THREE ESSAYS ON THE IMPACT OF INTERNATIONAL TRADE POLICY ON AGRICULTURAL INPUT MARKETS

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THREE ESSAYS ON THE IMPACT OF INTERNATIONAL TRADE POLICY ON AGRICULTURAL INPUT MARKETS

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This dissertation provides a thorough analysis of the impact of international trade policy on agricultural input markets. International agricultural trade are often affected by policies in importing and exporting countries. These policies can be directly or indirectly imposed on the production inputs. It is important to understand the markets' responses in both importing and exporting countries to the policies changes through vertical linkages between the input and output markets. This dissertation provides three essays to study this topic from the prospective of importer, exporter, input market, output market, and trade negotiation mechanism.

Essay 1 studies a European Union trade policy induced technological innovation, specifically on its impact on the U.S. apple markets. I adopt the *Ex Ante* approach to simulate the market reaction to both the European Union policy change and the technological innovation. The research finds that the policy induced technological innovation benefits the outputs that are intensive in the policy affected input. The methodology and conclusion contribute to research on markets with highly differentiated products.

Essay 2 is motivated by the decade-long cotton dispute between Brazil and the United States. The dispute was arbitrated based on several domestic policies of the

United States. This chapter analyzes the impact of a U.S. domestic policy on 1) land re-allocation with a difference-in difference model; 2) international cotton trade between the United States and the rest of world including Brazil with a partial equilibrium simulation model. Based on the analysis, I find limited policy impact of removing this particularly U.S. domestic policy on international cotton trade. The result is consistent to the World Trade Organization arbitration of the dispute.

Essay 3 summarizes three most common methods of quantifying the trade impact of non-tariff trade measures in the literature. I carefully compare the advantages and disadvantages between each method. A guidance of how to choose an appropriate method based on the characteristic of a non-tariff trade measure is summarized. To illustrate the guidance, I show a real example of apple trade with non-tariff trade measure imposed by the European Union.

BIOGRAPHICAL SKETCH

Lei Lei received her Bachelor degree in International Economics and Trade from Tianjin University of Science and Technology, China in 2007. Afterwards she pursued her M.A. degree in Economics and M.S. degree in Mathematics at Ohio University from 2007 to 2009. Lei started her Ph.D. program in the Applied Economics and Management Department at Cornell in 2009. Her current research interests are in the field of agricultural economics, international trade, and policy analysis.

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CHAPTER 1. INTRODUCTION

This dissertation contains three essays on international agricultural trade. Following three chapters correspond to these essays respectively. Chapter 2 studies a trade policy that induced technological innovation in the exporter's agricultural input market. It is about the exporters' market response to importer's policy change. Chapter 3 analyzes how a major exporter's domestic policy on agricultural input could affect international trade of the output. It is about international trade's responses to exporter's policy change. Chapter 4 summarizes and discusses methods on quantifying non-tariff measures (created by trade policy) with an example. The three chapters collectively provide a thorough analysis of the impact of international trade policy on agricultural input markets, from the prospective of the importer, exporter, input market, output market, and trade negotiators.

Chapter 2 "Effects of Trade Policy on Technological Innovation in Agricultural Markets" is motivated by a new European Union (EU) regulation change. The new regulation has lowered the residue level of a chemical that is commonly used in apple production. To continue exporting apples to the EU market, technological innovation was developed in apple production in the United States. This paper adopts the *Ex Ante* approach to stimulate potential U.S. market reaction to both the trade policy change as well as the technological innovation. The model is carefully designed to consider 1) the output substitution between different varieties of apple and 2) the vertical linkage between the input and output markets. The paper finds that the policy induced technological innovation (if effective) is beneficial, particularly to the product that is initially negatively affected by the policy change. It also has the potential to lead to product quality upgrade in the long run. The model and conclusion from this paper can be generally applied to other markets with highly differentiated products.

Chapter 3 "Has U.S. Agricultural Policy distorted International Trade? A Study on Planting Flexibility Impact on U.S. Exports" is motivated by the Brazil cotton case in the World Trade Organization (WTO) negotiation. The U.S. has lost the cotton case to Brazil due to various domestic policies of the United States, including the planting flexibility which affects land use. This paper aims to identify and quantify the impact of this U.S. land use policy on its cotton exports. I first use county-level acreage data to estimate the impact of the planting flexibility policy on land relocation between grain crop (including cotton) and fruit and vegetable crops. I found the policy did increase the land use to produce grain crop (including cotton). With the econometric estimation from the first step, I then develop a simulation model of international grain trade to analyze the "indirect" impact of the U.S. land use policy on the world cotton market. The paper finds limited policy impact on trade flow though removing the policy could still yield positive total welfare for foreign producers and consumers. The results shed light not only on a country's domestic policy making but also the WTO negotiation mechanism.

Chapter 4 "Revisiting How Nontariff Measures are Quantified: Barriers Applied to Inputs in Markets with Differentiated Products" provides a mechanism on how to quantify a NTM in academic research or policy making, with a real example for demonstration at the end. Based on characteristics of various NTMs, a thorough analysis of prevailing NTM quantifying methods with examples from previous literature is done. Suggestions of how to choose a method based on research purpose are made for creating the mechanism. To demonstrate how to follow the mechanism, I quantified the impact of the EU lowering Maximal Residue Level on international apples trade.

CHAPTER 2. EFFECTS OF TRADE POLICY ON TECHNOLOGICAL INNOVATION IN AGRICULTURAL MARKETS

2.1 Introduction

The increasing global inter-dependency between countries has induced a new set of technological innovations due to food safety issues and environmental policies in international trade (Hayami and Ruttan 1971; Cavallo and Mundlak 1982; Coeymans and Mundlak 1993; Carletto, De Janvry, and Sadoulet 1996; Macnaghten 2016). Among them, some technological innovations have specifically reformed the agricultural industry (Sunding and Zilberman 2000; Schut et al. 2016). These policy induced technological innovations are sometimes in favor of certain final commodities, which are most affected by the policy. This paper studies the impact of policy induced biased technological innovation in the U.S. agricultural industry. Following a conceptual model on biased technology in differentiated products, the paper tests the impact of the biased technological innovation using a specific example for the U.S. apple industry. Suggestions are provided to policy makers and agricultural producers.

Technological innovation has a significant impact on agricultural development (Schultz 1964; Cochrane 1979). Many technological innovations were induced by government policies and regulations (Sunding and Zilberman 2000). For example, the tomato harvester (biased towards labor input) was introduced following the end of the Bracero Program[1] in 1960s. In recent years, the food safety regulation and environmental concerns have led to more intensive research and alternatives for the widespread use of chemicals in many stages of the production process. In agricultural and food market, examples are the emergence of integrated farm management systems and various biotechnologies (Sunding and Zilberman 2000).

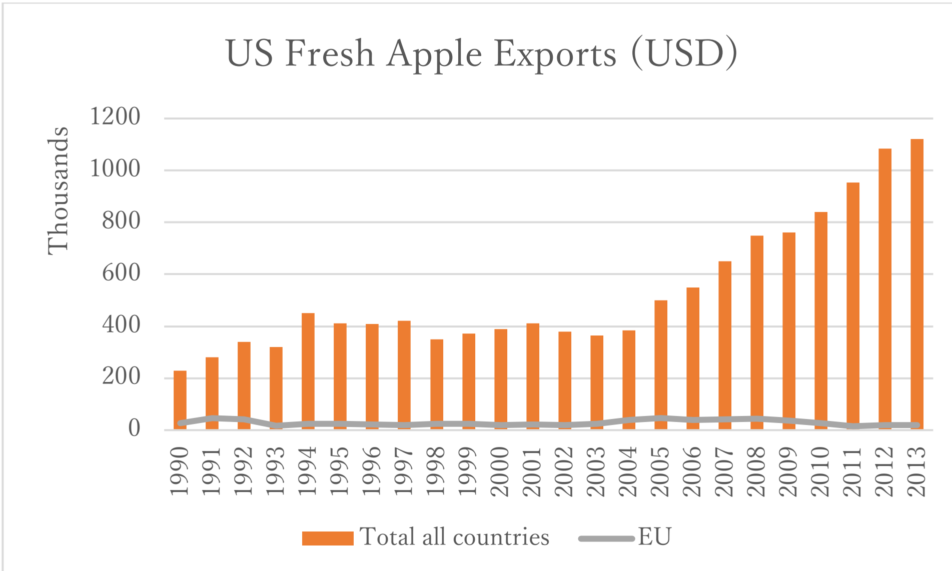
Internationally, the food safety regulation and environmental policies made by international organizations and major trade destinations also induce biased technological innovation for countries to 1) fulfill global responsibility; 2) avoid any non-tariff barriers (NTBs) or meet Sanitary and Phytosanitary (SPS) standards; 3) enjoy the favorable prices created by trade constraints. For example, because of the ozone-depleting effects, the use of methyl bromide in agricultural production was scheduled to be banned in the United States in 2005 under the Montreal Protocol. As a widely used fumigation in the agricultural sector, especially the strawberry industry, the economic impact of banning the methyl bromide can be significant and complex. Industry groups invested a lot in developing alternative fumigants. These alternatives are induced by the policy ban and biased towards the fumigant input (Carter et al. 2005; Goodhue, Fennimore and Ajwa 2005). Much research studied the market response to the policy ban and to the adoption of alternatives (Braun and Supkoff 1994; Duniway 2002; Byrd et al. 2005).

This paper provides a general framework to study such innovations focusing on how the biased technology affects differentiated products in different ways, and studies a specific example of a food safety policy that induced technological innovation to avoid SPS barriers in international trade. It focuses on analyzing the potential economic impact of the biased technology incorporating product differentiation. The implication could shed light on the development of innovative technologies, public research and development (R&D) efforts in agricultural markets, and the development of agricultural trade policies.

2.1.1 Policy Background

Because many member states in the EU have relatively high consumption of apples, the new policy will bring a significant impact on the global apple market, not only to the EU member states, but also the third countries and food business operators. The strictness of the new MRLs not only rules out the DPA treated products but also any cross-contaminated products in the process of storage, packing and shipping. In general, it will be difficult for any industry that has not operated in a DPA-free environment for the last few years to meet the new requirements (USAEC 2013). Concerns have been expressed from world major apple producers including Chile, South Africa and the United States. The new MRL set by the EU is more like a ban of DPA on apples in most cases.

The EU has been an important market for U.S. apple exports. The U.S. apple exports to the EU has maintained a steady upward trend since 1990. The share of total exports to the EU has been around 7% and it experienced a slight increase since 2004. The increasing trend has been steady (Figure 2.1). The largest import markets within the EU are the United Kingdom (UK). The UK has been one of the top six U.S. apple exporting destinations, accounting for about 69% of the total U.S. apple exports in the past three decades (USITC ITS 2010). Although there is the Brexit (still in negotiation) going on, there are other important markets in the EU for the U.S. apples, such as Finland, Netherland, Spain, Sweden, and so on.



Source: FAOSTAT

Figure 2.1. U.S. fresh apple exports

There were no SPS barriers for U.S. apples entering the EU before 2013. There could be a 50% or more decrease of the Washington apple exports to Europe with this new regulation (Karst 2013). The east coast, one of the apple major production regions, also faces challenges. Complaints have been raised from various stakeholders in the apple industry. However, although it is risky to export apples to Europe, most apple industry participants would be reluctant to give up the European market. It will depress the U.S. domestic apple market if the extra supply of apples are going to be absorbed domestically. Furthermore, exploring new export destinations could also be very expensive. In addition, the new MRL regulation of the EU has aroused attention from other countries on the use of DPA for apples. Similar discussions on reducing DPA on apples have been going on in other countries (Gillam 2014). Therefore, implementing brand new equipment, packing lines and storage rooms may be a sound investment in the long run. When a change in trade rules seems permanent, it may lead to a complete overhaul of the infrastructure, and that may enable adoption of new technology and modernization of agricultural practices (Sunding and Zilberman 2001). While increasing costs to producers, the overhaul also brings benefits. The actual effect on producer welfare can be very complex. It may differ depending on location, time, and degree of product differentiation. In this paper, I am going to study the economic impact of the EU policy change on the highly differentiated apple market of the United States with a focus on welfare measurements.

2.1.2 Producer Response to Input Ban in Agricultural Markets

Due to environmental and food safety concerns, there have been bans and other policy changes in the agricultural industry. Much research has been done to study the induced technological or non-technological alternatives to the banned substance or for becoming compliant to the new standards. Pesticide bans provide a strong incentive for the development of alternatives at the manufacturer level and for the adoption of alternative strategies including nonchemical treatment, biological control, etc. Examples include the elimination of dibromochloropropane that enhanced the adoption of drip irrigation that enabled applications of alternatives (Sunding and Zimmerman 2001). Banning methyl bromide on nursery plants induced both chemical and non-chemical innovations to replace it (Braun and Supkoff 1994; Duniway 2002; Byrd et al. 2005; Carter et al. 2005; Goodhue, Fennimore and Ajwa 2005). These papers show that because of the technology induced by policy, producers benefited and were rewarded from adopting the induced technology in the long run. However the short run investment and cost brought a welfare loss at the beginning. At the macro- level, the policy impact together with biased technology even affected agricultural trade patterns and production levels for certain regions (Lynch, Malcolm and Zilberman 2005).

In the DPA apple case, there is no perfect chemical alternative for DPA currently. The only feasible way for apple producers to meet the MRL set by the EU is through farm management. This includes expediting or postponing harvest, shorten postharvest period, enhancing sorting, packaging, transport and other stages in the postharvest stage (McPhee 1999).

With public R&D supported by the U.S. government, a recently developed biomarker technology may prove to be a solution due to its easy accessibility, cost-savings and effectiveness to solve the apple postharvest storage problems. This metabolic and genetic biomarker could predict, diagnose, and distinguish the potential development of the postharvest disorders and allow marketers to release the products before the disorders evolve too far. It ensures that high quality, and disorder-free products remain available across the supply chain. The biomarker technology is shown to be an effective alternative of DPA through various ways. It will bring a shift from treatment type apple storage to more economically feasible, sustainable, and management-based systems. In particular, the bio-marker favors the high value products - the highly susceptible apples, by enhancing the yield. To better evaluate the economics of biomarker on high value and low value commodities, the paper simulates the likely impact of biomarker use on prices and quantities of apples at the retail and farm levels, and on the welfare of producers and consumers.

2.1.3 Conceptual Model

Biased technological innovation has been playing a significant role in social development and economic growth. Labor saving, capital saving and neutral technological progresses all lead to economic growth in different ways (Ruttan and Hayami 1984; Ruttan and Hayami 1984; Lucas 1988; Helpman 1998; Card and DiNardo 2002). Previous research on biased technology focused on studying the relative factor prices, factor proportions in production, equilibrium analysis of the technology adoption and economic growth (Kennedy 1964; Romer 1990; Acemoglu 2007). These papers studied the biased technological innovation from the producer's perspective on adopting such technology to minimize cost and enhance firms' ability to maximize profit. However, most of this work focused on the biased technology impact directly on factors, rather than the impact on output being produced using the technologically innovated biased factors. In this paper, changes are developed based on the classical framework of biased-technological innovation to analyze how biased-technological innovation favors different outputs in industries with highly differentiated commodities. These commodities require different amounts of factors in production. Therefore, they are affected by the biased-technological innovation in different ways. The biased technological innovation favors certain commodities through the factors it is biased towards.

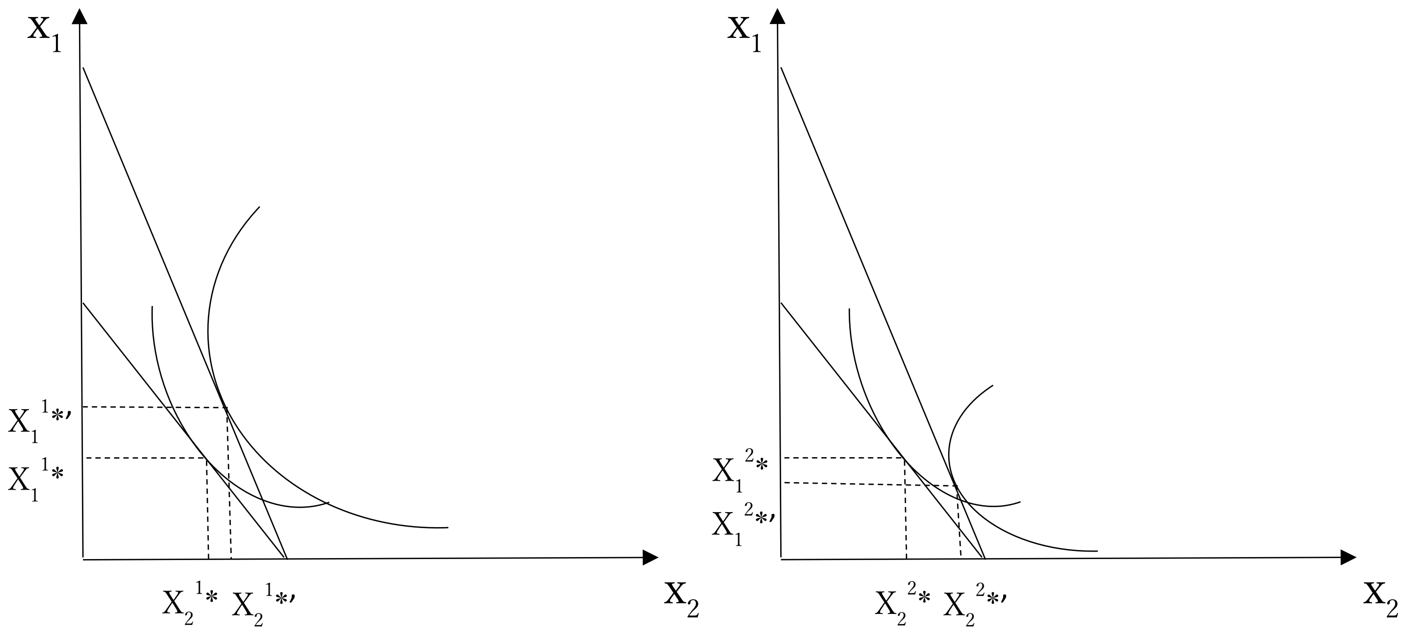
The model is set up following the basic set up of a producer profit maximization problem. Consider a producer produces two products y_1 and y_2, using two factors x_1 and x_2. Then y_1 and y_2 are two different types of products of the same commodity (imperfect substitution of each other). They are differentiated by some characteristics of the commodity. Factor ratios are fixed but different in the production of y_1 and y_2. Producing both products requires two common factors x_1 and x_2. Product y_1 is relatively more intense in factor x_1 than product y_2. In another words, producing one unit of product y_1 requires more x_1 than producing the same amount of product y_2. In our case, suppose a technological innovation biased towards factor x_1, is being adopted by the producer to use in the production of both y_1 and y_2. Consider the objective function of a profit maximizing producer that operates in a competitive goods market, facing given factor and goods prices as following:

$$\max_{x_1, x_2} \quad \pi = \pi^1 + \pi^2 = [P^1 g(x_1^1, x_2^1) - w_1 x_1^1 - w_2 x_2^1] + [P^2 g(x_1^2, x_2^2) - w_1 x_1^2 - w_2 x_2^2]$$

Where the superscript indicates output and the subscript is for input; P is the output price. Products y_1 and y_2 have different prices and they are not perfect substitutes of each other; g is the production function of the output commodities for both products. It is a real-valued function and twice continuously differentiable (first derivative with respect to x_1 is monotonic increasing evaluating at x_1). Products y_1 and y_2 are produced following the same production, but product y_1 is x_1 intensive relative to product y_2 in production. In addition, w_1 and w_2 are the prices of the two factors x_1 and x_2 respectively. The technological innovation enters the profit maximization problem by affecting the production function g.

For a biased technology that is x_1 augmenting, it favors the production of commodity y_1 which is relatively x_1 intensive in production. Adopting the technology leads to an increased cost because the factor price of x_1 increases from w_1 to w_1^t. With the new technology, the producer who only produces product y_1 will increase his/her profit π_1. This can be seen from the first order condition. With the technology, the marginal product of factor x_1 increases while the factor price of x_1 also increases to w_1^t. For the biased technology favored commodity y_1, $P^1 g_{x_1}(x_1^1*, x_2^1*) > w_1^t$. The producer could increase its profits π_1 by increasing the amount of x_1 that it uses. The marginal unit of x_1 contributes $P^1 g_{x_1}(x_1^1*, x_2^1*)$ to revenue, while it costs the producer only w_1^t. Hence, using a little bit more x_1 in production would generate more revenue than the associated cost. This is a net addition to profit. The producer will continue to do this until the first order condition holds with equality again. This process is shown in Figure 2.2a. With the biased technology, the initial equilibrium point for profit maximization (x_1^1*, x_2^1*) moves to (x_1^1*', x_2^1*') as the new tangent point of the new iso-cost and iso-quant line. The slope of the iso-cost line changed due to increased factor price of w_1^t. The new iso-quant line which is not parallel to the original one is because of the x_1 augmenting technology which means the marginal product of x_1 increases faster than the marginal product of x_2. In the new equilibrium, the producer increases its use of x_1 and produce more y_1 for higher profit.

