2015, which represents about 5% of China's soybean imports. The first two years, 2008 and 2009, China produces enough non-biotech soybeans to satisfy domestic demand.

Our low technology fee under scenario 2 is unlikely to occur because of China's biotechnology policy adopted by the Chinese government.  Table 2 presents the model results for non-biotech imports which are unrealistic under scenario 2 because a global supply and demand for non-biotech soybeans is not developed in the modeling framework to solve for non-biotech equilibrium price both for international and domestic market.  Strong demand for non-biotech would lead to higher prices both at the farm and retail levels and production of non-biotech would increase and demand for non-biotech soybeans would decrease and imports would be relatively small.  Scenario 1 is more realistic since non-biotech demand is not very large.  The development of a non-biotech soybean equilibrium price would have a much smaller effect on producers, consumers and imports, both domestic and international markets under scenario 1.

Additional reasons why the strong level of import demand for non-biotech soybeans by China may not be accurate and will be addressed in future research. These factors include assumptions about the share of the urban population who prefer non-biotech soybean oil. The future share may be too large since most urban growth is from rural to urban migration. In addition, the growth rate of urban per capita consumption of soybean oil may be too strong throughout the projection period, especially as compared to rural preferences. The most critical factor for scenario 2 is that no international price transmission for non-biotech soybeans trade was developed, so importers responded to biotech soybean international prices, which are much lower than non-biotech equilibrium price. Finally, the cost of segregation and handling of non-biotech soybeans may not be large enough as modeled and passed on to non-biotech consumers, which would lead to a lower demand for non-biotech soybeans and smaller international impact.

## Conclusions

We present preliminary results from modeling the impacts of commercializing herbicide-tolerant biotech soybeans in China under two scenarios of adoption rates in response to the level of technology fees charged to the producers. Only scenario 1 is discussed since the high technology fee is the policy most likely to be adopted by the Chinese government and exhibits a more realistic results. Adoption of biotech soybeans will be relatively low given the high technology fees and only a gradual increase in production of biotech soybeans. The production of non-biotech soybeans within China will be sufficient to satisfy domestic demand for non-biotech soybeans by a relatively small percent of urban consumers with a strong preference for non-biotech soybeans and soybean oil. The international effect and prices will be quite minimal and China's import demand of soybeans will not be significantly affected.