On the other hand, with the technology biased towards factor x_1, the producer who only produces y_2 will gain less or even experience a drop in profit π_2. This is because as the quality and productivity of product y_1 improves with the new technology, its price will increase and the price of product y_2 will decrease assuming there are only two products for the same commodity. Meanwhile, given the property of the production function $g_{x_1}(x_1^2*, x_2^2*) < g_{x_1}(x_1^1*, x_2^1*)$, and depending on the value of w_1^t, it is possible that product y_2 has the first order condition as $P^2 g_{x_1}(x_1^2*, x_2^2*) < w_1^t$. That is the value of marginal product of x_1 is less than its market price. The producer profit π_2 decreases because the addition to revenue of one more unit of x_1 is less than the marginal cost of using one more unit of x_1. This process is shown in Figure 2.2b. With the biased technology, the initial equilibrium point for profit maximization (x_1^2*, x_2^2*) moves to (x_1^2*', x_2^2*') as the new tangent point of the new iso-cost and iso-quant line. The producer keeps producing to reach the new profit maximization where the use of x_1 is actually reduced. Even if this profit π_2 decreasing case is not happening initially, it will later. Because product y_1 is making increasing profits, more resources will move to produce y_1 from y_2. Gradually the producer who only produces y_2 will have a reduction in profit.



a b

Figure 2.2. Profit maximization of products y_1 and y_2

It is better for producers to include both products into their production to balance the risks brought from the technology adoption. Whether producers who produce both products will benefit from the biased technological innovation depends on the share of y_1 and y_2 in their production set. Based on above conceptual model, the paper proposes the following hypothesis:

> H_0: technological innovation biases towards a certain factor favors the product in which the factor is intensive. Meanwhile it could lower the production of the product which is less intensive in the biased factor.

The paper will test this hypothesis using a simulation analysis in the following section. To avoid potential profit loss brought by the adoption of the new technology, producers could diversify their production bundle, producing both commodities to balance the increase and decrease of profits.

A simulation model is developed to test the hypothesis using data describing the U.S. apple industry. There are two factors in apple production: marketing and farm. Storage input is counted as a part of the farm factor. So the technological innovation, the biomarker, is biased to the marketing factor in apple production. As a highly differentiated commodity, I differentiate apples by their susceptibility to post-harvest disorders. Those highly susceptible apples are usually high-valued ones with higher market prices. The non-susceptible apples are relatively less-valued (Washington Grower House 2012). Therefore, in the apple industry, the biomarker favors the high-valued apples. It will increase high-valued apple producers' profits and welfare; while the bio-marker will have smaller impact for less-valued apples and their producers. To avoid the loss of adopting the biomarker, apple producers could consider to produce both high-valued and less-valued apples. This paper develops an equilibrium displacement model of the apple industry to simulate the impact of the biased technology impact on different stakeholders of the industry, and in particular the producers of different apple varieties.

2.2 Modeling the Apple Industry

Since the biomarker technology is still in the testing stage, an Ex Ante approach is adopted following the frameworks typically used by agricultural economists to analyze new technologies. Because of the highly differentiated characteristics across products in the apple market, the paper explicitly takes into account the 1) interrelationships between input usage in different output markets; 2) interrelationships between categories of apples defined according to variety and grade; 3) interrelationships between domestic demand and export demand of apples; 4) exogenous policy shifts in the input markets, technology adoption that causes shifts in input markets and the long-run consumer demand shift in the output market.

To better study the impact of the policy induced technological innovation that are biased to certain policy treated factor or commodities in the agricultural sector, special attention is required to the degree of product differentiation in agriculture. "Over the years, product differentiation in agriculture has increased along with an increase in the importance of factors beyond the farm gate and within specialized agribusiness" (Sunding and Zilberman 2000). This evolution is affecting the nature and analysis of agricultural research. When a policy induced biased technology enters the economy, it is important to study how the vertical market structure of agriculture and how farm-level innovation may contribute to changes in both the downstream and upstream sectors (Alston, Sexton and Zhang 1997; Hamilton and Sunding 1998).

The model is based on previous simulation studies that evaluate the impact of biotechnologies adopted in agricultural markets (Binswanger 1974; Heuth and Just 1987; Lemieux and Wohlgenant 1989) and extended to incorporate biased technological impact in a multi-input and multi-output model. Here exogenous shocks are imposed considering the vertical linkage of the multi-input and multi-output markets. The linear elasticity model has good compatibility with parameter values selected through econometric or programming approaches. In addition to the major empirical contribution in policy making and technological innovation in the agricultural industry, the analysis of the paper could be generally applied to other markets with highly differentiated products.

As a popular commodity that is consumed widely, there are about twenty major varieties of apples planted in the United States. There are many stakeholders in the commercial apple industry, from apple orchard through storage carrier, packing facilitator, wholesale, and retailer to international market. This model simplifies the apple market as shown in Figure 2.3. Since the focus of this paper is to study the EU-U.S. apple trade subject to the EU SPS regulation, in the output market, representative varieties of apples are selected as: 1) varieties exported to the EU market (Empire, Gala, Honey Crisp and Granny Smith); 2) varieties that suffer most from postharvest disorders (Honey Crisp, Granny Smith, and Empire). So among the four varieties of apple exported from the United States to the EU, three of them are the highly susceptible ones: Empire (browning, external CO_2 injury), Honey Crisp (soft scald) and Granny Smith (superficial scald). The non-susceptible variety is Gala. The

Empire, Honey Crisp and Granny Smith apples are higher value apples sold at higher prices in the market while the Gala apple is relatively less expensive. Therefore, the former group is considered as high value (H) type and the latter as the low value (L) type.

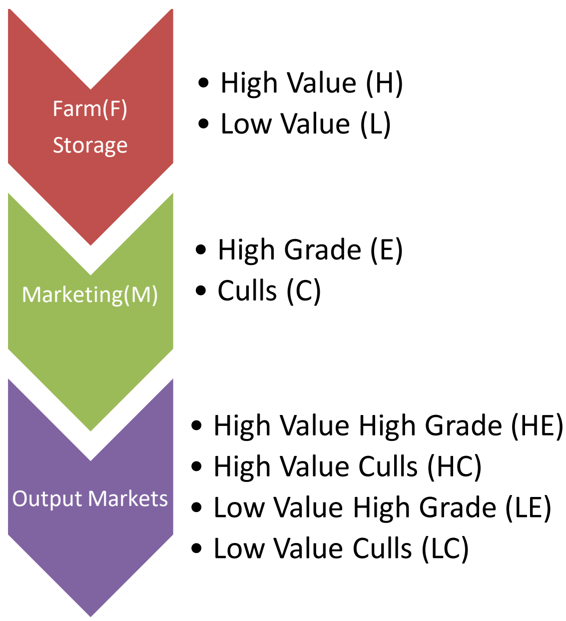


Figure 2.3. Apple market structure

In addition to variety classification, apples sold in the market are always categorized based on grade. Apple grades classify apples according to size, shape, color and overall quality. Higher grade (E) apples are sold as fresh fruit while the culls (C) are mainly being processed to make juice, jam and apple sauce. Combining the two classifications, the paper in total studies four types of apple output: higher value high grade (HE), higher value culls (HC), lower value low grade (LE), and lower value culls (LC). The high value and low value classification of apples could directly capture the biased impact of the biomarker which biases towards storage as an input. Further grade classification aims to explicitly study the policy and induced technology impacts. Higher grade apples are exported and directly being affected by the EU SPS regulation while the culls (C) apple are not much affected by the policy. In addition, the induced biased technological innovation – biomarker could “upgrade” culls to higher quality (E) apples. The detailed classification of apples is used to capture product-level details and substitution effects in the apple market.

The model includes two inputs: the farm input and the marketing input. Storage of apple is counted as a major component of the farm input. So apple varieties determine the farm input required. So, there are farm inputs used for higher value apples (FH) and farm input used for lower value apples (FL); apple grades determines how much marketing input needed. There are marketing inputs used for higher grade apple (ME) and marketing inputs for culls (MC). In general, higher grade apples require less marketing input than culls (Stewart et al. 2011). With the fixed factor proportion assumption, for a given grade the higher value apples use more farm input (which includes storage) per unit than lower value apples: FH>FL; for a given variety, higher grade apples use less marketing input than culls: ME<MC.

Overall the simulation model is developed and used to assess the impact of exogenous policy shocks and technological innovation shocks in the highly differentiated U.S. apple market in an open economy. A set of basic equations is used to describe demand, export demand, supply and the corresponding factor markets. This equilibrium displacement model includes markets for four outputs and two factors. It is a simplification of the U.S. apple market, but it does capture the critical characteristics found in the industry and provide a useful framework to examine the impact of policy change and biased technological innovation. The model is displayed as following:

(1) $QD^i = f^i(P, A^i)$

(2) $QX^i = g^i(P, AX^i)$

(3) $QS^i = QD^i + QX^i$

(4) $P^i = MC^i(W)$

(5) $XD_l = \sum_{i=1}^{N} \frac{\partial c^i(W_l, 1)}{\partial W_l} QS^i$

(6) $XS_l = h_l(W_l, B_l)$

(7) $XD_l = XS_l$

Apple output is denoted by superscript *i*. Input is denoted by subscript *l*. In the output retail/wholesale market, Variable QD is the domestic apple demand and there is an exogenous demand shift A in the output market. Variable QX is the apple exported abroad (international/ specific country apple demand) subject to an exogenous shift AX. Variable P is the apple price vector which assumes domestic price equals the world price. Variable QS is the apple supply. As for the two input markets, XS represents the input supply and XD is the derived input demand (output constant input demand function). The factor prices of farm input and marketing input are denoted by W . The adoption of new technology biomarker will bring exogenous shift on the input supply represented by B . In equation (4) and (5), MC is the marginal cost function and $c^i(W_l, 1)$ denotes the unit cost function.

Equation (1) and (2) are the domestic demand and export demand of output apple *i*. Equation (3) shows the apple output market clearing condition. Apple *i* retail/wholesale price equals marginal cost of producing it, equation (4) shows the competitive equilibrium, the price linkage between output and input market. Equation (5) is the derived demand function of input *l*. The summation of XD_l^i across all the varieties of apples, generates the total demand of input *l* which indicates the input market equilibrium. Equation (6) is the supply of input *l*. The last equation (7) is the input market clearing condition.

For simulation, total differentiating the above model yields following equations (1') to equation (7'). Equilibrium adjustments can be simulated by exogenously specifying changes in the shift parameters. In the following equations, for any variable V, notation E(V) represents $\frac{dV}{V}$ where *d* is the total differential.

$$(1') \qquad \mathrm{EQD}^i = \sum_{j=1}^{N} \eta^{ij}\mathrm{EP}^j + \alpha^i$$

$$(2') \qquad \mathrm{EQX}^i = \sum_{j=1}^{N} \eta x^{ij}\mathrm{EP}^j + \alpha x^i$$

$$(3') \qquad \mathrm{EQ}S^i = S^i\mathrm{EQD}^i + (1 - S^i)\mathrm{EQX}^i$$

$$(4') \qquad \mathrm{EP}^i = \sum_{l=1}^{M} \gamma_l^i \mathrm{EW}_l$$

$$(5') \qquad \mathrm{EXD}_l = \sum_{i=1}^{N} \lambda_l^i \sum_{k=1}^{M} (\gamma_k^i \sigma_{lk}^i \mathrm{EW}_k + \mathrm{EQS}^i)$$

$$(6') \qquad \mathrm{EXS}_l = \varepsilon_l \mathrm{EW}_l + \beta_l$$

$$(7') \qquad \mathrm{EXD}_l = \mathrm{EXS}_l$$

The notation for the shares and elasticities parameter values used in the simulation are reported in Table 2.1. Detailed definition of the parameters in the model is provided in the following section.

Table 2.1. Parameter Specifications

Symbol	Definitions	Formula	Source
η^{ij}	Apple i domestic elasticity of demand with respect to the price of apple j	$\eta^{ij} = \frac{\partial QD^i}{\partial P^j} \cdot \frac{P^j}{QD^i}$	Armington Specification with random drawn key parameters from prior distribution
ηx^{ij}	Apple i export elasticity of demand with respect to the price of apple j	$\eta x^{ij} = \frac{\partial QX^i}{\partial P^j} \cdot \frac{P^j}{QX^i}$	Armington Specification with random drawn key parameters from prior distribution
S^i	Domestic consumption share of US apple production	-	Calculated with industry data
γ_l^i	Cost share of input l in the production of apple i	$\gamma_l^i = \frac{W_l X_l}{P^i Q^i}$	Calculated with industry data
λ_l^i	Industry share of input l used in the production of apple i	$\lambda_l^i = \frac{X_l^i}{X_l}$	Literature and industry estimation
σ_{lk}^i	Allen elasticity of substitution between input land k	$\sigma_{lk}^i = \frac{d\ln(l/k)}{d\ln MRTS_{kl}}$[1]	Assumption
ε_l	Supply elasticity of input l	$\varepsilon_l = \frac{\partial h_l(W_l, B_l)}{\partial W_l} \cdot \frac{W_l}{X_l}$	Random draw based on prior distribution
α^i	Percentage change in consumer demand for apple i from adoption of bio-marker	$\alpha^i = \frac{\partial QD^i}{\partial A^i} \frac{A^i}{QD^i} EA^i$	Calculated based on industry information
β_l	Percentage change in costs due to adoption of bio-marker	$\beta_l = \frac{\partial h_l}{\partial B_l} \frac{B_l}{X_l} EB_l$	Calculated based on industry information

[1]$MRTS_{kl}$ is the marginal rate of technical substitution which equals the ratio between marginal product of input k and input l

2.2.1 Data and Parameters

Apple data from industry Washington Grower Clearing house, 2011-2012[3] are used in the model simulation[4]. All prices are weighted average monthly price at the “Free On Board” shipping point, based on price information received from the Washington apple growers and marketing firms in the area, taking consideration of sales price adjustment. A calculation is made to get the annual price, and a similar calculation is applied for the apple quantities in the two seasons. All the quantities are measured in "Cargo" which contains one thousand 40lb cartons. As mentioned before, three varieties, Empire, Honey Crisp and Granny Smith are selected for the high value (H) apples. The price and quantity data of the high value apples are calculated and weighted by the market share of each variety. For apple grade, Extra Fancy and Fancy (including U.S. Number 1) apple are the higher grade (E). There are no data of culls (C) available directly. Therefore, I use an average packout rate[5] of 85% from the industry to calculate the culls quantity based on the data of higher grade apples. Table 2.2 shows the data used in the model. It lists the quantity and price data of the four outputs and two inputs used in each output production.

Table 2.2. Apple and Factor Prices and Quantities

Apple	Quantity	Price
	1000 CTNS	$/CTNS
High Value High Grade (HE)	412.08	35.14
High Value Culls (HC)	61.81	0.16
Low Value High Grade (LE)	1556.75	18.07
Low Value Culls (LC)	242.78	0.16
Marketing		
High Grade (ME)	1968.83	21.28
Culls (MC)	304.60	0.128
Farm		
High Value (FH)	1799.53	3.51
Low Value (FL)	473.89	1.81

Note: 1 CNTS (box)=40lb; 1 Car=1,000 CNTS

Source: Author's calculation based on Washington Grower Clearing house

With the apple price and quantity data at the retail/wholesale market level, the input price and quantity data are calculated based on the fixed factor proportion assumption. Summing apple outputs by varieties is done to distribute the total farm inputs, which only varies by varieties. Similarly, summing apple outputs by grade is done to distribute the marketing input, which only varies by grade. Based on the model setting up, the key parameters in evaluating the economic impact of the biomarker are 1) elasticities of supply, demand, and export demand 2) cost and industry share 3) shock from the policy on the output demand side and shock from adopting the new technology on the factor supply side.

For parameters in (1), I first obtained baseline values of these parameters from the relevant literature. Then following Davis and Espinoza (1998, 2000), Griffiths and Zhao (2000), Zhao et al. (2000), and Rickard and Lei (2011), I apply prior distributions to these parameters for a sensitivity analysis. I set the baseline parameter as the central tendency and specify a variance of 0.04 to develop beta (3,3) distributions (Brester, Marsh and Atwood 2004). The beta distribution is ideal for generating elasticity parameters due to its unique property such as continuous, symmetrical when parameters are equal, and is equivalent to uniform distribution when parameters equal to 1. It is often used to model events that are constrained to take place within an interval defined by a minimum and maximum value. The beta distribution selected here constrains demand elasticities to be negative and supply elasticity to be positive. Iterated by 1,000 times, random values are drawn for the parameters to generate empirical distribution results.

Following previous estimates on the supply elasticity from the literature (Nerlove and Addison 1958; Gardner 1979), I set the baseline supply elasticity parameter for apples to equal to 0.5, expecting the supply of fruit is relatively inelastic. Since the apples are perennial crops, all cross-price elasticities of supply are set to equal to zero (Rickard and Lei 2011).

The domestic matrices of own- and cross-price elasticities of apple demand η^{ii} and η^{ij} are calculated following the Armington specification (Armington 1969).

(8) $\eta^{ii} = \varsigma^{i}\eta - (1 - \varsigma^{i})\sigma$

(9) $\eta^{ij} = \varsigma^{j}(\eta + \sigma)$

The Armington specification is typically used for calculating the elasticity of differentiated commodities. It extends the homogeneous goods model to examine the demand response for differentiated goods (Rickard and Lei 2011). Here it is used to define the matrix of own- and cross-price elasticities of demand of apples differentiated by both varieties and grades. In equation (8) and (9), the overall demand elasticity η and the elasticity of substitution across the four different apple types σ are set equal to baseline values from the literature. The baseline value of the overall demand elasticity η is based on the demand elasticity of the top eight apple varieties[6] estimated by Richard and Patterson (2000). I have averaged them weighted by market share of these varieties of apple. The value is is -0.762. The baseline value of the substitution across apples σ is set to equal to 1 following a range estimates used in the agricultural economic literature (Alston, Gray and Sumner 1994; Rickard and Lei 2011) studying the substitution between fruit products has not been directly estimated and is not available in the literature. Simulation results are relatively independent to the baseline elasticity of substitution and I find that the results are robust across a range of plausible values.

Several studies (Alston, Gray and Sumner 1994) discussed the limitation of the Armington specification. However based on specific differentiation of apples in the paper and the data availability, the Armington specification is an appropriate method to generate the matrices of elasticities here. As for the export demand elasticity, the same method is applied. The only difference is the overall demand elasticity in the export case is set to -1.5, more elastic than the domestic estimation case based on estimates by the U.S. International Trade Commission (2010). On average (between 2004 and 2008), about 8% to 16% of U.S. apple production was exported. Simulation results are robust to the value chosen for the demand elasticity within the range of -1.0 to -2.5.

Parameters in (2) are shares calculated on quantity data and using some assumptions. The share of consumption S is from USITC apple export studies (2010), using data in Table 2.2 and following assumptions and common knowledge supplied by stakeholders in the apple industry (Washington Grower House 2012; Reed, Elitzak and Wohlgenant 2002). The cost share of input γ_l^i is calculated following the “20% and 80%” rule (Stewart et al. 2011) for each dollar invested in apple production, 80 cents are used for marketing and 20 cents are used for farm production. For the industry share λ_l^i, I assume that the higher grade of apple usually needs less marketing than lower ones. Higher grade apples require a smaller share for marketing but more the farm share, 0.65:0.35. The culls are 0.85:0.15. The Allen elasticity of substitution σ_{lk}^i is assumed to be 0 across different inputs based on the fixed factor proportion assumption and 1 as for the same input (Sumner, Lee and Hallstrom 1999; Rickard and Lei 2011).

Parameters in (3) represent the exogenous shocks. The parameter α^i describes the

EU SPS regulation change and is used to introduce the effect of the policy shock in the simulation model. Given that the new SPS regulation was just implemented on March 2nd 2014, no accurate data is available to estimate this parameter. About 23% of the U.S. apple exports go to the European market (USITC 2010). With the new SPS regulation, the two major apple growing and exporting states in the United States, Washington State and New York State, have exports that are expected to drop largely. About 8% to16% of U.S. apple production is exported between 2004 and 2008 (USITC 2010); taking the maximum at 16%, there will be about 5% drop in apple demand by calculation. Because the higher value apples are susceptible to postharvest disorders and higher grade apples are being exported to the EU, the high value and high grade apple will be the most affected by the policy shock, I assume that the same shock will also affect the export demand for U.S. apples.

The parameter β^i which describes technological change as an exogenous variable is used to introduce shocks brought by the biased technological innovation in the simulation model. The biomarker increases marginal product of the farm input. On the other hand, there is a cost for apple producers to buy the biomarker. So the difference between them will be the net shock applied to the farm input. Due to limited data availability and complexity of the impact, assumptions and some approximations are made in the calculation. The main benefit of biomarker could bring to apple production is that: using biomarker could "upgrade" low grade apple to high grade, i.e. from culls to high value apples. Given the packout is 85%, assuming 50% of culls can be upgraded into high grade apples after applying the biomarker in postharvest stage[7]. The new pack out will become 92.5%. There is a 7.5% improvement in packout as a benefit with adoption of the biomarker. On the cost side, the biomarker hasn't been priced yet. Data are required to understand consumer's willingness to pay in order to determine the price. For now, based on information provided by the biomarker developer, the production cost is quite low. I assume adopting the biomarker will only increase the farm input cost by 2.5%. Therefore, the net benefit brought by adopting the technological innovation, is 5% to the farm input used for the higher value apples.

2.2.2 Measuring Welfare

Simulated changes are reported for prices and quantities from the EU policy change. Changes in the welfare accruing to consumers and producers are measured using information about initial product prices and quantities, and the simulated changes in product prices and quantities. To get a mean prediction of the changes in surplus measures, 1,000 iterations are repeated in the simulation model. Each iteration draws values for elasticity parameters from empirical distributions that rely on estimates in the literature while the initial prices and quantities remain the same across all the iterations. Because the welfare calculated is based on a range of elasticities with fixed prices and quantities, the welfare results are also generated as distributions. Studying the welfare results provides a better understanding of the impact of the technological change.

The following equations are used to calculate the welfare accruing to consumers of product *i* and to producers from factor *l*. Changes in the market due to the policy or technological innovation are reflected by the variable EP, EQD, EW, and EXS. Therefore the following equations capture the changes in welfare:

$$\Delta CS^i = -P^i QD^i EP^i [1+0.5EQD^i] \qquad (10)$$

$$\Delta PS_l = W_l XS_l EW_l[1+0.5EXS_l] \qquad (11)$$

The initial price and quantity of apple *i* and initial price and quantity of factor *l* are shown in Table 2.2. The factor quantities are calculated based on output quantities following the fixed factor assumption and each value is weighted by market shares of different apples. The factor prices are calculated according to the “20% and 80%” rule based on output prices and also being weighted on market shares.

2.3 Results and Discussion

I report results for the following four simulations:

1. A 5% decrease in export demand of high value high grade apple due to EU SPS regulation change, but no change to other apples;
2. A 5% increase in farm input for high value apple because of the biased new technology, but no changes to other apple;
3. Simulation 1 and 2 simultaneously;
4. In the long run with consumer recognition of the biomarker treated apples, a 15% increase in both domestic and export demand for high value high grade apples in conjunction with simulation 2.

The purpose of simulation 1 is to capture the EU SPS impact on the U.S. apple market. The 5% exogenous shock is applied to high value high grade apple, because this type of apple is the product affected by the change of it. It is highly susceptible to postharvest disorders. Using DPA is a must in its storage. In addition, the high grade fresh apples are mainly exported to the European market (USITC 2010). Simulation 2 is the case that the new technology, biomarker is being adopted[8]. Therefore, the 5% net benefit brought by the biomarker is imposed on the farm input, specifically on farm input used for high grade apples. Because the 5% net benefit brought by biomarker is mainly from culls that are upgraded to high grade apples.

Simulation 3 is aimed to compare the policy impact and technology impact to see the effectiveness of the biomarker technology. Can it be an effective alternative method to avoid using DPA so that U.S. apples can be compliant to the new MRL set up by the EU? Will it be able to mitigate some policy impact on the U.S. apple market? If so, by how much? Simulation 4 shows the long run result. Assuming the biomarker is an effective alternative of the DPA, there is no policy shock to the U.S. market any more. Given the function of the biomarker, in the long run, it is expected to be well accepted by the consumers since the treated apples will not suffer postharvest disorders (flesh browning, superficial scald etc.). There will be a demand increase of these good quality apples from consumers. In addition, lower grade apples are also expected to experience a quality upgrade with biomarker, the consumer demand of these types of apples may also change. So will the supply of different types of apples change. Given the share of high grade apples of each variety is 85% and the market share of the three high value varieties selected here is about 17%, a conservative estimation of the increase in consumer demand e is set to be 15%.

Each simulation imposes exogenous shock(s) to the system of equations and generates empirical distributions for the changes in prices and quantities, and welfare changes for four apple outputs and two input factors used in four outputs. The empirical distributions are used to calculate the mean and a 95% confidence interval for price, quantity and welfare variables across 1,000 iterations (more iterations of the model have also been calculated, but the results do not differ greatly. Therefore I report the mean value in the results table plus a 95% confidence interval.

Table 2.3 shows price and quantity effects of the apple output and input markets focusing on the supply side. The four columns correspond to each of the simulation scenarios. The first column is the case when the U.S. apple market is subject to the policy change. The EU SPS regulation change affects the apples exported to the EU with postharvest disorder problems. With a natural decrease in apple export demand from the European market, the supply of high value high grade apple product decreases by 16.73%. This drop of 16.73% is distributed to a decrease of 13.98% of the farm input and a slight increase of the marketing input at 0.12%. The decrease supply of the farm input also affects high value cull apples by -0.58% because high value apples are intensive in the farm input. Decreasing the supply of all high value apples leads to increasing production of low value apples in both grades, as substitutes for consumers. So the policy shock decreases supply (and demand) of all high value apples for exports but have a positive effect on the low value apples. The derived demand of farm supply decreases which is mainly due to the lower MRL in the EU. Before an effective alternative is introduced, this trend is expected to continue.

Table 2.3. Simulation Results of Price and Quantity Changes

		Policy	Biased Tech	Policy & Biased Tech	Demand & Biased Tech
		-5% in high value high grade apple export demand	+5% in farm supply for high value apple	-5% in high value high grade apple export demand & +5% in farm supply input for high value apple	+15% in high value high grade apple demand &+5% in farm supply for high value apple
		Percent change in quantity (Confidence interval)			
Marketing Supply	High grade	0.12	1.37	2.46	-0.03
		(0.06, 0.18)	(0.89, 2.01)	(1.09, 2.98)	(-1.86, -0.003)
	Culls	-0.17	2.17	0.18	0.04
		(-0.22, -0.07)	(1.96, 3.02)	(-0.03, 0.34)	(0.003, 0.12)
Farm Supply	High value	-13.98	2.34	-12.61	3.49
		(-15.01, -12.08)	(1.08, 2.99)	(-15.28, -9.98)	(1.64, 5.03)
	Low value	2.12	-0.01	4.29	-0.53
		(1.88, 2.42)	(-0.018, 0.12)	(2.89, 5.01)	(-2.05, -0.0068)
Retail Price	High value high grade	-5.23	-1.04	-6.27	1.98
		(-6.00, -4.46)	(-2.22, 0.34)	(-8.09, -3.02)	(0.23, 3.53)
	High value culls	0.61	0.75	1.37	-0.15
		(0.02, 1.23)	(0.33, 1.02)	(0.65, 2.05)	(-1.23, 0.08)
	Low value high grade	-2.17	-1.82	-3.99	0.54
		(-2.80, -1.68)	(-2.9, -0.06)	(-5.02, -1.98)	(0.10, 1.86)
	Low value culls	0.15	0.32	0.47	-0.04
		(0.02, 0.28)	(0.18, 0. 43)	(-0.09, 1.53)	(-2.06, 1.12)
Apple Supply	High value high grade	-16.73	1.72	-12.19	4.18
		(-18.01, -14.73)	(0.98, 2.35)	(-15.01, -8.92)	(2.64, 5.83)
	High value culls	-0.58	-0.37	-0.02	0.15
		(-0.78, -0.38)	(-1.88, 1.19)	(-0.28, -0.01)	(0.003, 0.25)
	Low value high grade	2.61	2.63	4.67	-0.65
		(1.56, 3.58)	(0.96, 3.56)	(2.30, 5.99)	(-2.39, 0.86)
	Low value culls	0.03	0.14	0.16	-0.003
		(0.002, 0.036)	(0.02, 0.30)	(-0.01, 0.92)	(-1.56, 1.63)

Note: The 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

In the second scenario, adopting the biased technological innovation increases the farm factor supply of the high value apples by 2.34% effectively. Together with the marketing input supply, the retail level supply of three types of apples except for high value culls all increase. The decrease in supply of high value culls apple proves the effectiveness of the biomarker, which is “upgrading” apples by avoiding further development of postharvest disorder problems. This “upgrading” contributes to a part of the high value high grade supply increase. Retail price of apples changes accordingly, and depends on the equilibrium status of the retail market. When adopting the biomarker technology is the only shock to the apple industry, the new technology seems to be an effective alternative to the banned farm input.

It is meaningful to compare the results of simulation 2 and 3 to emphasize the degree of biasness of the technological innovation. In the presence of both policy change and adopting biased technology, high value apple supplies still drop (−12.19% and −0.02%). However, the drops in both grades of high value apples are smaller compared to the results in simulation 1. Moreover, all the results listed in column 3 have the same sign as in column 1. But the absolute values of all the negative changes are smaller in simulation 3 compared to simulation 1; the values of all the positive changes are larger than in simulation1. Therefore, the biomarker technology effectively mitigates the effects of EU policy ban on the U.S. apple market.

In the long run (simulation 4), the biomarker is being accepted by consumers. Better quality and higher grade apples are being produced because of the biomarker. With both positive impacts from the biased technology (+5%) and consumer recognition (+15%) on high value high grade apples, the farm supply of high value apples increases by 3.49% (compared to 2.34% with only biomarker adoption in simulation 2) and low value decrease by 0.53% (compared to −0.01% with only biomarker in simulation 2). Meanwhile 0.03% less marketing input is need to sell high value apple products but 0.04% more for low value ones. Apple producers have to put more efforts on promoting low value apples sale. This result can also be observed in the retail level. Both grades of the high value apples increase by 4.18% and 0.15% for high grade and culls respectively, while the decreases of 0.65% and 0.003% happen for the low value high grade apple and low value culls. More high value apples are demanded and supplied while less low value apples are demanded and supplied. The price of the high value, high grade apple product increases by 1.98%. With this, higher profits for high value, high grade apple producers could be expected.

In addition to the price and quantity results, Table 2.4 presents the welfare changes in the four simulations. In the first column, the SPS regulation change makes farm input producers lose 7.86 million dollars from the high value apple markets and 0.36 million from low value one. Producers of marketing input gain a surplus of 11.32 million dollars from the high grade apple but lose 20 million from culls. Producers are worse off in general, especially those who produce high value, high grade apples, which are mostly hurt by the EU policy ban. Consumers of high value high grade apples lose 79.91 million dollars because of the policy change. This may because of two reasons: 1) realizing the health risks by consuming high value high grade apples; 2) fewer high value high grade are available in the market to consume. They could be better off if they switch to consume low value apples.

Table 2.4. Simulation Results Welfare Changes

		Policy	Biased Tech	Policy & Biased Tech	Demand & Biased Tech
		+5% in high value high grade apple demand	-5% in farm supply for high grade apple	-5% in high value high grade apple demand & +5% in farm supply input for high grade apple	+5% in high value high grade apple demand &+5% in farm supply for high grade apple
		Welfare change in million USD (Confidence interval)			
Producer Surplus Marketing	High grade	11.32	-1.71	-24.40	-2.89
		(9.90, 13.29)	(-1.89, -1.65)	(-27.06, -21.24)	(-3.81, -1.09)
	Culls	-20.00	0.12	-0.13	0.18
		(-22.01, -18.65)	(0.01, 0.19)	(-1.02, -0.06)	(0.06, 0.35)
Producer Surplus Farm	High value	-7.86	1.13	14.91	24.26
		(-8.21, -5.96)	(0.53, 1.82)	(13.38, 15.56)	(22.51, 26.12)
	Low value	-0.36	0.18	-4.56	-5.82
		(-1.09, -0.02)	(0.17, 0.31)	(-5.10, -3.85)	(-6.16, -3.08)
Consumer Surplus	High value high grade	-79.91	-31.12	184.1	-474.9
		(-81.25, -78.01)	(-33.29, -29.98)	(179.2, 195.3)	(-458.1, 490.6)
	High value culls	0.31	-0.73	-0.45	-1.68
		(0.19, 0.50)	(-1.23, -0.28)	(-1.02, -0.01)	(-1.88, -1.02)
	Low value high grade	46.40	19.46	-8.15	117.1
		(45.89, 46.96)	(18.53, 21.02)	(-9.66, -7.32)	(112.2, 121.6)
	Low value culls	0.35	-0.66	-0.32	-1.62
		(0.28, 0.46)	(-0.18, -0.03)	(-1.00, -0.08)	(-1.99, -0.35)

Note: The 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

With the biased technology, producers using the farm input the technology is biased towards are better off, especially those who produce high value apples, gaining

1.13 million dollar. Those who produce low value apples are also better off but at a much smaller level (0.18 million dollars). In the third scenario, in the present of both policy and technology shocks, the impact of the biased technology becomes more dominant in the welfare measure. With a policy specifically imposed on high value high grade apples, the biomarker benefits the producers of high value apples and hurts producers of low value apples. The producer surplus for the former is 14.91 million dollars and is −4.56 million dollars for the latter. Furthermore, in simulation four, with more consumer demand of high value apples, the producer surplus for the high value apple is 24.26, much more than it is in simulation 2. The double positive effects for high value high grade apple demand lead to a positive effect for producers, while the producer surplus of low value apple suffers a loss at 5.82 million dollars. The double pressure deteriorates the low value apple producers through the factor market. On the consumer side, consumers of the high value high grade apples lose welfare, with a consumer surplus loss of 474.9 million dollars. This loss may be caused by the 1.98% price increase of the apple in the retail level.

2.4 Implication and Conclusion

The focus of this paper is on the relationship between trade policy and biased technological innovation in agricultural markets. How will they shift production and consumption in a market and what changes will happen to welfare of each stakeholder in the market? The paper uses an example of the U.S. apple market. The EU changed its SPS regulation on imported apples. This particular policy change directly affects a key input – storage (farm input) in apple production. A biased technological innovation is a potential solution to the policy change. This paper evaluates the impact of a trade policy change and the corresponding technology adoption to shed light on the effects of agricultural trade in a market with highly differentiated products. In addition, the paper tests a hypothesis on the biased technology to provide suggestions about production decision and technology adoption to producers and other stakeholders in the industry.

Simulation 1 studies the impact of a European trade policy change on the U.S. apple market. Although the EU market only counts for about 16% (at most, in 1991) of the U.S. apple exports, it has a non-trivial impact on the U.S. domestic market. This is due to the complexity of non-tariff barriers in agricultural trade. As long as the U.S. apple producers would like to continue to export to the European market, they will have to rebuild the storage, sorting, packaging facilities and even transportation facilities to avoid cross contamination, to meet the new MRL made by the EU. In this case, producers who have the capacity will be able to earn substantial profits. Other producers will have to completely give up the EU market and suffer economic consequences.

The policy has a negative impact both on the U.S. apple input and output markets. It causes a producer welfare loss for those who intensively use the policy affected farm input and consumer welfare loss for those consume the exporting high value high grade apples. The U.S. government and other stakeholders in the apple industry should actively seek solutions to avoid the potential loss brought by the trade policy. In addition to looking for alternative storage methods, the U.S. apple producers should also explore other exporting destinations.

Simulation 2, 3 and 4 show the effectiveness of the biased technological innovation by studying the impact on the quantity and price and welfare of stakeholders. The biomarker effectively increases supply of high value apples at both farm and retail levels, by enhancing the efficiency of postharvest storage in apple production. The long run impact indicates that if there is acceptance of this new technology in the future, then the consumer demand on high value high grade apples may increase. The development of such a technology should be supported from both public and private sectors. The technological innovation is important for every industry, especially the agricultural industry, which always involves multi-factor in production (Binswanger 1974).

Simulation 2, 3 and 4 also test the hypotheses that biased technology favors a certain output through the input factor for which the technology is biased towards. Producers that produce high value apples enjoy a welfare gain in the three scenarios. Others who produce low value apples suffer and have a welfare loss. This is consistent with the H_0 raised in the conceptual model section. In the presence of a biased technology, the producers in the industry should diversify their production bundle by increasing production of the commodity that the technology is biased towards and decreasing production of other commodities. In this way, the producers could maximize their welfare and minimize risks from exogenous shocks such as policy and regulation changes, market failure and natural disasters. The initial cost to shift production will not be too high when the market includes highly differentiated products. The factors required in the production will not differ too much.

To sum up, a country's trade policy change will affect its trading partners. One response may be technological innovation to cater to the new policy so as to continue to trade. These policy induced technologies may bias towards certain aspects in the production of the traded commodity to be in line with the changing direction of the trade policy. In our case, to meet the new MRL of DPA, a chemical as farm input, the new technology biases towards the farm input. The biased technology will bring shifts in production and consumption. Especially when the market includes highly differentiated products, the shifts are complex due to substitute effects between outputs, inputs and the vertical linkage between input and output markets. However, the complexity also brings opportunities for producers to avoid loss and enjoy additional surplus. In particular for the producers who produce the products that are affected mostly by the trade policy change, there will be a loss if there is no effective alternative/ technology. However, with a new technology the negative impact brought by the trade policy change can be mitigated. To gain more, the producers could shift their production more towards the products that the policy and biased technology affect most. Therefore in a market with highly differentiated products, with an effective policy induced technology, the trade policy shock may lead to net benefit for the producers in the exporting country if they adopt the appropriate technologies.

END NOTES

[1] The termination of the Bracero Program resulted in reduced availability of cheap immigrant labor for California and Florida growers.

[2] COMMISSION REGULATION (EU) No 772/2013 of 8 August 2013 - amending Annexes II, III and V to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for diphenylamine in or on certain products. Pear is another product targeted in the regulation in addition to apple. In this paper, I only focus on studying the apple market.

[3] Washington Grower Clearing house, 55th Annual Apple Price Summary for the 2011-2012 Marketing Season

[4] Only the non-organic apples are considered in this research because organic apples are not applying DPA for postharvest storage.

[5] "The percentage of fruit deemed acceptable for a fresh market outlet is known as the "packout percentage." For example, if a load of navel oranges has a packout of 64%, this means that out of 100 navel oranges, 64 were deemed acceptable for the fresh market. The remaining 36 were sorted out and sent to the processing plant." (Muraro, Roka and Timpner 2007)

[6] Red Delicious, Golden Delicious, Granny Smith, Fuji, Gala, Braeburn, Jongold and Rome.

[7] The 50% of culls are upgraded into a higher grade is a general assumption based on the composition of culls. Culls are small size, non-normal shape, and apples not good looking. Some bad appearance is caused by the postharvest disorder (Rules and Regulations Relating To NEW YORK STATE APPLE GRADES. Available at:

http://www.agriculture.ny.gov/FS/pdfs/farmcircs/circ859.pdf)

[8] Full adoption is assumed here.

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CHAPTER 3. HAS U.S. AGRICULTURAL POLICY DISTORTED INTERNATIONAL TRADE? A STUDY ON THE IMPACT OF PLANTING FLEXIBILITY ON U.S. EXPORTS

3.1 Introduction

In September 2002, Brazil requested consultations from the World Trade Organization (WTO) with the United States regarding a series of U.S. agricultural programs on cotton. Brazil charged that these U.S. agriculture programs were depressing international cotton prices so that reduced the quantity and value of the cotton exports from Brazil, causing damage to Brazil's domestic cotton sector (WTO 2014). After a decade-long negotiation between the United States and Brazil, in October 24th, 2014, this WTO dispute settlement was finally terminated. The two countries have reached a mutual agreement that "Brazil giving up its rights to countermeasures against the U.S. trade or any further proceedings in the dispute" while the United States operating the current Farm Bill 2014 consistent with the agreed terms and providing financial compensation to the Brazil cotton sector (USTR 2014, USDA 2014). More details about the cotton case are shown in Table 3.1.

The WTO arbitration on the U.S.-Brazil cotton case was made mainly because of 1) the export credit guarantees[1] that are prohibited as subsidies according to the WTO rule; 2) the marketing loan[2] and counter-cyclical payments[3] that caused serious prejudice to Brazil; 3) production flexibility contract (planting restriction) and direct payment[4] programs are not "green box"[5] measures (WTO 2014, USTR 2014, USDA 2014). In points 2 and 3, the planting restriction is related to both the direct and counter-cyclical payments. It has aroused many discussions in the dispute settlement panel (WTO 2014). It is important for countries to learn the scope of the WTO regime and dispute settlement process from this U.S.-Brazil cotton case for future domestic policy making. For this purpose, many researches have been done and they can be grouped mainly in two categories: 1) papers evaluating the WTO disputes settlement and negotiation mechanism by explicitly analyzing this case and the consequences of the WTO settlement decision (Goodloe 2013; Suyama et al. 2016); 2) papers examining the economic impact of the cotton case through analyzing the relevant policies (direct payment, commodity loan programs (where the marketing loan belong to) on the U.S. domestic market (Young et al. 2007; Gardner, Hardie and Parks 2010; Balagtas et al. 2012; Graddy-Lovelace and Diamond 2017). However limited research has been done to specifically study the impact of the planting restriction which affects both the direct and counter-cyclical payments.