**Table 1. Impacts of High Technology Fee on China's Soybean Production and Consumption, Scenario 1 .**

| Countries and Scenarios | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| **China** | | | | | | | | |
| Area Harvested Base (1000 ha) | 9053 | 9221 | 9324 | 9512 | 9673 | 9862 | 9967 | 9988 |
| Scenario 1: High Technology Fee Quantity | 0 | 65 | 91 | 96 | 101 | 106 | 113 | 117 |
| Percentage | 0.00 | 0.70 | 0.98 | 1.00 | 1.04 | 1.07 | 1.14 | 1.17 |
| Scenario 2: Low Technology Fee Quantity | 37 | 98 | 159 | 166 | 173 | 181 | 191 | 198 |
| Percentage | 0.40 | 1.07 | 1.70 | 1.75 | 1.79 | 1.84 | 1.92 | 1.98 |
| Area Harvested non-biotech Base (1000 ha) | 9053 | 9221 | 9324 | 9512 | 9673 | 9862 | 9967 | 9988 |
| Scenario 1: High Technology Fee Quantity | -421 | -1062 | -1721 | -1836 | -1938 | -2035 | -2115 | -2177 |
| Percentage | -4.65 | -11.52 | -18.46 | -19.3 | -20.04 | -20.64 | -21.22 | -21.79 |
| Scenario 2: Low Technology Fee Quantity | -4073 | -5374 | -6718 | -7100 | -7434 | -7758 | -8018 | -8211 |
| Percentage | -44.99 | -58.28 | -72.05 | -74.65 | -76.86 | -78.66 | -80.44 | -82.21 |
| Area Harvested biotech Base (1000 ha) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Scenario 1: High Technology Fee Quantity | 458 | 1161 | 1880 | 2002 | 2111 | 2217 | 2305 | 2375 |
| Percentage of Total Area | 5.06 | 12.59 | 20.16 | 21.05 | 21.82 | 22.48 | 23.13 | 23.78 |
| Scenario 2: Low Technology Fee Quantity | 4073 | 5439 | 6809 | 7196 | 7535 | 7864 | 8131 | 8329 |
| Percentage of Total Area | 44.99 | 58.98 | 73.03 | 75.65 | 77.90 | 79.74 | 81.58 | 83.39 |
| Production Base (1000 mt) | 16578 | 17101 | 17466 | 18082 | 18652 | 19292 | 19725 | 20000 |
| Scenario 1: High Technology Fee Quantity | 108 | 288 | 468 | 499 | 529 | 563 | 598 | 625 |
| Percentage | 0.65 | 1.68 | 2.68 | 2.76 | 2.84 | 2.92 | 3.03 | 3.13 |
| Scenario 2: Low Technology Fee Quantity | 370 | 618 | 798 | 853 | 906 | 962 | 1013 | 1053 |
| Percentage | 2.23 | 3.62 | 4.57 | 4.72 | 4.86 | 4.98 | 5.14 | 5.27 |
| Production non-biotech Base (1000 mt) | 16578 | 17101 | 17466 | 18082 | 18652 | 19292 | 19725 | 20000 |
| Scenario 1: High Technology Fee Quantity | -772 | -1972 | -3228 | -3496 | -3743 | -3988 | -4191 | -4366 |
| Percentage | -4.65 | -11.53 | -18.48 | -19.33 | -20.07 | -20.67 | -21.25 | -21.83 |
| Scenario 2: Low Technology Fee Quantity | -7460 | -9969 | -12587 | -13501 | -14339 | -15179 | -15871 | -16445 |
| Percentage | -45 | -58.29 | -72.06 | -74.66 | -76.88 | -78.68 | -80.46 | -82.22 |
| Production biotech Base (1000 mt) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Scenario 1: High Technology Fee Quantity | 880 | 2260 | 3696 | 3995 | 4272 | 4551 | 4789 | 4991 |
| Percentage of Total Production | 5.31 | 13.22 | 21.16 | 22.09 | 22.90 | 23.59 | 24.28 | 24.96 |
| Scenario 2: Low Technology Fee Quantity | 7830 | 10587 | 13385 | 14353 | 15245 | 16140 | 16884 | 17498 |
| Percentage of Total Production | 47.23 | 61.91 | 76.63 | 79.38 | 81.73 | 83.66 | 85.60 | 87.49 |
| Consumption Base (1000 mt) | 54935 | 57906 | 61134 | 64486 | 67191 | 69936 | 72451 | 74900 |
| Scenario 1: High Technology Fee Quantity | 15 | 38 | 59 | 64 | 67 | 71 | 73 | 73 |
| Percentage | 0.03 | 0.07 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Scenario 2: Low Technology Fee Quantity | 50 | 84 | 105 | 113 | 120 | 123 | 125 | 126 |
| Percentage | 0.09 | 0.15 | 0.17 | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 |
| Soybean Food Consumption Base (1000 mt) | 8187 | 8120 | 8134 | 8100 | 8086 | 8040 | 8005 | 7947 |
| Scenario 1: High Technology Fee Quantity | 10 | 23 | 34 | 34 | 34 | 35 | 35 | 35 |
| Percentage | 0.12 | 0.29 | 0.42 | 0.42 | 0.42 | 0.43 | 0.44 | 0.45 |
| Scenario 2: Low Technology Fee Quantity | 34 | 50 | 60 | 59 | 60 | 61 | 62 | 62 |
| Percentage | 0.41 | 0.62 | 0.73 | 0.73 | 0.74 | 0.76 | 0.77 | 0.78 |
| Soybean Oil Consumption Base (1000 mt) | 10036 | 10763 | 11532 | 12349 | 13123 | 13920 | 14679 | 15441 |
| Scenario 1: High Technology Fee Quantity | 1 | 2 | 4 | 5 | 6 | 7 | 7 | 7 |
| Percentage | 0.01 | 0.02 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 |
| Scenario 2: Low Technology Fee Quantity | 3 | 6 | 8 | 10 | 11 | 11 | 12 | 12 |
| Percentage | 0.03 | 0.05 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |

**Table 2. China's non-biotech Imports Under High and Low Technology Fee, Scenario's 1 and 2.**

| Countries and Scenarios | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| **Baseline** | | | | | | | | |
| Production non-biotech (1000 mt) | 16578 | 17101 | 17466 | 18082 | 18652 | 19292 | 19725 | 20000 |
| Non-biotech Soybeans for Food | 6188 | 6710 | 7182 | 7676 | 8207 | 8849 | 9543 | 10278 |
| Non-biotech Soybeans for Soybean Oil | 8187 | 8120 | 8134 | 8100 | 8086 | 8040 | 8005 | 7947 |
| Total Non-biotech Soybeans Consumed | 14375 | 14830 | 15316 | 15776 | 16293 | 16889 | 17548 | 18225 |
| Production Exceed Consumption Non-biotech | 2203 | 2271 | 2150 | 2306 | 2359 | 2403 | 2177 | 1775 |
| Total Soybean Imports | 38441 | 40895 | 43763 | 46485 | 48663 | 50806 | 52932 | 55099 |
| **Results from Scenario 1 High Tech Fee** | | | | | | | | |
| Production Non-biotech (1000 mt) | 15807 | 15129 | 14239 | 14586 | 14909 | 15305 | 15534 | 15634 |
| Non-biotech Soybeans for Food | 6188 | 6710 | 7181 | 7676 | 8206 | 8848 | 9543 | 10277 |
| Non-biotech Soybeans for Soybean Oil | 8197 | 8143 | 8168 | 8134 | 8120 | 8075 | 8041 | 7982 |
| Total Non-biotech Soybeans Consumed | 14385 | 14853 | 15349 | 15810 | 16326 | 16923 | 17584 | 18259 |
| Non-biotech Soybean Imports Required | 0 | 0 | 1110 | 1224 | 1417 | 1618 | 2050 | 2625 |
| Total Soybean Imports | 38349 | 40648 | 43357 | 46052 | 48203 | 50316 | 52409 | 54548 |
| Share Non-biotech to Total Imports % | 0.0% | 0.0% | 2.6% | 2.7% | 2.9% | 3.2% | 3.9% | 4.8% |
| **Results from Scenario 2 Low Tech Fee** | | | | | | | | |
| Production Non-biotech (1000 mt) | 9118 | 7132 | 4879 | 4581 | 4313 | 4113 | 3854 | 3555 |
| Non-biotech Soybeans for Food | 6187 | 6709 | 7181 | 7675 | 8206 | 8848 | 9542 | 10276 |
| Non-biotech Soybeans for Soybean Oil | 8221 | 8170 | 8193 | 8159 | 8146 | 8101 | 8067 | 8009 |
| Total Non-biotech Soybeans Consumed | 14408 | 14879 | 15374 | 15834 | 16352 | 16949 | 17609 | 18285 |
| Non-biotech Soybean Imports Required | 5290 | 7747 | 10495 | 11253 | 12039 | 12836 | 13755 | 14730 |
| Total Soybean Imports | 38128 | 40365 | 43074 | 45749 | 47879 | 49971 | 52046 | 54174 |
| Share Non-biotech to Total Imports % | 13.9% | 19.2% | 24.4% | 24.6% | 25.1% | 25.7% | 26.4% | 27.2% |

**Table 3. Global Trade and Price Effects from Impacts of biotech Soybean High Technology Fee, Scenario 1 .**

| Countries and Scenarios | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| **World** | | | | | | | | |
| Trade Base (1000 mt) | 77546 | 81242 | 84588 | 88161 | 90986 | 93563 | 96713 | 99586 |
| Change in Quantity (1000 mt) | -59 | -170 | -289 | -326 | -347 | -371 | -394 | -417 |
| Percentage | -0.08 | -0.21 | -0.34 | -0.37 | -0.38 | -0.40 | -0.41 | -0.42 |
| **China** | | | | | | | | |
| Import Base (1000 mt) | 38441 | 40895 | 43763 | 46485 | 48663 | 50806 | 52932 | 55099 |
| Change in Quantity (1000 mt) | -92 | -247 | -406 | -434 | -460 | -491 | -523 | -551 |
| Percentage | -0.24 | -0.60 | -0.93 | -0.93 | -0.95 | -0.97 | -0.99 | -1.00 |
| **United States** | | | | | | | | |
| Export Base (1000 mt) | 26671 | 22997 | 22997 | 23133 | 23133 | 23269 | 23541 | 23814 |
| Change in Quantity (1000 mt) | -30 | -101 | -168 | -186 | -176 | -187 | -198 | -207 |
| Percentage | -0.11 | -0.44 | -0.73 | -0.80 | -0.76 | -0.80 | -0.84 | -0.87 |
| **Brazil** | | | | | | | | |
| Export Base (1000 mt) | 37371 | 44409 | 47563 | 50545 | 53052 | 55346 | 57747 | 59737 |
| Change in Quantity (1000 mt) | -26 | -60 | -106 | -124 | -156 | -167 | -178 | -190 |
| Percentage | -0.07 | -0.14 | -0.22 | -0.24 | -0.29 | -0.30 | -0.31 | -0.32 |
| **EU-25** | | | | | | | | |
| Imports Base (1000 mt) | 13592 | 13516 | 13354 | 13236 | 13124 | 13031 | 12859 | 12630 |
| Change in Quantity (1000 mt) | 2.90 | 6.23 | 8.73 | 7.14 | 7.23 | 7.62 | 8.03 | 8.07 |
| Percentage | 0.02 | 0.05 | 0.07 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 |
| **International Reference Price** | | | | | | | | |
| Price Base (US$/metric ton) | 269 | 265 | 248 | 239 | 230 | 225 | 218 | 213 |
| Change in Quantity | -0.29 | -0.70 | -0.98 | -0.86 | -0.81 | -0.82 | -0.84 | -0.83 |
| Percentage | -0.11 | -0.26 | -0.40 | -0.36 | -0.35 | -0.36 | -0.38 | -0.39 |
| **US Average Farm Price** | | | | | | | | |
| Price Base (US$/metric ton) | 7.25 | 7.30 | 7.00 | 6.90 | 6.80 | 6.80 | 6.75 | 6.75 |
| Change in Quantity | -0.01 | -0.02 | -0.03 | -0.02 | -0.02 | -0.02 | -0.03 | -0.03 |
| Percentage | -0.11 | -0.26 | -0.40 | -0.36 | -0.35 | -0.36 | -0.38 | -0.39 |

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