Table 3.1. Timeline and Selected Brief Summary of the WTO Dispute Settlement DS267: United States – Subsidies on Upland Cotton

Complainant: Brazil	Respondent: United States	
27 September 2002	Request for Consultations received	Brazil contented U.S. agricultural program (providing assistance to the U.S. upland cotton industry) is inconsistent with the United States' WTO commitments;
8 September 2004	Panel Report circulated	1. "Peace Clause[1]" did not apply to U.S. domestic support measures for upland cotton; 2. Production flexibility contract and direct payment programs are not green box measures; 3. The effect of marketing loan and counter-cyclical payments provided to United States upland cotton producers was significant price suppression, constituting serious prejudice to Brazil's interests; 4. Export credit guarantees were "export subsidies" (prohibited); 5. The United States should withdraw prohibited subsidies without delay and remove the adverse effects or withdraw subsidies that caused serious prejudice to Brazil.
3 March 2005 – 2 June 2008	Appellate Body Report	
31 August 2009	Arbitration Report circulated	
16 October 2014	Mutually acceptable solution on implementation notified	1. Formal termination of the DS267 within 21 days; 2. Brazil relinquish all rights to countermeasures against U.S. trade; 3. The United States make a onetime final[2] contribution of 300 million USD to the Brazil Cotton Institute; 4. New rules governing the fees and tenor U.S. domestic support measure and guarantees under the program of issue;

Information are from WTO DS267 settlement report (WTO 2014) and Office of the United States Trade Representative (USTR 2014)
Note:[1] Peace Clause – "Article 13 holds that domestic support measures and export subsidies of a WTO Member that are legal under the provisions of the Agreement on Agriculture cannot be challenged by other WTO Members on grounds of being illegal under the provisions of another WTO agreement. The Peace Clause has expired on January 1, 2004." – WTO legal texts (Available at: https://www.wto.org/english/docs_e/legal_e/legal_e.htm)
[2] The United States have made monthly payments to the Brazil Cotton Institute for technical assistance and capacity building activities since the June 2010 Memorandum of Understanding between the two countries.

Both the direct and counter-cyclical payments are computed using the base acres[6] (USDA 2003). The direct payment program is a way to restrict the type of crops planted in the base acres, because the payments are not based on producer's current production choice but are tied to acreage bases and yields. The payment amount for each crop year equals 85% of the farm's base acreage *times* the farm's direct payment yield *times* the direct payment rate (USDA 2003). Counter-cyclical payment is made to participating farmers when the marketing year average price received by farmers for a covered commodity is less than the target price, providing support counter to the cycle of market prices in the event of low crop prices (USDA 2003). The payment amount equals 85% of the farm's base acreage *times* the payment rate (difference between the target price and average market price of the commodity) (Womach 2005). In order to receive both payments, the farmer should comply with another U.S. domestic policy – the planting restriction.

Since 1990, the "Fruit/Vegetable and Wild Rice" restriction limits the planting of specialty crops[7] on land that has historically been used to plant program crops[8]. This provision within "The 1990 Food, Agriculture, Conservation and Trade Act" which regulated the planting of any crop except fruits and vegetables on up to 25% of any participating program crop's acreage base. "The 1996 Federal Agriculture Improvement and Reform Act" mandated that participants may plant 100% of their total base acreage to any crop, except with limitations on fruits and vegetables. "Planting of fruits and vegetables (excluding mung beans, lentils, and dry peas) on base acres is prohibited unless the producer or the farm has a history of planting fruits and vegetables, but payments are reduced acre-for-acre on such plantings" (USDA

1996 page 8). When the counter-cyclical payments were introduced in the 2002 Farm Bill, it is said that the recipients of direct and counter-cyclical payments have planting flexibility on their base acres except for fruits, vegetables and wild rice, and payments tied to base acres are partially or fully forfeited when fruits and vegetables are harvested.

As a result, planting restrictions have the capacity to influence the amount of land that is used to produce program and specialty crops (Johnson et al. 2006). When binding, the planting restriction may reallocate base acres between fruit and vegetables versus program crops, in the direction of crowding out fruit and vegetable acres to grow program crops. Previous research on planting restrictions have 1) studied the barriers to switch to fruit and vegetable production in regions with high competition of land in alternative uses (Young et al. 2007; Thornsbury Martinez and Schweikhardt 2007); 2) estimated the acreage response to a hypothetical removal of the planting restriction (Fumasi et al. 2006; Balagtas et al. 2013). These studies largely show that the planting restriction has small to modest effects on fruit and vegetable acres in selected regions. However, would these acreage relocation effects on base acres increase U.S. cotton exports in the international trade? If so, by how much?

According to the WTO, the planting restriction provision has effectively led to direct payments (of which the cotton program is a part) that are not “minimally trade distorting” (Johnson et al. 2006). The United States has listed direct payments as “green box” (minimally trade-distorting), given the direct payments are not tied to current market prices or production, or not tied to a specific crop. The cotton case let the WTO raise the question of whether direct payments should be exempt from WTO to obligations (ie. being moved from “green-box” to “amber-box”[9]) (Goodloe 2013). Because of this, in the subsequent farm policy debates, the U.S. government has considered the elimination of the planting restriction to maintain the non- trade distorting property of the direct payment program (Johnson et al. 2006).

The 2014 Farm Bill shows that the United States took action to modify their domestic policy in accordance with the WTO regulations on trade. In Title I concerning Crop Commodity Programs[10] of the 2014 Farm Bill, both the direct and counter-cyclical payments have been eliminated. Naturally, the planting restriction, the existence of which depends on those payments has been eliminated too. To continue assisting the covered crops (corn and other feed grains, wheat, rice, soybeans and other oilseeds, peanuts, and pulses) producers in the transition period, several new programs[11] were provided. The upland cotton producers (producing on land considered as “generic base acres”) were able to participate in a new cotton insurance program as part of the 2014 Farm Bill. Both new programs still provide price or revenue benefit to grain crop producers. Planting fruit and vegetables (including wild rice) on the base acres enrolled in the new payment program, are still discouraged as they receive smaller payments. The major change is that although the new programs are still based on historical base acres, they allow relocation of base acres with the most recent planting history and also allow updating of program yields used in the payment calculation.

To better understand the planting restriction effects of fruit and vegetable acres reduction on the international trade, I examined the effects that the planting restriction had on land use in the United States when it was first introduced in 1990. I will first econometrically estimate the planting restriction impact on U.S. land allocation between fruit vegetable crops and program crops. Then apply the estimation result to simulate how the planting restriction will affect U.S. crop trade if dropping it out.

3.2 Acreage Response Estimation

Agricultural economists have studied the impact of commodity policy on land use in the United States (Johnson 1950; Houck and Ryan 1972; Lee and Helmberger 1985; Wu 2000; McDonald and Sumner 2003). These papers have used a range of econometric methods for studying acreage responses to policy and other changes. However, the empirical literature studying the effects of farm polices on land allocation between crops has been very general and only captures the average effects of a bundle of different polices on land use (Moss and Schmitz 2008; Gardner, Hardie and Parks 2010; Balagtas et al. 2014).

The combination of deficiency payments or production flexibility contract payments and the planting restriction together increased returns to growing program crops and decreased returns to growing fruit and vegetable crops on base acres (Young et al. 2007). Figure 3.1 shows the change in program crop acres between 1987 and 1997. Soon after 1987, the planting restriction was introduced in the 1990 Farm Bill and therefore the 1997[12] acreage data is a suitable method to capture the effects of the planting restriction. In Figure 3.1, the light grey colored regions mainly on the east and west parts of the United States showed a decrease of 5% or more in acreage used to produce program crops. Along the East Coast and in the Midwest there are regions that have more than 5% acres being converted into program crops. Figure 3.2 is the county-level percentage changes in fruit and vegetable acres between 1987 and 1997 in some southern and eastern counties. There were 5% or more acreage decreases, and 5% or more acreage increases in selected counties throughout the country.

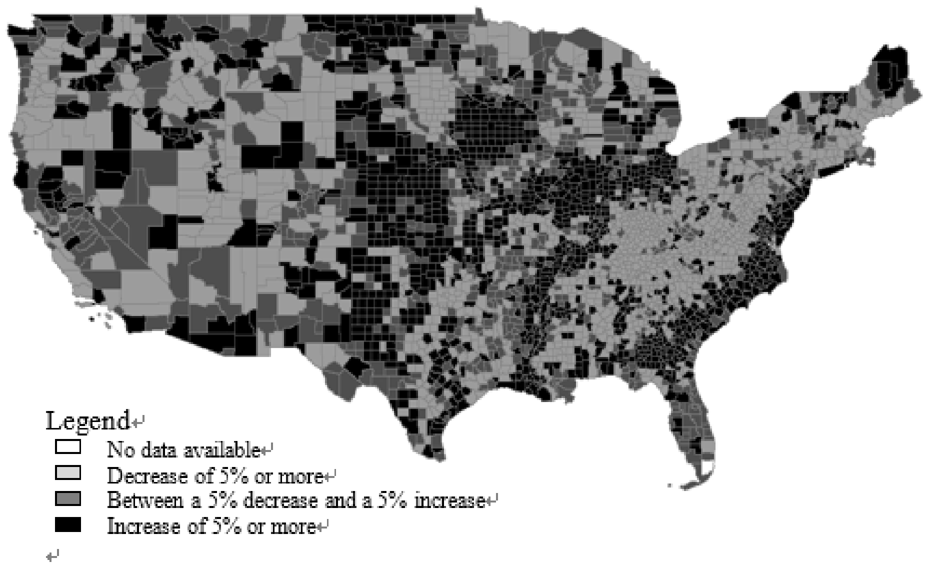

Figure 3.1. County-level changes in program crop acreage, 1987 to 1997

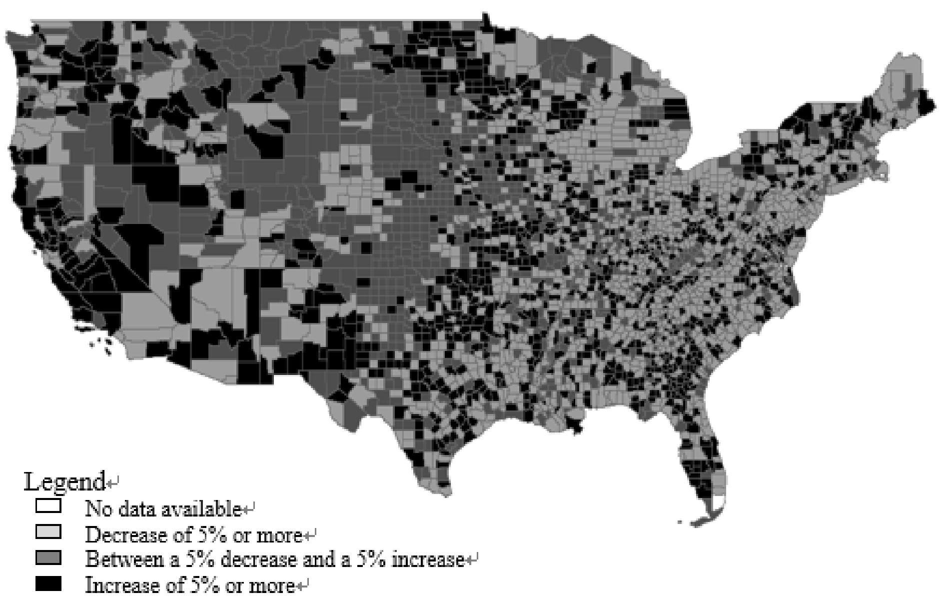

Figure 3.2. County-level changes in fruit and vegetable acreage (including tree nuts, melons, and wild rice), 1987 to 1997

To examine these acreage changes more closely, a Difference-in-Difference (DiD) model with county specific data for individual crops is adopted. The approach exploits a discrete change in farm policy and geographic variation in implementation (Balagtas et al. 2013). The DiD model is ideally used to measure the change induced by a particular event or treatment in two distinct time periods. Here the time periods are pre- and post- 1990 Farm Bill, as this was the Bill that introduced the planting restriction. The policy change refers to the farmers with a history of program crop acreage that: (1) can receive program payments on those acres; and (2) are restricted planting fruit and vegetable crops on those acres.

Different from the classic DiD model which has treatment and control groups so as to estimate the policy impact, this model measures the policy impact in a continuous scale. There is no distinction of control and treatment groups, but this DiD policy variable measures the degree to which the planting restriction is binding. The hypothesis is that the planting restriction led to a reduction in fruit and vegetable acres and an increase in program crop acres. The degree to which the planting restriction is binding for a given area of land is measured by the portion of the acreage that was previously used to produce program crops (so subject to the planting restriction). This hypothesis is tested while the acreage re-allocation between the two crop categories is estimated using the acreage data. In the subsequent step, the estimated acreage change will be used to simulate the impact of the planting restriction on U.S. exports of program crops.

3.2.1 Econometric Model

The following reduced-form econometric model was used to estimate changes in fruit and vegetable acreage in county *i*:

$$\Delta AFV_i = \beta_0 + \beta_P AP_i + \beta_X \mathrm{X}'_i + \varepsilon_i$$

The dependent variable ΔAFV_i is the change in fruit and vegetable acres of county *i* between 1987 and 1997; AP_i is the acres used for program crops in county *i* in 1987; X'_i is a vector of other covariates that influence fruit and vegetable acreage in country *i* and includes several agronomic variables. The term ε_i is the stochastic error terms which captures unobserved factors that influence fruit and vegetable acres in county *i*.

As mentioned before, the variable AP_i is the acres for program crops in county *i* in 1987. It measures the acres that were subsequently subject to the planting restriction. We interpret it as an exogenous policy treatment as producers did not know in 1987 that program crop acres would be restricted as a pre-condition for receiving farm payments. The corresponding parameter β_P is the DiD estimator of the effect of the policy on fruit and vegetable acres between 1987 and 1997, which we attribute to the planting restriction.

Whether the DiD estimator could identify the policy effect depends on how well the model captures other factors (in addition to the policy change) that might influence county-level changes in fruit and vegetable acreage. Covariates were also included in the regression to describe factors known to influence cross-sectional and time-series variations in county-level plantings of fruits and vegetables. The total crop acreage in 1987 of each county is included in vector X_i, because the total crop acreage affects the land area that is used to plant fruit and vegetables. The vector X_i includes agronomic and climatic variables that affect the suitability of land for fruit and vegetable production; this includes variables describing temperature, elevation, and net precipitation. In addition, there are unobservable factors that may describe how well land is suitable for fruit and vegetable planting such as urban development pressure, the relative demographics of specialty crop and program crop producers, specific market-level economic conditions, and regional technological innovations. To control for these conditions, state-level dummies in vector X_i are included to control these factors in the state level. Other time-invariant unobservable factors are left in the error term, and do not bias estimates of the policy effect. Because the DiD estimator permits time-invariant selectin bias.

In addition, the dependent variable ΔAFV_i is left-censored by total fruit and vegetable acres in 1987. Because counties can reduce fruit and vegetable acreage by, at most, the total fruit and vegetable acreage in 1987. So equation (1) is estimated by a generalized Tobit estimator that allows each county to have a unique censoring value of the county's total fruit and vegetable acreage. Moreover, since each county is different in size and in agricultural production capacity, so each observation is weighted by total crop area.

3.2.2 Data

County-level acreage data from the USDA Census are used to describe acres planted in various crops in 1987 and in 1997. The year 1987 is the pre- and the year 1997 is the post-policy year. The data was organized into two crop categories: 106 horticultural (fruit and vegetable) crops and 10 program crops. Soybeans were not added to base acres until 2002, and therefore are not included as a program crop because the analysis focuses on the period prior to 2002. In addition, total acreage is calculated by adding remaining annual crops to the horticultural and program crops (164 crops in total).

There are 3,143 counties and county-equivalents in the United States. The five counties in the state of Hawaii and the 27 county-equivalents in the state of Alaska are excluded from the data and the 80 counties that did not plant any annual crops in 1987 and 1997 were not included in the analysis. Therefore, data from 3, 031 counties were used in the regression work. Table 3.2[13] lists the acres used to produce fruits and vegetables in 1987 and 1997. In addition, to show the relative changes in acreage of these two years, the ratio of fruit and vegetable acres to total cropland were calculated and also shown in Table 3.2. The second and fourth columns in Table 3.2 shows the actual acreages used to plant fruits and vegetables in 1987 and 1997. Columns three and five are the shares of fruit and vegetable acres of total acres in 1987 and1997. From this table, it appears that there were not significant changes in fruit and vegetable acres after 1990.

The agronomic data were collected from the Rocky Mountain Research Station of USDA Forest Service – the Historic Climate data (1940-2006) for the 48 conterminous states at the county spatial scale based on PRISM9 (Parameter-elevation Regressions on Independent Slopes Model) climatology (Coulson and Joyce 2010). The dataset contains monthly totals of precipitation in millimeters (mm), monthly means of daily maximum (minimum) air temperature in degrees Celsius (C), and computed monthly mean of daily potential evapotranspiration (mm) and mean grid elevation in meters (m).

Some adjustments were made to the agronomic data before being applied in the model. First, the maximum monthly temperature and the minimum monthly temperature were used to calculate an average monthly temperature. Second, evaporation was subtracted from the precipitation to calculate a measure of the net precipitation. As a result, there are four agronomic variables in vector X for each county in each time period: elevation, growing-period (the nine months including March to November), averages for temperature, and net precipitation.

Table 3.3 shows the summary statistics for a sample of county-level data. The three top fruit and vegetable producing counties in the state of California were selected to provide a snapshot of the information contained in our dataset. As the table shows, almost all the acres used for horticultural crops increased from 1987 to 1997 in the three counties. However, these changes might have been due to various reasons other than the 1990 planting restrictions, so we employ a regression model to isolate the impacts of the policy change in 1990.

Table 3.2. Fruit and Vegetable Acreages and Share of Total Acreages in the 1987 and 1997

State	Fruit and vegetable Acres in 1987		Fruit and vegetable Acres in 1997		State	Fruit and vegetable Acres in 1987		Fruit and vegetable Acres in 1997	
	1,000 acres	*% of all crops*	*1,000 acres*	*% of all crops*		*1,000 acres*	*% of all crops*	*1,000 acres*	*% of all crops*
AL	60	2.06%	51	1.74%	**NE**	204	1.11%	185	0.90%
AZ	201	20.87%	265	21.37%	**NV**	2	0.19%	2	0.24%
AR	29	0.36%	23	0.24%	**NH**	8	3.97%	7	3.89%
CA	2855	30.82%	3432	34.10%	**NJ**	112	18.80%	79	13.68%
CO	215	3.25%	193	2.66%	**NM**	58	4.79%	76	5.60%
CT	10	4.64%	10	4.73%	**NY**	352	5.58%	337	5.68%
DE	81	14.70%	68	11.89%	**NC**	129	2.91%	108	2.05%
FL	1030	50.59%	1117	51.34%	**ND**	488	2.31%	660	2.85%
GA	198	5.18%	288	6.42%	**OH**	83	0.77%	62	0.55%
ID	447	7.84%	443	7.55%	**OK**	63	0.68%	102	0.92%
IL	79	0.35%	66	0.27%	**OR**	326	7.97%	329	7.22%
IN	34	0.28%	32	0.25%	**PA**	140	2.26%	115	1.88%
IA	7	0.03%	13	0.05%	**RI**	4	20.30%	3	14.86%
KS	14	0.06%	11	0.04%	**SC**	74	3.95%	49	2.30%
KY	9	0.14%	7	0.09%	**SD**	8	0.05%	19	0.10%
LA	32	0.76%	36	0.78%	**TN**	27	0.51%	25	0.42%
ME	26	4.95%	23	4.18%	**TX**	404	2.07%	348	1.46%
MD	50	2.76%	42	2.22%	**UT**	42	2.46%	27	1.46%
MA	42	13.18%	35	13.42%	**VT**	7	0.70%	7	0.80%
MI	841	10.06%	689	7.97%	**VA**	69	1.89%	56	1.43%
MN	384	1.86%	498	2.18%	**WA**	543	10.12%	721	12.77%
MS	29	0.62%	35	0.68%	**WV**	20	2.06%	14	1.22%
MO	28	0.18%	34	0.20%	**WI**	428	2.93%	376	2.98%
MT	20	0.16%	21	0.15%	**WY**	34	1.19%	29	0.98%

Table 3.3. Descriptive Statistics of the Top 3 Fruit and Vegetable Producing Counties in CA, 2 Years

County	Year	Program Acre (Base acre proxy)	Acres of Veg	Acres of Fruits	Acres of F&V	Total Acre	Dummy	Elevation	Net Precipitation	Temperature
Fresno	1987	459023	197639	144721	342360	1063042	0	1022.4	169.1	281.1
	1997		271243	196329	467572	1116687	1	1022.4	63.6	291.6
Kings	1987	331154	23571	15368	38939	495464	0	106.6	23.5	372.5
	1997		30155	23874	54029	513354	1	106.6	-10.4	383.1
Tulare	1987	302500	149553	17262	166815	680969	0	1311.2	140.5	259.3
	1997		166806	17244	184050	666813	1	1311.2	63.2	269.5
Mean		364225.7	69133	139827.8	208960.8	756054.8		813.4	74.9	309.5
Std.Dev.		74539.46	80267.66	96931.17	167322	270077.7		562.5	68.4	54.1
Min		302500	15368	23571	38939	495464		106.6	-10.4	259.3
Max		459023	196329	271243	467572	200494		1311.2	169.1	383.1

3.2.3 Results

The purpose of the regression analysis is to test the hypothesis that the planting restriction led to a reduction in fruit and vegetable acreage and an increase in program crop acreage by considering the degree to which the planting restriction is binding. Also, the estimation results will provide a measure of the acreage re-allocation between the two groups of crops. The focus of the estimation is the policy variable, the estimated coefficient of variable AP_i which is the program crop acres in 1987. A negative coefficient on the variable implies that the more program crop acres county *i* has, the county is more likely to experience a larger reduction of fruit and vegetable acres due to the planting restriction. It also suggests that the planting restriction provision did crowd out the fruit and vegetable crops.

Table 3.4 shows the results from estimations using all 3, 031 counties reporting crops. The first column presents results from using the change in area for all fruit and vegetable crops as the dependent variable. The coefficient for the key policy variable β_P is -0.0426, and it is statistically significant. The results indicate that the average effect of the planting restriction is a reduction in fruit and vegetable acres by 4.26 acres for every 100 acres of program crops planted in 1987.

Table 3.4. Censored Regression Results, All U.S. Counties

	Dependent variable is the change between 1987 and 1997 in fruit and vegetable area	
Explanatory variables	Estimated coefficient	Standard error
1978 Program crop area	-0.0426**	0.0158
1987 Total crop area	0.0534**	0.0182
Elevation	-0.30130	3.9174
Net precipitation	-2.8896	2.9811
Temperature	-38.2052	43.8058
Censored observations	615	
P-value for Wald test for significance of the regression	0.000	

Note: 1) * and ** : significant at the 10% and 5% level respectively

2) All standard errors are computed using a robust estimator of the covariance matrix. Regression results for the state dummy variables and the intercept have been suppressed upon request.

3) Sample size: 3,031 counties in 48 states

Assuming all the reduction in fruit and vegetable acres were converted to plant program crops as the upper bound of the planting restriction impact on land relocation. Therefore, with the planting restriction, there is a 4.26% increase in program crop acres. An important point to understand is how much is the reduction in fruit and vegetable acres for every 100 program acres? I use the industry share (λ) of land to calculate this reduction (more about the industry share will be given in the later simulation section). Based on USDA census data, the average ratio of land used to produce fruit and vegetables versus program crops is approximately 2:8 (Stewart et al. 2011). It means for 100 acres of land supply, 20 acres are dedicated to fruit and vegetables and 80 are used to plant program crops. Therefore the 4.26% increase in program crop acres would bring following impact on fruit and vegetable acres:

$$= \frac{\text{program crop acres} \times 4.26\%}{\text{fruit and vegetable acres}} \times 100$$

$$= \frac{\text{total land supply} \times \lambda_{land}^{grain} \times 4.26\%}{\text{total land supply} \times \lambda_{land}^{hort}} \times 100$$

$$= \frac{\lambda_{land}^{grain} \times 4.26\%}{\lambda_{land}^{hort}} \times 100$$

$$= \frac{0.8 \times 4.26\%}{0.2} \times 100$$

$$= 17.0\%$$

Using the estimation results, I calculate that the real effect of planting restriction on fruit and vegetable acres is a decrease of 17.0%. To capture the maximum impact of the land re-allocation from the planting restriction, I assume there could have been a 4.26% increase in program crop acres and I use this percentage to study the planting restriction effects on the international market for the United States and the rest of world including Brazil in the next section.

3.2.4 Impact on the World Market

According to my estimation results, the planting restriction did affect acreage allocation for both program crops and fruit and vegetable crops in the United States. However for the U.S.-Brazil cotton case, in order to claim that the planting restriction increased exports of program crops (cotton) into the international market and depressed the world price, two things should be clarified: 1) Will the planting restriction's impact on input (land) markets affect price and quantity in output markets of fruit and vegetable and cotton? Will an increase (decrease) in price and quantity in the input market necessarily lead to an increase (decrease) of price and quantity in the output markets fruit and vegetable and cotton? 2) The impact on the program crop acreage is limited (4% in 1987). If there is a relationship between the input and output markets, by how much will the impact on the input market transfer to the output market? Moreover, will this impact also affect international markets? A simulation model with the estimated exogenous shocks is used to capture the effect of the planting restriction on international markets. The simulation will provide a clearer picture of the connection between a country's domestic farm policy and international trade. It will also help to understand the effect of a country's domestic policy on trade, as well as provide insights about the trade negotiation mechanism, and relevant WTO decisions.

I model the effects of the planting restriction brought to the on international markets through its impact on U.S. domestic land allocation between horticultural and program crops. A multi-input and multi-output model with international trade is adopted to simulate the impact of the planting restriction. There are two groups of crops in the model: fruits and vegetables (referred to as the horticultural crop) and program crops (referred to as the grain crop). The grain crop includes cotton, which was the focus of the U.S.- Brazil WTO case, and the issue that initiated the trade policy debate related to the planting restriction. Both groups of crops are exported by the United States and Brazil to the world market. Three common inputs (land, labor, and other inputs) are used to produce the two crops. The “other” input includes a set of factors of production such as fertilizer, fuel, irrigation, storage, and marketing services. The input market is closed and therefore the three inputs can freely move between the domestically produced crops, i.e. between horticultural and grain crops, but are not traded.

The model describes a multi-input and multi-output market in an open economy with trade. It is based on Rickard, Okrent and Alston (2013) as an equilibrium displacement model adjusted following Sumner (2003) and Mohanty et al. (2005) to further focus the U.S.- Brazil cotton case. The basic argument behind the simulation model is illustrated in Figures 3a and 3b. To simplify the illustration, crops are produced using only one input. The grain crop is relatively dominant in terms of total factor usage. In the figure, I only focus on the export flow of grain crop as this was the focus of the Brazil cotton case. Horticultural crop trade is not discussed here but will be included in the simulation later. The impact of the planting restriction is reflected in the input market as a re-allocation of land input between horticultural and grain crops– a decrease in producing horticultural crops and an increase in producing grain crops.

In Figure 3.3a, the original input supply for the two crops before implementing the planting restriction are X_h and X_g, where X represents the input supply. Subscript h denotes horticultural crop and subscript g denotes grain crop. The total input supply is the bold $\boldsymbol{X_s}$. The equilibrium input quantities supplied are h and g. With the planting restriction, an exogenous policy shock shifts X_h to the left to h' and shifts X_g to the right to g'.

Changes in the factor market affect output markets and trade flows are shown in Figure 3.3b. The original export quantity from the United States to the world market equals to $t-n$ at the world price p. The amount of t and n are determined by output supply Q_s and demand D. The change in input supply caused by the planting restriction shifts the output supply to Qs'. As a large country which has the power to influence world markets, the world grain price falls with the increasing supply. Therefore, the new level of U.S. exports to the world market is $t'-n'$. The $t'-n'$ can be greater or less than initial exports $t-n$. Whether the grain exports are increased or decreased depends on the magnitude of input re-allocation, increase in grain supply and the supply response of horticultural crops. This example highlights the importance of cross commodity linkages through factor markets. More detailed analysis will be described in the simulation model section next.

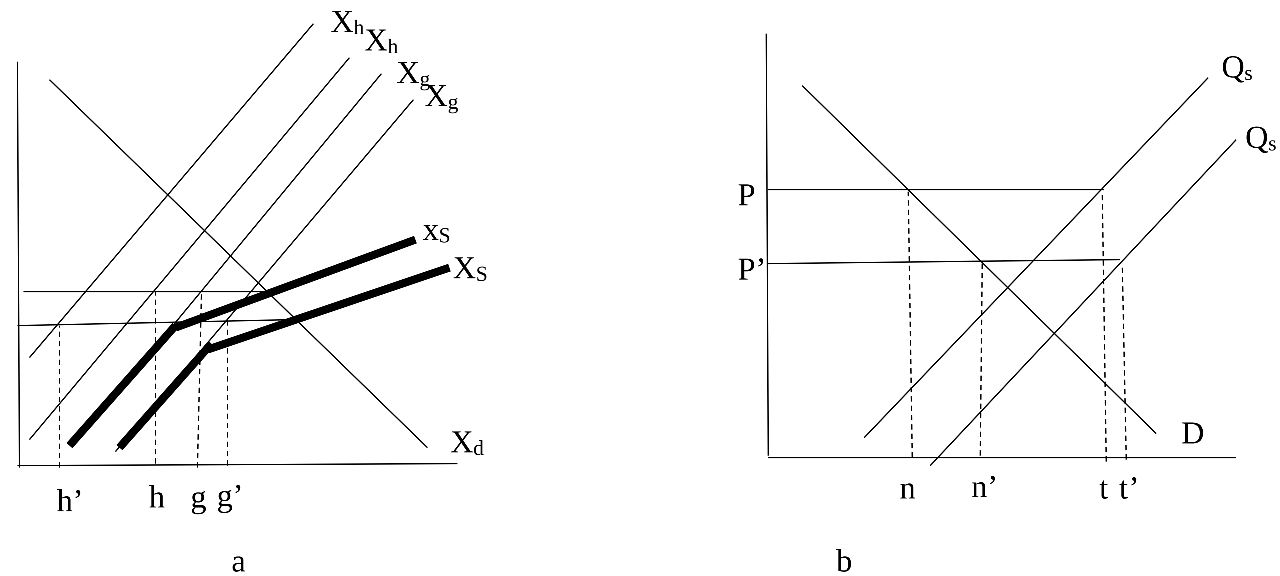

Figure 3.3. The impact of the planting restrictions on input and output markets

3.3 Simulation Model

To analyze the effects of the planting restriction on U.S. grain exports through changes in factor markets, specifically land re-allocation between grain and horticultural crops, an equilibrium displacement model is adopted. The basic form of the model is from Muth (1964). Subsequent developments to accommodate multiple input and output markets are used in Hertel (1989) and Sumner, Lee and Hallstrom (1999). The simulation model is developed and used to assess the impact of planting restriction impact on the U.S. crop market and in international markets. A set of basic equations is used to describe demand, export demand, domestic demand for the imported crop, supply and the corresponding factor markets. This equilibrium displacement model includes markets for four outputs and two factors in two regions. It is a simplification of the U.S. and the international crop markets, meanwhile it does capture the critical characteristics found in the industry and provides a useful framework to examine the impact of a policy change.

There are N outputs from $1\ldots N$, categorized into two broad crop categories: grain and horticultural crops. There are two regions in the model, the United States and the aggregated rest of world (ROW). For simplification, there are two trade flows between the two regions: the United States exports grain crops to the ROW; and the ROW exports the horticultural crop to the United States. Both regions are large enough to have the capacity to influence world prices. I assume that the world price of grain and horticultural crops are equal to U.S. domestic grain price and the ROW domestic horticultural price. I do not consider the role of tariff barriers and therefore do not include tariffs in the price vector here. The two tradable outputs are produced using three inputs: land, labor, and other agricultural production inputs (includes capital, fertilizer, fuel and marketing services).

In order to better capture the acreage change in land use for both horticultural and grain crops, I explicitly list all the inputs. Land, labor, and other inputs are differentiated based on output crop types. For example, there are two land inputs: land for horticultural crops and land for grain crops. Superscript *i* denotes the output and subscript *k* denotes the input. The specific model is displayed as following:

(1) $$QD_i^y = f_i^y(P, V^y)$$

(2) $$QX_i^y = g_i^y(P, Z^y)$$

(3) $$QM_i^y = m_i^y(P, R^y)$$

(4) $$QS_i^y = QD_i^y + QX_i^y - QM_i^y$$

(5) $$P_i^y = \frac{\partial TC_i^y(W_k^y, QS_i^y)}{\partial QS_i^y}$$

(6) $$x_{i.k}^y = \frac{\partial TC_i^y(W_k^y, QS_i^y)}{\partial W_k^y} QS_i^y$$

(7) $$XS_k^y = h_k^y(W_k^y, U^y)$$

(8) $$XS_k^y = \sum_{i=1}^{N} x_{i,k}^y$$

There are eight equations with eight unknown variables in the model. Equation (1) is the output demand, where QD_i^y is the domestic demand of output *i* in region *y*. Two regions are denoted with subscript *y* here. The output price (domestic price) vector for all crops is denoted by **P** and the vector of exogenous variables is denoted by $\mathbf{V}^y$.

Equation (2) is the export demand function, with QX_i^y as the export demand for output *i* in region *y* and it is influenced by an exogenous vector of variables $\mathbf{Z}^y$. Demand in region *y* demand for the imported crop *i*, denoted as QM_i^y is shown in equation (3) with a vector of exogenous variables $\mathbf{R}^y$. Equation (4) is the output market clearing condition and QS_i^y is the total supply of output *i* in region *y*. Equation (5) shows the competitive equilibrium and TC_i^y is the region *y* total cost function of output *i* in region *y*. The equation shows the market clearing condition for domestic produced product *i*: marginal cost equals domestic price. The derived input *k* demand in region *y* is shown in equation (6), where W_k^y is the price of input *k* in region *y*. Equation (7) is the supply function for input *k* in region *y*. The vector $\mathbf{U}^y$ denotes a set of exogenous variables that affect supply. Equation (8) is the input market clearing condition in region *y*.

Total differentiating equation (1) to (8) yields the following linear elasticity model. Here η_{ij}^y is the demand elasticity of output *i* in region *y* with respect to the price of output. Similarly, the export demand elasticity is η_{xij}^y and import demand elasticity is η_{mij}^y. Parameter $\gamma_{i,k}^y$ is the cost share of input *k* in the production of output *i* in region *y*. Its summation over input *k* is equal to 1. The parameter $\sigma_{i,kl}^y$ is the Allen elasticity of substitution between input *k* and *l* used in the production of output *i*. In Equation (7'), ε_k is the elasticity of supply of input *k* in region *y*. In the last equation, the industry share of input *k* in the production of output *i* in region *y* is denoted as $\lambda_{i,k}^y$. After specifying the key parameters in the above system, the model will be used to simulate the changes in the U.S. and international crop markets with a series of exogenous shocks driven by changes in the planting restriction.

$$(1') \qquad \mathrm{EQD}_i^y = \sum_{j=1}^{N} \eta_{ij}^y \mathrm{EP}_j$$

$$(2') \qquad \mathrm{EQX}_i^y = \sum_{j=1}^{N} \eta_{xij}^y \mathrm{EP}_j$$

$$(3') \qquad \mathrm{EQM}_i^y = \sum_{j}^{N} \eta_{mij}^y \mathrm{EP}_j$$

$$(4') \qquad (\frac{QS^y}{QD^y})\mathrm{EQ}S_i^y = (\frac{QD^y}{QS^y})\mathrm{EQD}_i^y + (\frac{QX^y}{QS^y})\mathrm{EQX}_i^y - (\frac{QM^y}{QD^y})\mathrm{EM}_i^y$$

$$(5') \qquad \mathrm{EP}_i^y = \sum_{k=1}^{M} \gamma_{i,k}^y \mathrm{EW}_{\mathrm{k}}^y$$

$$(6') \qquad \mathrm{Ex}_{\mathrm{i,k}}^y = \sum_{k=1}^{M} \gamma_{i,k}^y \sigma_{i,kl}^y \mathrm{EW}_k^y + \mathrm{EQS}_{\mathrm{i}}^y$$

$$(7') \qquad \mathrm{EXS}_k^y = \varepsilon_k^y \mathrm{EW}_k^y + shock_k^y$$

$$(8') \qquad \mathrm{EXS}_k^y = \sum_{i=1}^{N} \lambda_{i,k}^y \mathrm{Ex}_{i,k}^y$$

3.3.1 Parameterization of the Simulation Model

Value and sources for all of the baseline parameters that are used in the simulation model are listed in Table 3.5. Each will be discussed in detail here. For all the elasticities (elasticity of demand, export elasticity of demand and supply elasticity), I first obtained baseline values from the literature that studies issues related to the specific crops. Following Davis and Espinoza (1998), Zhao et al. (2000), and Rickard and Lei (2011), I applied prior distributions to the baseline elasticity parameters as a way to conduct a sensitivity analysis. Setting the baseline parameter as the central tendency with a specified variance at 0.04 to develop beta (3,3) distributions (Brester, Marsh and Atwood 2004). Beta distribution is a family of continuous probability distribution which is symmetric when the two parameters are set to be equal. It has been applied to model the behavior of random variables limited to intervals of finite length in many disciplines including economic analysis. Because of this characteristic, the beta distribution is selected here to ensure negative demand elasticities and positive supply elasticities. The simulation model randomly draws values following beta distribution for these parameters to generate an empirical distribution of results with 100 iterations.

Table 3.5. Baseline Parameter Specification

	Horticultural Crops	Grain Crops	Source
Demand elasticity			
Horticultural Crops	-0.63	0	Rickard, Orkent and Alston (2013)
Grain Crops	0	-0.98	Rickard, Orkent and Alston (2013)
Export Demand elasticity			
Horticultural Crops	-1.44	0	Epperson and Lei (1989)
Grain Crops	0	-1.40	Reimer Zheng and Gehlhar (2012)
Domestic Demand elasticity of imports			
Horticultural Crops	-0.88		FAOSTAT
Grain Crops		-0.0098	FAOSTAT
Input cost share by industry			
Land	0.54	0.45	UC Davis-Current Cost and Return Studies
Labor	0.31	0.21	
Other inputs	0.15	0.43	
Industry input usage share			
Land	0.20	0.80	USDA Census data
Labor	0.68	0.32	
Other inputs	0.59	0.41	
Input supply elasticities to crop production			
Land	0.2	0.2	
Labor	0.2	0.2	
Other inputs	1	1	

Note: The Allen elasticity of substitution (6×6) is not shown here due to limited space.

For the United States, the baseline demand elasticity is obtained from the paper of Rickard, Okrent, and Alston (2013). In the paper, they used latest data and estimated the demand elasticities for 9 major food categories in the United States. I used the fruit and vegetable elasticity for horticultural crop categories and the cereals and bakery elasticity as the elasticity for the grain category. For the export demand elasticity of grain crops, there are a number of estimations in the literature for U.S. crops such as soybean, corn and wheat. I have averaged the corn and wheat elasticities weighted on their shares in program crops to get a baseline value that is employed in the simulation model. Since soybeans were not included as a program crop in the 1990 Farm Bill; I haven't incorporated these values in the baseline value calculation. As for the elasticity of import demand, Kee et al. (2008) has estimated the import demand elasticities of goods for a large set of countries. As a large country in the world market, the United States has very elastic import demand elasticity for general goods at the HS- 6-digit level. Here it is assumed that the United States is a net importer of horticultural crops. Therefore, it will be relatively less elastic compared to all other agriculture commodities and I set the baseline value of the elasticity of import demand for horticultural crops as -1.0.

The baseline value of supply elasticities for the land and labor inputs are set at 0.2, which reflects limited movement of these resources out of crop production. The supply elasticity for the other inputs are set at 1.0 (Sumner, Lee and Hallstrom 1999). The aggregated input category is more elastic than labor and land because of its relative flexibility to move between sectors. The sensitivity analysis shows that the results do not depend heavily on the selection of the supply elasticities, and in general the results do not change across a plausible range of elasticity values.

The input cost shares are calculated based on the cost and return studies for major crops from University of California, Davis. I have selected major horticultural crops[14] produced and exported by the United States, and major grain crops[15] in the program crop category. The industry factor usage share λ_k^i are calculated using the county-level data from the DiD regression estimation. The estimation of Allen elasticities of input substitution are not available from literature and therefore I follow other simulation studies (Sumner, Lee and Hallstrom 1999; Rickard and Sumner 2008) with multiple inputs and set σ_{lk}^i to be 0 across different inputs and 1 for the same input.

The elasticities and shares as for the ROW are obtained in similar ways. The demand elasticity of grain crops is derived from Food and Agricultural Policy Research Institute (FAPRI) elasticity database. The database offers elasticities of a number of commodities for many countries and regions. I have averaged the elasticities of Africa, EU, Oceania, EU, South America, and North America excluding the United States by market share to calculate the ROW demand elasticity of grain crops as -0.35. For horticulture crops, there are no direct estimates from the literature and so following Sumner, Lee and Hallstrom (1999), the ROW demand elasticity of horticulture crops is set as -0.83. The export demand elasticity for horticultural crop is obtained from the USDA-ERS study of international food demand. Some aggregations across countries by market share are made to calculate the elasticity for ROW as -1.06. The import demand elasticity of grain crops for the ROW follows Kee et al. (2008) and is set to -1.5.

Because the ROW are aggregated major trading countries in the world, it is difficult to find appropriate average input or industry shares for all the countries, I follow the “20%:80%” rule (Reed, Elitzak and Wohlgenant 2002) of farm margin to estimate the cost shares. The industry input usage shares are proportions of total input used by all industries. Thus for each input, the shares across industries sum to one. Given the ROW is a net horticultural crop exporting region and the horticultural crops are more important users of labor and other inputs, I have assumed that the industry share in the horticultural industry in the ROW as 7:2:1 (for labor, other, and land input); the industry shares in the grain industry in the ROW is 5:2:3 (for labor, other, and land input). As mentioned before, the Allen elasticities of input substitution are set to 0 across different inputs and 1 for the same input. The industry input usage shares here are the calculated average share of the top five horticultural exporting countries according to the Johnson (2016).

The model also requires the cross-price elasticities between imported and domestically produced horticultural or grain crops. With no reliable empirical estimates in the literature, the Slutsky equation in elasticity form implies that the ratio of Marshallian cross-price elasticities between goods *i* and *j*, $\frac{\eta_{ij}}{\eta_{ji}}$ equals the expenditures on good *j* divided by expenditures on good *i* when their income elasticities are the same. Therefore, for the United States, I use data on the value of domestic production as a share of imports (Johnson 2016). The elasticity ratio of domestic horticultural products and imported horticultural products is approximately 2.5. For the ROW in 2015, U.S. grain exports were about 0.21 of the world grain export market (USDA FAS 2017). These share values are used to develop the ratio of the cross-price elasticities.

3.3.2 Simulation Results and Discussion

With the specified set of baseline parameters, I use the model to simulate the effects of the planting restriction on the international market for horticultural and grain crops. One way to examine the effects is to see what will happen in the international markets once the planting restriction is eliminated. Because the U.S. 2014 Farm Bill did eliminate the planting restriction by repealing the direct and counter-cyclical payment programs. I now measure the economic impact of eliminating the planting restriction on U.S. and international markets based on the estimation results from the 1987 - 1997 period. The results could serve as a prediction of the acreage re-location between horticultural crops and grain crops for the time period when the U.S. - Brazil cotton case took place.

Based on the estimation results from the DiD model, lifting the planting restriction will increase horticultural crop (fruit and vegetable) acres by 17.0% and decrease the grain (program) crop acres by 4.26%. These two percentage changes in the land input market are the exogenous shocks to the simulation model via equation (7') on the land use for horticultural crops and land use for grain crops in the United States. The price and quantity changes in the input markets and output markets are reported for a 17% increase on land use for horticultural crops and a 4.26% decrease on land use for grain crops after eliminating the planting restriction.

Table 3.6 shows the simulation results for the input market. The first column of Table 3.6 shows the input price and quantity changes of horticultural crop production; the mean value is shown along with the 95% confidence interval. There is an increase of the land input used for producing horticultural crops by 1.1%. Accordingly, the supply of labor and other inputs both increase by 0.13% and 1.5%, respectively. The second column presents the changes in land used for grain crops. All three inputs decrease, and the land input decreases most at 1.2%. The smaller decreases in the factors are a reflection of the inelastic property of input supply. Based on both columns, without the planting restriction, land resource is relocated from planting grain crops to horticultural crops. But the relocating amount is not much, so are the labor input and the other inputs.

Table 3.6. Simulation Result of the U.S. Input Markets

		Horticultural crops	**Grain Crops**
		Percent change in quantity (Confidence interval)*	
Supply	**Land**	1.1	-1.2
		(0.9, 1.2)	(-1.3, -0.8)
	Labor	0.13	-0.2
		(0.07, 0.2)	(-0.4, -0.03)
	Other Inputs	1.5	-0.7
		(0.5, 2.5)	(-0.8 -0.7)
Price	**Land**	0.05	-1.3
		(0.001, 0.08)	(-1.9, -0.008)
	Labor	1.2	0.03
		(0.8, 1.8)	(0.01, 0.26)
	Other Inputs	-0.03	0.2
		(-0.1, -0.02)	(-0.04, 0.3)

Note: *The 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

The quantity changes of the three inputs also lead to prices changes of the three inputs. The prices of land input and labor input for horticultural crop production increase by 0.05% and 1.2% respectively. While the price of other inputs for horticultural crop production decreases a little by 0.03%. As for the grain crop production, the land input price decreases by 1.3% while the prices of labor input and other input increase by 0.03% and 0.2% receptively.

The impact on the U.S. output markets are shown in Table 3.7. In the first column, we observe a 2.7% increase of the total horticultural supply in the United States. This leads to a decrease in U.S. imports of horticultural crops from the ROW by 0.5% and the price of the horticultural crops decreases by 0.01%. For the grain crops, there is a 1% decrease in the U.S. grain crop supply and an increase in the world grain price by 0.01%. Meanwhile, the export demand of the grain crops faced by the United States decreases by 2.3% which might be the result of the grain price increase.

Comparison of the simulation results for the ROW output markets is shown in Table 3.8. In the first column, the domestic supply of the ROW horticultural crop increases by 0.04%. Although the export demand of horticultural crops decreases by 0.2%, but the world price of horticultural crops decreases by 0.01%. This might have resulted in the supply drop of horticultural crops in the ROW. The second column of Table 3.8 lists the results for price and quantity changes for grain crops in the ROW. Because of the changes in the U.S. grain market, the grain crop supply of the ROW increases by 0.4% and leads to a 0.42% decrease in the imports of grain crops. As a price taker in the grain crop market, the ROW faces a 0.01% increase in the grain crop price. Table 3.8 also shows the planting restriction has limited impacts on U.S. grain crop trade. Eliminating the planting restriction increases the ROW grain crop production slightly, but this supply increase may still lead to an increase in the grain crop market share for the ROW. The decrease of the ROW imports of grain crops of 0.42% might be a result of the increasing of world grain price. Reducing importing grain crops from the United States, there can be an increasing of internal trade among countries of the ROW. With the world grain price increase, the grain producers in the ROW may benefit. I will discuss the welfare impact later.

Table 3.7. Simulation Result of the U.S. Output Market

	Horticultural crops	Grain Crops
	Percent change in quantity (Confidence interval)*	
Supply	2.7 (2.5, 3.5)	-1.0. (-2.4, 0.1)
Export Demand	-	-2.3 (-2.5, -1.6)
Domestic Demand of Imports	-0.5 (-0.9, -0.1)	-
Price	-0.01 (-0.03, -0.006)	0.01 (0.003, 0.12)

Note: *The 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

Table 3.8. Simulation Result of the ROW Output Market

	Horticultural crops	Grain Crops
	Percent change in quantity (Confidence interval) *	
Supply	0.04 (0.01, 0.1)	0.4 (0.1, 0.7)
Export Demand	-0.2 (-0.3, 0)	-
Domestic Demand of Imports	-	-0.42 (-2.3, -0.27)
Price	-0.01 (-0.03, -0.006)	0.01 (0.003, 0.12)

Note: *The 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

Elimination of the planting restrictions in the United States will re-allocate the land input: increase the land supply for horticultural crop and decrease the land supply for the grain crop in the United States. The trade flows between the United States and the ROW of both crops will also change with changes in the world prices. Based on the quantity and price changes, the simulation results suggest that eliminating the planting restriction would have decreased the export of grain crops from the United States to the ROW and allow the ROW to produce more grain crops. To study the welfare changes associated with eliminating the planting restrictions, I calculated the surplus changes for both the United States and the ROW.

The following equations are used to calculate the changes in welfare accruing to consumers of product *i* and to producers of factor *k* in region *y*. Welfare is measured in terms of changes in factor and product prices and quantities in the following equations:

$$\Delta CS_i^y = -P_i^y QD_i^y EP_i^y [1+0.5EQD_i^y] \qquad (9)$$

$$\Delta PS_k^y = W_k^y XS_k^y EW_k^y [1+0.5EXS_k^y] \qquad (10)$$

The initial product and factor prices and quantities for grain crops and horticultural crops were introduced previously as part of the elasticity estimations. I have obtained aggregate product price and quantity information from the Johnson (2016), USDA Census, and USDA FAS for the United States and the ROW. For the horticultural data in the ROW, quantity information is obtained for U.S. imports; the price information is aggregated data from top 14 horticultural exporting countries, particularly those that the United States had imports from in 2015[16]. For both the United States and the ROW, the factor quantities are calculated based on output quantities following the fixed factor assumption. The factor prices are calculated according to the "20% and 80%" rule based on output prices. Both calculations are weighted on market shares.

The change in total producer surplus in region *y* is the sum of the producer surplus from each factor market: $\Delta PS^y = \sum_k (\Delta PS_k^y)$ and the change in the total consumer surplus in region *y* is the sum of the consumer surplus across output markets $\Delta CS^y = \sum_i (\Delta CS_i^y)$. Results for the welfare changes are shown in Table 3.9.

The first column of Table 3.9 shows the welfare changes in the United States after eliminating the planting restriction. Producers of horticultural crops have an increased surplus of 2.6 million United States dollar (USD) and the producers of grain crops have a surplus reduction of 3.1 million USD. These changes may be due to the input price changes for horticultural and grain crops. Consumers of the horticultural crops has a surplus increase of 1.4 million USD. This might be due to the decreasing price of the horticultural crops. While consumers of the grain crops has a surplus loss of 0.3 million USD, which could be the result of the world grain price increase and reducing the supply of grain crops. The second column of Table 3.9 shows the results for the ROW. Here is a 1.6 million USD reduction in welfare for horticultural crop producers and a 2.0 million USD welfare gain for the grain crop producers. These changes might be due to the changes in the supplies of horticultural and grain crops. Consumers of horticultural crops have a welfare gain of 0.4 million USD while consumers of grain crops have a welfare loss of 0.2 million USD in the ROW which might be due to the world grain price increase.

Based on the welfare calculations, overall the net consumer welfare changes in the United States and ROW are both gains of 1.1 million USD and 0.2 million USD respectively. This may be due to the decreased prices and increased consumption of domestic/local goods. Moreover, the net U.S. producer welfare change is negative with a gain for horticultural crop producers and a loss for the grain crop producers. The net producer welfare change of the ROW is positive however with a loss to the horticultural crop producers but a gain to the grain producers. With the positive consumer welfare of the ROW, the overall net welfare is also positive. Based on the welfare results, eliminating the planting restriction reduces the welfare for certain groups of stakeholder but overall it benefits the ROW producers and consumers.

Table 3.9. Welfare Result of Eliminating the Planting Restriction

	The United States	**ROW**
	Welfare change in 2015 million USD (Confidence Interval) *	
Horticultural producer	2.6 (1.9, 2.6)	-1.6 (-1.8, -1.4)
Grain producer	-3.1 (-3.2, -2.9)	2.0 (1.9, 2.8)
Horticultural Consumer	1.4 (1.3, 1.7)	0.4 (0.3, 0.6)
Grain Consumer	-0.3 (-0.8, -0.1)	-0.2 (-0.8, -0.1)

Note: *The 95% confidence intervals are based on empirical beta distributions generated by variances on underlying elasticity parameters.

3.4 Conclusion and Implication

The focus of this paper is to understand how U.S. domestic farm policy is linked to trade disputes and international trade. The paper first estimates the acreage response to the planting restriction introduced in the 1990 Farm Bill. The planting restriction affects acreage allocation between program crops (grain crops) and horticultural crops (fruit and vegetable). The U.S – Brazil cotton dispute forced the U.S. government to rethink its domestic farm policy and led to the elimination of the planting restriction along with direct and counter-cyclical payments in the 2014 Farm Bill, in addition to other commitments and compensations made to Brazil. To understand whether the planting restriction had an impact on the international grain market, in particular the cotton market, a simulation model was built to analyze the elimination of the planting restriction.

The use and development of the economic simulation model relies on existing agricultural models and other elasticity estimates. A set of estimates was used as the baseline values and were borrowed from current and well-cited literature. In addition, additional simulation results show that my findings are not sensitive significantly to the values of parameters used in the model. Other econometric studies about the effect of removing U.S. subsidies for upland cotton have found much bigger or even opposite effects than those identified in this study (Sumner 2003). This is because in this paper I specifically examine the planting restriction rather than all polices applied to U.S. agricultural markets. Because the planting restriction is the key that makes other decoupled U.S. policies become trade distorting, it is important to detangle it from other policies and analyze the specific impact of the planting restriction on the cotton trade dispute.

In addition, this is the first study to use results based on county-level data to simulate the economic impact of removing the policy in the international market. The exogenous shocks which are important to a simulation model tend to be more accurate. The estimation results from the county-level data were able to capture detailed changes in acreage response to policy. When using more aggregate data, different changes in individual county's acreage responses may be ignored in the estimation. Moreover, my simulation model incorporates multiple crops. It is important for an agricultural policy simulation framework to include multiple commodities as the different crops can compete for the same land. In addition, some crops have a complement or substitute relationship in demand and policy changes for one crop can influence production and demand of other commodities.

Although the planting restriction indeed affected the planting and supply of U.S. domestic grain crops, the simulation results show that eliminating the planting restriction brings limited benefit to U.S. producers, with a producer surplus gain of horticultural crop producers but a loss of grain crop producers. The benefit to the ROW is also limited but towards what the Brazil government hoped and followed the WTO dispute settlement arbitration. The world price of grain crop increases a little and along with it the grain crop producers in the ROW enjoy a surplus gain (though the producer surplus of horticultural crop growers in the ROW loses). With this U.S. domestic policy change, the ROW grain crop producers would have been better off with an increase in their grain crop production and a larger market share in the world grain market (as intra-regional trade which cannot be captured in this model setting up).

In general, the paper finds that the planting restriction has a limited impact on world grain trade. This result is consistent with the finding made by the WTO dispute settlement panel on the U.S. – Brazil cotton case. The panel found that the U.S. planting restriction is trade distorting, but the loss it caused to Brazil may not be serious because Brazil failed to prove a necessary causal link between the planting restriction and significant price suppression. However because the planting restriction is the key that makes other decoupled U.S. policies become trade distorting, it directly affects the direct and counter-cyclical payments (the latter is judged to have caused significant price suppression by the WTO). Hence the planting restriction has been one of the focuses in the U.S. – Brazil cotton case and was eliminated in the 2014 Farm Bill.

There are limitations of the current analysis given the data and information availability. The assumption of the complete acreage relocation between horticultural crops and grain crops after removing the planting restriction may not be true in reality. Given the production requirement and capacity constrain, the land used to grow grain crops or particularly upland cotton may be used to plant other grain crops or crops with similar farming requirement rather than fruit and vegetables. In addition, according to Young et al. (2007), the land relocation after lifting the planting restriction is mostly likely from California, the Upper Midwest, and the coastal plain in the Southeastern States where the grain producers are mostly likely to switch from planting grain crops to fruit or vegetables. But the acreage shifts in these regions would not necessarily be large because the current planting restrictions may not always be binding for some producers. For example, some producers might have not followed the planting restriction in the first place by leasing non-base land, planting fruit or vegetables on owned (base) acres, and reconstituting the farm entity to preserve government payments. In addition, with the flexibility of growing fruit and vegetables on base acre, the grain producers might still be hesitating to switch to plant fruit or vegetables. Because securing sufficient labor for harvesting, the difficulty in establishing pre-harvest marketing contract with buyers, and other agronomic factors would also deter many grain producers. Given all these constraints, the result from the paper can still impose some implication for future studies in related issues.

With increasing global interdependency and growing international trade, domestic agricultural policies are becoming more and more influential to other countries through international trade. The planting restriction and the decade-long cotton dispute may serve as an example. Based on this paper’s analysis, policy makers should be more careful in domestic policy design, particularly to some domestic policy which may not directly link to trade but have the capacity to distort trade through decoupled programs. Meanwhile, it is expected that the WTO will continue to clarify the regulations, design more supportive agreements, and improve the trade negotiation and dispute settlement mechanism.

END NOTES

[1] Export credit guarantee program (GSM-102) provides credit guarantees to encourage financing of commercial exports of U.S. agricultural products. Specifically it reduces financial risks to lenders, credit guarantees encourage exports to buyers in developing countries mainly (USDA FAS. Available at: https://www.fas.usda.gov/programs/export-credit-guarantee-program-gsm-102). Now (2017) the upland cotton is covered in the program anymore.

[2] Marketing loans were started for rice and upland cotton in 1986 under provisions of the 1985 Farm Act. Later it included other crops such as soybeans, other oil seeds, wheat, and feed grains. Producers can benefit from the marketing loan program when they repay the loan at a lower prevailing world market price (at which the repayment rates for upland cotton is based on) (Westcott and Price 2001).

[3] Counter-cyclical payment is defined as transfers that vary inversely with market prices and are available for eligible commodities under the 2002 Farm Act whenever the effective commodity price is less than the target price. The payment amount for a farmer equals the product of the payment rate, the payment acres, and the payment yield. Payments are tied to historical base acres and program yields (ERS, 2010).

[4] Direct payments are defined as annual transfers to producers from the government based on payment rates specified in the 2002 Farm Act and a producer's historical program payment acres and yields (ERS, 2010).

[5] Green-box: The green box is defined in Annex 2 of the Agriculture Agreement. In order to qualify, green box subsidies must not distort trade, or at most cause minimal

distortion (paragraph 1). They have to be government-funded (not by charging consumers higher prices) and must not involve price support (WTO website).

[6] Base acreage is defined as farm's crop-specific acreage of wheat, feed grains, upland cotton, rice, oilseeds, or peanuts eligible to participate in commodity programs under the 2002 Farm Act (ERS, 2010).

[7] Specialty crops are defined as fruits, vegetables, tree nuts, dried fruits, nursery crops, and floriculture. They are also referred to as horticulture crops (ERS, 2010).

[8] Program crops are defined as crops for which Federal support programs are available to producers, including wheat, corn, barley, grain sorghum, oats, extra long staple and upland cotton, rice, oilseeds, peanuts, and sugar (ERS, 2010).

[9] Amber-box: All domestic support measures considered to distort production and trade (with some exceptions) fall into the amber box, which is defined in Article 6 of the Agriculture Agreement as all domestic supports except those in the blue and green boxes. These include measures to support prices, or subsidies directly related to production quantities (WTO Glossary: Available at: https://www.wto.org/english/thewto_e/glossary_e/amber_box_e.htm.)

[10] The 2014 Farm Bill available at: http://www.ers.usda.gov/agricultural-act-of-2014-highlights-and-implications/crop-commodity-programs.aspx#.U2QQx_ldXuM

[11] Two new programs—Price Loss Coverage (PLC) and Agriculture Risk Coverage (ARC). Producers of covered commodities (corn and other feed grains, wheat, rice, soybeans and other oilseeds, peanuts, and pulses) can choose to enroll in one of the two programs - USDA Farm Policy Glossary

[12] Although data in 1982 and 1992 are available, they are not used in the model because: data from 1982 was from a different source of 1987, 1992, and 1997 data; and the 1992 data may not be able to capture the changes of land use immediately after 1990 policy change.

[13] Data in Table 3.2 are from U.S. Census Report on Total Cropland acres and Program crop acres in 1987 and 1997 (USDA Census of Agriculture Historical Archive. Available at: http://agcensus.mannlib.cornell.edu/AgCensus/censusParts.do?year=2002)

[14] Major horticultural crops are selected: almonds, avocado, asparagus, blackberry, blueberry, broccoli, cabbage, celery, cherry, citrus, grapes, lettuce, melon, peach, pear, plum, prune, raspberry, strawberry, tomato, and walnut.

[15] Major grains in the program crops are selected: corn, cotton, oats, rice, sorghum, and wheat.

[16] By the share of total import value in 2015, top horticultural suppliers of the World in particular of the United States are Mexico (44%), Canada (13%), Chile (8%), the European Union (7%), China (6%), Peru (5%), and Costa Rica (3%). Other leading suppliers were Guatemala, Thailand, Brazil, Argentina, Turkey, the Philippines, and Ecuador. All other importing countries accounted for about 5% of trade. (Johnson 2016)

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CHAPTER 4. REVISITING HOW NONTARIFF MEASURES ARE QUANTIFIED: BARRIERS APPLIED TO INPUTS IN MARKETS WITH DIFFERENTIATED PRODUCTS

4.1 Introduction

Nontariff measures (NTMs) are becoming the major source of trade distortions contribute to fall in recent international trade negotiations (Yue Beghin and Jensen 2005; Liu and Yue 2009; Orefice 2017). In general, NTMs are the collection of policies other than tariffs that restrict and distort trade by changing quantities or prices, or both simultaneously (Liu and Yue 2009; Imbruno 2016). Some of the most commonly used NTMs include: import quotas, customs and administrative procedures, technical barriers to trade (TBTs), sanitary and phytosanitary barriers (SPSs), and rules of origin (Liu and Ye 2009; Imbruno 2016).

Among the various NTMs, the SPSs and the rules of origin are particularly prevalent in agricultural and food trade, especially in the period since the Doha Round negotiation (WTO 2001). The increasing use of SPSs and rules of origin is related to consumers' growing concerns on product quality and food safety issues (Korinek, Melators and Rau 2008; Beestermoeller, Disdier and Fontagne 2016). These concerns are also shared by governments as we see increased regulations in this area as a major topic in trade agreement negotiations. For example, in the Transatlantic Trade and Investment Partnership (TTIP) between the EU and the United States, there is heated discussion about government regulations concerning NTMs.

The TTIP has been under discussion since July 2013. It is aimed to increase trade and investment cooperation between the United States and the EU; it also aimed to harmonize standards and regulations across product and service sectors of the two regions (Seshadri 2013). According to the latest U.S.- EU joint report on TTIP progress released in January 2017, many discussions have been made about NTMs (USTR 2017), such as provisions surrounding SPSs, uniform standards and certification requirements. These discussions are not only about trade between developed economics, but also the potential impact of TTIP on developing countries, specifically on how to help developing countries meet the NTMs imposed by developed countries. In fact, the NTMs are of particular concern to exporters in developing countries, as they are a major impediment to international trade and can prevent market access (Khouilid and Echaoui 2017).

Despite the importance of NTMs in international trade, there are no already identified methods to quantify the effects of NTMs in the economics literature. Deardorff and Stern (1998) pointed out specific details of the NTMs are needed to be carefully looked at when choosing the quantifying methods, such as product type, imposing scope and so on. Many other research have been studied the same topic by reviewing available methods in the literature and adopt a most appropriate one for their specific purpose in quantifying the effects of a particular NTM (Beghin and Bureau 2001; Anderson and Wincoop 2004; Ferrantino 2006; Disdier, Fontagne and Mimouni 2008; Hoekman and Nicita 2011). The choice of appropriate quantify methods is important. These methods need to incorporate specific characteristics of the traded product and the careful details on the imposed regulations (Beghin and Bureau 2001; Agrekar 2017). However a better analysis of the effects of NTMs on trade is important not only for understanding the effects of regulations in ongoing trade negotiations, but will also clarify concerns among policy makers and others involved in the negotiations. There are a number of reasons why we need to further develop modeling effects of NTMs.

First, it is necessary to assess the actual effects of the NTMs to make decisions on trade agreement discussions such as in TTIP. This is because the attention in international trade has shifted from tariffs to countries' domestic regulations that affect production and trade (Beghin and Bureau 2001). Second, in order to solve trade disputes better, an effective technique to accurately estimate damages to trading partners caused by a country's mandated regulations is crucial. This type of estimation work also serves as a basis for calculating compensation claims. Third, the NTMs set up by developed countries have the capacity to create obstacles for exporters in developing, especially within the agricultural and food product sector (Cato and Lima dos Santos 1998; Otsuki, Wilson and Sewadeh 2000; Black and MacBean 2016; Murina and Nicita 2017). Developing countries are often motivated to enter the developed countries' markets (Hoekman and Nicita 2011) in the agriculture and food sectors since the Uruguay Round. However, previous exporting experiences show that the developing countries have gained little welfare, or even had welfare losses due to the NTMs imposed by developed countries (Fischer et al. 2008; Murina and Nicita 2017). Whether the NTMs are prohibitive or not, the compliance costs have led to increased trading costs for firms in developing countries (Fischer et al. 2008).

Motivated by the current TTIP negotiation which includes a focus on harmonizing NTMs, this paper first revisits previous studies on the impact of NTMs on international trade, particularly in the agricultural and food sector. Methods that have been used to quantify the trade effects of NTMs are in agricultural input markets are summarized as a first step. The reason to focus on regulations on agricultural inputs is because this is the most common part of the supply chain that involves NTMs in agricultural and food trade. An analysis in the input markets can be more complex considering the vertical market linkages between input and output markets. As a second step, I outline a strategy for choosing the appropriate method to quantify the effects of NTMs. In addition, a specific example of an input restriction imposed by the EU is analyzed to demonstrate the quantification of a real world NTM.

4.2 Review of Methodologies Used to Assess NTMs

4.2.1 Classification of NTMs

Korinek, Melatos, and Rau (2008) have classified NTMs by the type of policy instrument, scope of the barrier, regulatory target, legal discipline, type of market restriction, product category, and geographical region. Such a classification helps to identify differences in NTMs in agricultural and food trade among countries that could have a tendency to protect their domestic markets. To simplify or generalize these classifications, all NTMs can be analyzed based on the policy magnitude and the policy design.

The magnitude or degree of a NTM measures the stringency of the measure. For example, a policy magnitude can be as strict as an import ban (prohibitive), or it can be less strict through the use of Maximal Residue Levels (MRLs) based on the Codex[1] standard. The policy design of a NTM includes two components: 1) where the NTMs are imposed (e.g. on the input used to produce a product or on the final product content directly) and; 2) how the NTMs are implemented. For two examples: in terms of the geographical scope, the discriminatory or non- discriminatory NTMs are applied to domestic or/and foreign producers. In terms of product scope, he discriminatory or non- discriminatory NTMs are to all types of products or to a specific type of product when there is product differentiation in the market. Methods of quantifying NTMs will be analyzed based on above two classifications.

4.2.2 Price Wedge

The NTMs create a price "wedge" between the domestic price of the traded product in the importing country and the world price of the product. As mentioned before all NTMs can be categorized into two general types based on the policy magnitude (level of stringency), either stopping trade flows completely (prohibitive) or raising the transactions costs to reduce trade flows. In both cases, the price wedge exists. A direct way to measure the impact of the NTMs then is simply to calculate this price wedge (Korinek, Melators and Rau 2008; Beghin and Xiong 2016).

The key for the price wedge method is to separate other trade impediments from the NTMs in the process of calculation. There are many other factors that may also lead to a higher importing price. It is difficult to clearly distinguish the impact from the NTMs to other "distractions" such as transport costs, distribution costs, and perceived quality differences. Once these "distraction" factors are identified, it may be possible to determine the "equivalent" (ad valorem or specific) tariff rate that induces both the restricted import level and the higher domestic price induced by NTMs (Korinek, Melators and Rau 2008).

Another key assumption for the price wedge method is perfect substitution, or the homogenous products assumption which requests that the domestic and the imported products are perfect substitute. This assumption is especially difficult to hold in markets with standards such as agricultural and food markets with numerous food safety standards. Producers not only select the quantity to produce but also the quality. In addition, agricultural and food markets often include highly differentiated products (for example, food can be differentiated by production location, by variety, by size, by color, by harvesting time and so on) and calculating tariff equivalents for NTMs with the price wedge method may therefore be difficult. When firms can select both the quantity and quality of output (Alchian and Allen 1964; Hummels and Skiba 2004), there may not be a tariff equivalence for every quota and the price wedge method may fail.

Despite the difficulty, the price wedge method has been most often applied in analysis of agricultural and food trade. Krissoff, Calvin, and Gray (1997) used time series data to estimate the tariff rate equivalents of: SPS standards to prevent fire blight, codling moth, apple maggot, and other pests imposed by Japan, South Korea, and Mexico on U.S. apple exports. Meanwhile they compared the effects of removing tariff rates and removing NTMs with the estimated tariff rate equivalents. The paper showed the tariffs and the NTM barriers substantially decrease global apple trade in the examining time period.

Later, Calvin, and Krissoff (1998) further considered the effects of fire blight on transmitted on trade. They quantified the SPS barriers to U.S. apple exports to Japan by calculating the tariff equivalent using a partial equilibrium model. They simulated the trade and welfare results of eliminating the SPS and the tariffs when there is no transmission of the disease and when there is the transmission of the disease through international trade. They found that the NTMs and tariff barriers have much larger effects particularly on the U.S. apple trade than on other countries, with a short run effect at about 9% reduction in U.S. apple trade and a long run effect at about 35% reduction of U.S. apple trade.

Relaxation of the homogeneous product assumption is commonly used in studies that examine the effects of NTMs. Yue, Beghin, and Jensen (2005) derived a revamped tariff equivalent estimate of NTMs. In addition, they accounted for the large and costly border effects from transportation, linguistic differences, poor infrastructure and law enforcement. Specifically, they identified tariffs, quality differences, and marketing costs as three other possible reasons a price wedge between the domestic and foreign prices. They then developed a methodology to distribute the observed price gap back to these four sources. A partial equilibrium model was defined and simulated with apples differentiated as either domestically produced or imported. Yue, Beghin, and Jensen (2005) calculated the tariff equivalent for the SPS requirements for the U.S. apples. For different degrees of domestic preference and for different values for the elasticity of substitution, they found that removing the Japanese NTMs would actually generate limited export gains to the United States.

A limitation of the price wedge method is that it cannot be used when the magnitude of NTMs is very high and when the NTMs create prohibitive trade barriers, such as a policy ban. When there are no bilateral trade flows observed, there will not be a price difference to create a tariff equivalent. Yue and Beghin (2009) have solved this problem by using Wales and Woodland (1983)'s Kuhn-Tucker approach to estimate corner solutions in the consumer choice set. They derived a random utility model and used it to calculate the tariff equivalent of prohibitive NTMs imposed by Australia on New Zealand apple exports. By estimating the forgone apple trade between the two countries they found that the Australian NTMs have significantly decreased trade and created welfare losses of about 50million U.S. dollar for Australia.

Based on the above description and from examples in the literature, I summarize the price wedge method with the following properties: 1) to measure the magnitude (level of stringency) of NTMs, the price wedge method can be used to analyze a wide range of NTMs from the prohibitive (a ban) to less strict levels with different models and assumptions; 2) to measure the design (on what and how) of NTMs, it works for homogeneous products as well as heterogeneous products. The method can be used for NTMs imposed on inputs or outputs of the traded products; 3) the method is often used as a first step in a general equilibrium or partial equilibrium model to simulate market changes in price and quantity and to calculate welfare changes. It also facilitates the use of the gravity model method as it provides the tariff equivalent variable for that regression analysis.

4.2.3 Gravity Model

As one of the most commonly used methods in international trade economics, the gravity model has been often used to assess various issues in trade (Xiong and Beghin 2013a), such as distance, common borders and language, fixed trade cost between countries (Helpman, Melitz and Rubinstein 2008), as well as NTMs (Maskus and Wilson 2001). Gravity models typically use panel or cross-section data to regress bilateral trade values (exports or imports) on the above mentioned factors that are interpreted as explanatory variables. These coefficients provides a quantification of the impact of the NTMs on trade (Korinek, Melators and Rau 2008).

To better measure various NTMs, the gravity model is a flexible method that can accommodate a number of different approaches. A NTM can be measured according to it design of being either input-oriented or output- oriented (van Beers and van den Bergh 1997). The input-oriented measures quantify the factor inputs involved in meeting a given standard such as investments in pollution abatement and control, or public expenditure on research and development. The output-oriented measures, on the other hand, quantify the direct impact of the standard or regulation on the products themselves.

To measure the magnitude of NTMs, some research has used the gravity model to incorporate frequency and coverage measures. Gravity model analyses that use frequency and coverage measures of standards usually cover a wide range of products that are subject to NTMs. Estimation results concentrate on the direction of the trade impact, that is, whether standards are trade-restricting or trade-promoting. Some regress explicit standards and requirements such as MRLs directly into the model. Specific examples will be shown below in the discussion, as well as limitations of this extension of gravity modeling.

The analysis using gravity model is often subject to heteroscedasticity problems due to the “multilateral resistance term” that is omitted in the equation specification (Xiong and Behgin 2013b). Previous studies have examined heteroscedasticity in such applications (Anderson and van Wincoop 2003; Baldwin and Taglioni 2006; Silva and Tenreyro 2009) and have adopted various techniques properly to estimate the gravity equation (Silva and Tenreyro 2006; Martin and Pham 2008).

Munasib and Roy (2013) addressed structural issues and heteroscedasticity by introducing a new measure called the bridge to cross (BTC), which considers the regulatory gap between the exporting and importing countries for a particular NTM. Because the BTC effect varies over time by the trading partners, it is able to account for unobserved heterogeneity (multilateral resistance) in empirical trade models and in reduced form gravity models. As for application, Munasib and Roy (2013) used a specific SPS regulation example, the aflatoxin contamination in maize. The results showed that the BTC effect is higher for the less developed countries, which provided policy implications about market access for those countries.

Another point that generates concern with the gravity model specification is endogeneity. In theory, instrumental variable estimation can be used to mitigate endogeneity, however it may be difficult to find the suitable instruments (variables which explain the existence of the policy variable yet do not influence bilateral trade). Xiong and Beghin (2013b) addressed potential endogeneity by separating the NTM's impact on the import demand for the trading partners' supply of the products. As an empirical test Xiong and Beghin (2013b) used the example of high-income OECD countries importing plant products. The OECD countries set the MRL for the pesticide and antibiotic residues on the plant products. Xiong and Beghin (2013b) emphasized the fact that the same NTMs affect different trading partners in different ways. For an exporting county that already had similar MRLs as compared to other OECD countries, its exports to the market with a new MRL policy would be less affected when compared to other exporting countries. The results showed that the new MRL enhances the import demand and could hinder foreign exporters' supply. Moreover, exporters from less and least developed countries are more constrained by the MRL than those from developed countries.

The gravity model is summarized here comparing to the price wedge method. Similar to the price wedge method, the gravity model can also be used to measure different magnitude (level of stringency) of NTMs from the most prohibitive to less strict level. Compared to the price wedge method, the gravity model has less flexibility. There are two ways to measure the stringency of the NTMs, using the frequency and coverage measures of standards and using explicit standards requirements such as the MRL. In terms of measuring the design (on what and how) of NTMs, the gravity model approach works for NTMs imposed either on input or output markets. Compared to the price wedge method, it may work better for homogeneous products. When studying the heterogeneity products, the endogeneity issue can be taken care by separating different impacts on NTMs on products. In addition, the gravity model has been widely used especially in environment relevant policy analysis. It is focused on trade flow/volume estimation in terms of quantifying the effects of NTMs. In recent literature, the gravity model is also applied to price and welfare analysis when sufficient data is available (Disdier and Marette 2010).

4.2.4 Cost-Benefit Accounting

To measure the trade effects of NTMs, it is not only important to calculate the actual trade costs, but also to measure indirect costs associated with trade for both exporting and importing countries. The cost-benefit accounting method is designed to incorporate demand supply shocks that arise from the implementation of the NTMs. These shocks are especially important in conducting welfare analysis.

Increasing level of international trade have brought additional external effects (Van Tongeren, Beghin and Marette 2009) such as NTMs influenced production decisions, improved product quality, reduced asymmetric information, and changes in consumer demand. To become compliant with NTM standards, there will be additional production costs for firms (for example, labelling, testing, and obtaining certification). In addition, firms may have to adopt new production techniques for environmental or health or safety reasons. Standards can also change input requirements; for example, firms may need to add new machines to comply with regulations and this may affect the use of other inputs.

On the other hand, being compliant to NTM standards also bring benefits. It may reduce a firm's marginal cost of production by encouraging the firm to upgrade its facilities. There can also be the first mover advantage for firms entering new markets with specific NTMs. Consumer demand can also be altered as firms comply with NTMs. For example, when a NTM standard is implemented to enhance product quality, consumers should be willing to consume more products once the products meet a higher standard. Consumers may gain utility from the better quality (compliant) products and will be willing to pay higher prices for these products.

From another prospective, the cost-benefit accounting approach is able to assess the economic impact of market failures. There are three general market failures. First for consumers due to imperfection information and product quality concerns; second for producers due to output and input problems; third for society due to environmental and eco-system issues (Van Tongeren, Beghin and Marette 2009).

The cost-benefit accounting framework essentially employs a partial equilibrium model, with demand and supply relationships that can be calibrated to empirical data and therefore allows for the calculation of economic welfare effects. Usually, the demand side is modeled as a utility maximization problem and the supply side is modeled as a profit maximization problem. Specific utility and production functional forms can be structured according to specific NTM cases. In the simple case, a reduced functional form can be used with an exogenous parameter included in either/both demand and supply side to capture market shocks.

Peterson and Orden (2008) illustrated two characteristics of the cost-benefit framework with an example of Mexican avocado exports to the United States subject to SPS standards. They showed how the cost-benefit framework model is able to evaluate complicated changes in NTM standards and how it can be used to measure welfare changes, for both importing and exporting countries (Korinek, Melators and Rau 2008; Petterson and Orden 2008). Using a partial equilibrium model, the authors measured the welfare impact for both consumers and producers from both importing and exporting countries under three possible policy scenarios. They found that removing the remaining compliance measures would reduce the net welfare gain, so the results depend on specific measures and the estimated probabilities of pest infestations.

Another example is from Liu and Yue (2009). They first quantified the combined effects of SPS measures and customs and administrative procedures (two major NTMs) and followed the cost-benefit accounting framework to estimate the effects of these two NTMs in the Japanese cut flower market. They used specific function forms to model the consumer preference and production, paying special attention to incorporate the quality changes that occur for highly perishable agricultural products. The results that the two major NTMs had limited Japanese cut flower imports.

Van Tongeren, Beghin and Marette (2009) applied the cost-benefit accounting framework and provided both a theoretical and empirical illustration. The empirical example showed that the cost-benefit accounting method can be used to model markets with differentiated products. The research assessed the impact of mandatory labelling in the case of fish consumption in France (Matette et al. 2008). It evaluated the impact that a label providing health information had on consumer choice. There were two types of fish that consumers in France could choose from, a relatively "risky" type of fish and a type of fish that is not only "less risky" but also offers some health benefits. Fish exporters in the Ivory Coast and Seychelles faced a declining demand after the labeling scheme was implemented in France. Experimental data on the value of the information was collected for the simulation. Other key parameters in the model were either calculated or obtained from industry sources. They found that there was a positive net welfare gain from informing households at risk though some losses for the high risk fish producers and for consumers not concerned by the revealed information. The model successfully captured different consumers' (concerned and non-concerned about the health information provided on the label) responses to the labeling, and how different fish producers lost or gained from labeling. Among producers, the no risk and healthy information provided fish producers' welfare gain outweighed the loss of the risk fish producers.

Comparing to the price wedge and gravity model methods, the cost-benefit accounting method may be the easiest one to capture different levels of NTMs by calibrating parameters in the model set up. The prohibitive regulation such as an import ban can be easily analyzed as the autarky situation. Fewer assumptions are needed compared to the gravity model method. Similar to the price wedge and gravity model methods, the cost-benefit accounting method is able to measure the NTMs on homogeneous products and heterogeneous products, as well as NTMs imposed either on input or output markets for the traded products. The variations can be modeled as part of the utility and production functions. It can also be used together with the other two methods (Disdier and Marette 2010). With calculation or estimation results from the other two methods, the cost-benefit accounting method can be used to calculate the welfare of the NTM impacts. Another feature of the method is that in addition to historical trade data, the method is also able to use experimental data collected from laboratory or field research.

4.2.5 Summary of Methodologies

In section 2, I discussed three popular methods to quantify the impact of NTMs on trade and welfare. The three methods are evaluated based on their abilities to quantify the magnitude of a NTM and to assess the design of a NTM effect. Table 4.1 is a brief summary of these methods. All three methods can be used to measure different level of stridency of NTMs. The cost-benefit accounting method requires less assumption or modeling techniques. All the three methods are able to study the NTMs impact on input and output, on homogenous and heterogamous products. The gravity model method may requires most assumption in this case. The requirement for the data used in the gravity model can also be challenging. The price wedge method is the most direct way to quantify the actual cost involved in implementing NTMs and it is always used in conjunction with other methods to estimate trade flow and welfare effects. The gravity model method relates the degree of regulation to the value of bilateral trade between countries or to an individual firm's export decision. The frequency measure or coverage measure of a given standard determines the degree of regulation (Korinek, Melators and Rau 2008). The cost-benefit accounting method explicitly models how producers and consumers response to price changes induced by implementing or eliminating the NTMs.

Table 4.1. Summary of the Three Methods

Methods	Magnitude	Design		Others
		Object	**How**	
Price wedge	Y	output	Y	Always combined with other methods
Gravity model	Y	Y	Y	Trade flow estimation
Cost-benefit accounting framework	Y	Y	Y	Can be used with other methods; focusing on welfare measures

Although the three methods discussed in the paper are widely used by agricultural economists studying the effects of NTMs, there are limitations their application to estimation and simulation approaches. For the simulation model, the results depend on the specifications of utility and production, and the selection of parameters. The reduced-form econometric models of bilateral trade may have problems such as missing variables and incorrect functional forms. Therefore, sensitivity analysis is necessary when using the simulation methods.

Despite the limitations, these methods are still able to conduct reasonable impact analysis of NTMs on trade and welfare and to provide policy implications that are useful for trade negotiations. It is important to understand the mechanism of these methods so as to 1) choose the appropriate one to conduct research 2) to improve the current methods and to develop new methods to quantify the impact of NTMs. For policy makers and economists to determine which method is the most suitable, three issues need to be considered: 1) does the NTM tend to have significant impact on trade/ welfare? Answering this question requires reasonable predictions based on actual evidence and experience in the field; 2) what are the magnitude (prohibitive or not) and design (on input or output) of the NTM; 3) what are the characteristics of the products subject to the NTM? For example, highly differentiated or not? In the following section, I will provide a real example to taking these three issues into consideration to determine the most suitable method.

4.3 Empirical Application

Following the above analysis on how to choose an appropriate method to quantify the effects of a NTM, I will use an example in this section. A chemical, diphenhydramine (DPA) that is applied to apples during the postharvest storage may have negative impacts on human health. Due to this concern, the EU lowered the MRL of DPA on apples to a rate that is 50 times smaller than what is allowed in other major apple consuming countries in March 2014.

To quantify the effect of the new MRL regulation, an appropriate method should be chosen. First, it is likely that this particular NTM will cause a significant impact to EU apple trade as the EU is one of the largest apple importing region in the world. The MRL change will bring changes in welfares for major trading partners who export apples to the EU market. Moreover, the EU consumer and producer welfare will also change when it is being “protected” by the new MRL.

Second, the magnitude (prohibitive or not) and design (on input or output) of the NTM is critical to understand. This specific drop is prohibitive, 50 times lower than the Codex standard which is widely followed by most apple producing countries. The reduction in the MRL can be considered as a ban of the particular chemical to some extent as the new MRL is too low to even allow cross-contamination. Storage, packaging, and transportation facilities that are used for apples processed with DPAs could cause the problem of exceeding the new MRL even after stop using DPAs to future production. This huge reduction is expected to be met for both EU domestic apple producers as well as apple exporters. Hence the NTM is introduced with no discrimination. There is no difference between the EU home produced apples and the imported apples. This MRL drop affects a particular input in apple production;

Third, it is important to assess the characteristics of the products subject to the NTM. Apples are a highly differentiated agricultural category. There are many varieties of apples that differ in taste and appearance. Also, the NTM has the capacity to lead to quality improvements for products that are compliant with the standard.

Taking all these issues into consideration, the cost-benefit accounting method appears to be the most suitable method to adopt for quantifying the EU MRL reduction. The price wedge method is not sufficient to capture the trade flow changes and welfare changes and would need to be combined with another method in order to address the third issue of assessing product characteristics. Both the gravity model and the cost-benefit accounting method are able to address the second and third issues listed above. However, the cost-benefit accounting method focuses on welfare analysis and this is a priority in this case. In addition, there are limited trade data given that the

NTM was recently implemented which may add difficulties when using the gravity model. In the following section, the specific modeling approach will be shown and described further.

4.3.1 A Model to Study the Effects of a DPA Ban for EU Apple Imports

To model the effect of a NTM, the appropriate product analysis is important. With apples there are many different varieties. Some varieties of apples suffer severely from specific postharvest disorders while others do not, and those apples that are susceptible to postharvest disorders are treated with DPA when stored. The MRL reduction concerning the use of DPA is a NTM that only targets certain apple varieties. While other varieties of apples are not directly affected by the NTM. My model will highlight this product differentiation by assuming different varieties of apples are imperfect substitutes. The nutrition content may not vary too much but other factors such as taste, fragrance, and textures that are directly related to consumers' preference as highly differentiated. In addition, the new MRL is applied to both the European apple producers and foreign apple producers without discrimination. Therefore, for the same variety of apples, the domestic produced apples (assuming there are the same varieties produced in the EU) and the imported apples are perfect substitutes for one another.

The NTM created by decreasing the MRL on stored apples can be conceptualized as a negative shock on supply, specifically on the storage input used in apple production. The new MRL requirement will increase production costs because producers need to make effort to become compliant to the new MRL standard. The MRL for the DPA imposed by the EU is the lowest in the world; it is 50 times lower than the previous Codex standard the EU and other major apple producing countries used (Calvo 2010). This implies that the effort level required to become compliant to the new MRL is significant.

For producers, it is expected that producers in the EU and elsewhere will become compliant to the MRL so as not to give up the EU market. Non-EU apple producers may have more flexibility because it is easier for them to switch to other export markets, however entering new markets elsewhere can also be costly. The EU apple producers will have to become compliant to the NTM despite the increase in production costs.

Although apples are highly differentiated products, different varieties of apples may not be perfect substitutes for each other. The reduction in the most affected varieties from the EU may result in an increase in supply of other varieties of apples that are not much affected by the NTM. These less-affected apples require less storage input in their production. So the NTM won't increase their production cost as much as the apple varieties that requires more DPA in postharvest storage. It is expected that both EU production and EU imports of these less affected apples will increase and these producers may enjoy a welfare gain.

The NTM will increase consumers' surplus by improving apple quality as this particular NTM is a MRL reduction in a chemical that could potentially threaten human health. Therefore apples that are compliant to the NTM are considered to have better "quality" in the EU market. In addition to the quality improvement, there will be consumer surplus change due to a reduction in the supply of the affected apples and an increase in the supply of the apple not affected by the MRL. The overall EU consumer surplus is expected to be positive in the long run under the new NTM.

Based on the above analysis on the NTM, for apples imported into the EU, a partial equilibrium model is developed to examine the NTM and to understand the likely effect on production, consumption, and international markets. To model the consumer demand, apples are considered to be heterogeneous by varieties. For simplicity, assuming the EU is importing all N varieties of apples, denoted by i, $i=\{1,\ldots, N\}$ from foreign countries and producing them domestically. These apples are categorized into four groups: domestic produced apples susceptible/non-susceptible to postharvest disorders (such as Gala/ Honey Crisp and Granny Smith), imported susceptible/non-susceptible to postharvest disorders (such as Gala/ Honey Crisp and Granny Smith). To focus on quantifying the NTM of dropping the MRL on DPA, tariffs are not included in the model.

On the supply side, there are M inputs, denoted by k, $k=\{1,\ldots, M\}$, that are commonly used in the production of all domestic produced varieties. The model includes two main types of inputs: farm input (storage input) and marketing input. The input ratios used in apple production vary across different varieties of apples. For example, the apples susceptible to postharvest disorders require more storage input and thus have a bigger input ratio of the storage input compared to the varieties that are non-susceptible to postharvest disorders. The production inputs are assumed to not be non-tradable and for simplicity, fixed input proportions are assumed here. The particular NTM set up by the EU will affect the storage input in the apple production. The production cost of the apples susceptible to postharvest disorders will increase relatively more than the non-susceptible because the susceptible apples have a bigger cost share for the storage input.

To focus on the EU apple trade, the model is simplified to include only two regions: the EU and the – rest of world (ROW) apple producers. In the model, the EU is considered to be a net apple importer and the ROW is considered to be a net apple exporter. Apple trade among the countries in the ROW region is viewed as intra-regional trade and will not be captured in the model. Therefore, the model is set up to only study the apple trade between the EU and the ROW. In addition, the model also considers input market to analyze the NTM imposed on the particular storage input (the farm input). The model is able to address the effect of a NTM imposed directly on the output market, especially in the case of product differentiation in the output market.

Following the cost-benefit framework, a partial equilibrium model with the features described above is set up as following:

(1) $$QD_i^y = f_i^y(P, V^y)$$

(2) $$QM_i^y = m_i^y(P, Z^y)$$

(3) $$QX_i^y = g_i^y(P, R^y)$$

(4) $$QS_i^y = QD_i^y + QX_i^y - QM_i^y$$

(5) $$P_i^y = \frac{\partial TC_i^y(W_k^y, QS_i^y)}{\partial QS_i^y}$$

(6) $$x_{i.k}^y = \frac{\partial TC_i^y(W_k^y, QS_i^y)}{\partial W_k^y} QS_i^y$$

(7) $$XS_k^y = h_k^y(W_k^y, U^y)$$

(8) $$XS_k^y = \sum_{i=1}^{N} x_{i,k}^y$$

There are eight equations with eight unknown variables in the model. Equation (1) is the output demand, where QD_i^y is the domestic demand of output *i* in region *y*, where $y \in \{\text{EU, ROW}\}$. The price vector *P* is *p*={p_1, …, p_N}. It is the same for both domestic produced and foreign produced apples. The vector of exogenous variables is denoted by V^y which includes policy changes such as government mandate and changes of consumers' preferences. Equation (2) is region *y*'s demand for the imported crop *i*; QM_i^y is the import demand function with a vector of exogenous variables Z^y. This equation is only for the EU that has import demand for apples Equation (3) is the export demand function of apples. Vector R^y is the vector of exogenous variables including factors that affect the exports demand such as existence of free trade agreement, natural disasters in the importing countries, transportation costs and so on. Equation (4) is the output market clearing condition and QS_i^y is the total supply of output *i* in region *y*. Equation (5) shows the competitive equilibrium and TC_i^y is the total cost function of output *i* in region *y*. The equation shows the market clearing condition for domestic produced product *i* where marginal cost equals domestic price. The derived input *k* in region *y* is shown in equation (6), where W_k^y is the price of input *k* is in region *y*. Equation (7) is the input *k* supply function in region *y*. The vector U^y denotes a set of exogenous variables that affect supply in region *y*. Here both foreign and domestic apple producers are subject to the new NTM created by the lower MRL of DPA on apples. Equation (8) is the input market clearing condition in region *y*.

Total differentiating equation (1) to (8) yields the following linear elasticity model. Here η_{ij}^{y} is the demand elasticity of output *i* with respect to the price of output *j* of region *y*. Similarly, import demand elasticity is η_{mij}^{y} and the export demand elasticity is η_{xij}^{y} in region *y*. Parameter $\gamma_{i,k}^{y}$ is the cost share of input *k* in the production of output *i* in region *y*. Its summation over input *k* equal to 1. Parameter $\sigma_{i,kl}^{y}$ is the Allen elasticity of substitution between input *k* and *l* used in the production of output *i* in region *y*. In Equation (7'), variable ε_k is the elasticity of supply of input *k* in region *y*. In the last equation, the industry share of input *k* in the production of output *i* in region *y* is denoted as λ_k^i. After specifying the key parameters in the above system, the model will be able to capture the changes in apple trade flows. With the simulated changes in output price, output production quantity and export quantity, welfare changes of apple consumer and producer due to the NTM imposed by the EU on apple production input can also be calculated.

$$(1') \qquad \mathrm{EQD}_i^y = \sum_{j=1}^{N} \eta_{ij}^{y} \mathrm{EP}_j$$

$$(2') \qquad \mathrm{EQM}_i^y = \sum_{j}^{N} \eta_{mij}^{y} \mathrm{EP}_j$$

$$(3') \qquad \mathrm{EQX}_i^y = \sum_{j=1}^{N} \eta x_{ij}^{y} \mathrm{EP}_j$$

$$(4') \qquad \left(\frac{QS^y}{QD^y}\right)\mathrm{EQ}S_i^y = \left(\frac{QD^y}{QS^y}\right)\mathrm{EQD}_i^y + \left(\frac{QX^y}{QS^y}\right)\mathrm{EQX}_i^y - \left(\frac{QM^y}{QD^y}\right)\mathrm{EM}_i^y$$

$$(5') \qquad \mathrm{EP}_i^y = \sum_{k=1}^{M} \gamma_{i,k}^y \mathrm{EW}_{\mathrm{k}}^y$$

$$(6') \qquad \mathrm{Ex}_{\mathrm{i,k}}^y = \sum_{k=1}^{M} \gamma_{i,k}^y \sigma_{i,kl}^y \mathrm{EW}_k^y + \mathrm{EQS}_{\mathrm{i}}^y$$

$$(7') \qquad \mathrm{EXS}_k^y = \varepsilon_k^y \mathrm{EW}_k^y$$

$$(8') \qquad \mathrm{EXS}_k^y = \sum_{i=1}^{N} \lambda_{i,k}^y \mathrm{Ex}_{i,k}^y$$

4.3.2 Parameterization

Parameterization of the model is done by selecting and aggregating data across apple varieties and trading countries. Since apples are a highly differentiated product, I have categorized the data based on two features: the postharvest disorder property and the place of origination.

According to the European Commission Agricultural and Rural Development (2011), the EU imports mainly apple varieties that are mid-sized and have sour and sweet flavor based on the preferences of the European consumers. The most popular EU produced and imported apple varieties are Gala, Honey Crisp, and Granny Smith. Among them, the varieties that suffer most from postharvest disorders are Honey Crisp and Granny Smith. The varieties that is non-susceptible to postharvest disorders is Gala, which is not much affected by the new NTM. In the model, I have aggregated the information of Granny Smith and Honey Crisp apples to describe the properties for their varieties that are susceptible to postharvest disorder varieties and use the Gala information to describe the varieties that are non- susceptible to postharvest disorders.

For the ROW producers that export apples to the EU, I have identified Chile, New Zealand, South Africa, Brazil, and Argentina from the Southern Hemisphere and the

United States, China, and Canada from the North Hemisphere (European Commission 2011) as representative countries. These countries are the major apple exporting countries to the EU markets and I aggregated trade flow patterns from these countries to describe ROW apple producers.

A consistent demand specification, including all of the exogenous variables, would require the various adding up properties implied by production differentiation and the budget constraint to hold. However, given the model is partial equilibrium in nature, the aggregate income and prices of products outside of the apple sector would remain constant throughout the adjustment process. The own price elasticities for output apples were obtained from the SWOPSIM database developed by the Economic Research Service of the US Department of Agriculture (USDA SWOPSIM). Combining with studies of Lechene (2000) and Cerda et al. (2004), I have obtained the overall demand elasticity for apple in the EU and in the ROW region as -0.26 and -0.41. Kee, Nicita, and Olarreaga (2008) estimated the import demand elasticities for a large set of countries at a disaggregated level of product detail. The estimated import demand elasticities for the EU is about -0.1 for apple. The cross-price elasticities for different varieties of apples are obtained from Richards and Patterson (1998) and aggregated based on European market share for the non-susceptible and susceptible varieties as 0.35. For both categories of apples, I assume that domestic produced and imported apples are perfect substitution for each other. For the foreign apple producers, there is no reliable estimates in the literature to describe the export demand elasticity for foreign markets. I set the export demand elasticity as -1.5 given it is relatively more elastic for the foreign producers following Stone (1979) and Reimer, Zheng and Gehlhar (2012). Using these elasticity parameters (demand, import demand, and export demand), I used the Armington specification with market shares of different varieties of apples in the EU domestic apple market and the EU import apple market to calculate the elasticities of the susceptible and non-susceptible varieties[2]. Following previous estimated supply elasticities in the literature (Nerlove and Addison 1958; Gardner 1979), I set the baseline supply elasticity parameter for apples equal to 0.5 for both the EU and the foreign apple producers, assuming that the supply of fruit is relatively inelastic. Since apples are perennial crops, all cross-price elasticities of supply are set to equal to zero (Rickard and Lei 2011).

These elasticity values that were obtained from empirical studies are used as the baseline value of elasticities. Later, a Monte Carlo simulation is adopted to conduct a sensitivity analysis across a range of parameters. Therefore, I set the baseline parameters as the central tendency and specified a variance of 0.04 to develop beta (3,3) distributions (Brester, Marsh and Atwood 2004). The distributions are selected to ensure negative demand elasticities and positive supply elasticities in the analysis. The beta distribution is often used to model events that are constrained to an interval between a minimum and maximum value.

I have calculated cost and industry shares for European domestic producers based on European Commission data. For the ROW region, I follow Sumner, Lee and Hallstrom (1999) and the USDA-ERS “20%:80%” marketing margin[3]. All the price and quantity data for apples are obtained from the European Commission (EUROSTAT) and USDA Foreign Agricultural Service’s report on apple and pear production in 2011. These initial price and quantity values are also used for the calculation of welfare changes.

The exogenous shock brought by the NTM is imposed on equation (7’). As mentioned before, the new MRL of DPA on apples increases the production cost, especially for the susceptible varieties of apples which require more DPA in the storage stage. According to the industry information (USAEC 2013), it is difficult to estimate how much the NTM could increase production costs. Because the new MRL is so low, apples can also be contaminated by the DPA in packing, shipping, and in other stages in addition to the storage stage of the apple production, as long as the apple producers continue using their old facilitates. To become compliant to the new MRL, not only do producers need to update storage techniques and equipment, but also they need improvement in the storage stage and also they need investment in other stages and therefore the strictness of the NTM has made it complex to calculate the increased cost for apples producers. However, what can be certain is that the strict MRL will increase production cost and is considered to be prohibitive for some small apple producers with limited capacities. Therefore, in the model, I simply assume a plausible range of increases in storage input costs for apple production between 25% and 35%. This plausible range is based on the production cost case study of the EU apple in 2011.

4.3.3 Results

Results from the partial equilibrium model are reported in Table 4.2. The three columns show the results when production costs increased by 25%, 30%, and 35% respectively. The first two rows show the price changes for the susceptible and non-susceptible apple varieties. Because of the MRL reduction of the DPA, the storage input cost increases. Therefore the price of apple varieties that are intensively using this input also increase. The results show that the price of susceptible apples would increase by 2.01%, 2.04% and 2.23% with different increases in the cost of the farm input. However, the increases in the storage input production cost do not affect the production of the susceptible variety of apples in a significant way. The slight price decreases may be due to the substitution effects between different varieties of apples, increasing supply of the other variety, or more abundant supply of the other input due to the decreasing production of the other varieties of apples.

As for the apple imports into the EU, there is approximately a 15% decrease in EU imports of susceptible apples from the ROW suppliers. Some of these export reductions may be temporary yet some of them may be permanent because some foreign producers may give up exporting the susceptible varieties due to the new NTM. However, the foreign apple producers meanwhile increase their exports of the non-susceptible varieties to the EU. There is an obvious substitution effect between the susceptible and non-susceptible apples. The EU imports more non-susceptible apples to its market, to “make up” for loss in exports of the susceptible apples. In all the three scenarios, there is a 10% increase in the EU imports of non-susceptible apple varieties.

Table 4.2. Economic Effects of Reducing MRL of DAP on Apples in the EU			
	Increasing farm input cost by 25%	Increasing farm input cost by 30%	Increasing farm input cost by 35%
Price Changes (unit %)			
Susceptible variety	2.01 (1.8, 2.05)	2.04 (2.0, 2.1)	2.23 (2.2, 2.6)
Non-susceptible variety	-0.16 (-0.18, -0.1)	-0.16 (-0.2, -0.06)	-0.18 (-0.19, -0.16)
Quantity Changes (unit %)			
EU imported susceptible variety	-13.86 (-13.98, -12.11)	-15.19 (-15.80, -13.99)	-16.01 (-16.82, -15.82)
EU imported non-susceptible variety	7.95 (7.22, 8.01)	9.98 (8.76, 10.10)	10.56 (9.53, 11.00)
EU produced susceptible variety	-3.02 (-3.67, -2.96)	-3.95 (-4.32, -3.63)	-4.24 (-4.89, -3.90)
EU produced non-susceptible variety	13.23 (12.08, 14.21)	15.68 (15.60, 16.12)	17.99 (16.34, 18.32)
Surplus Changes (unit million USD in 2011)			
Foreign producers of susceptible variety	-0.81 (-0.86, -0.78)	-0.98 (-0.98, -0.96)	-1.08 (-1.12, -0.99)
Foreign producers of non-susceptible variety	0.88 (0.83, 0.93)	1.00 (0.96, 1.26)	1.02 (0.95, 1.10)
Net producer surplus changes	*0.07* *(-0.03, 0.15)*	*0.02* *(-0.02, 0.3)*	*-0.06* *(-0.26, 0.11)*
EU producers of susceptible variety	-0.09 (-0.11, -0.02)	0.01 (0.01, 0.06)	0.01 (0.008, 0.05)
EU producers of non-susceptible variety	0.32 (0.30, 0.42)	0.33 (0.31, 0.42)	0.35 (0.29, 0.36)
Net producer surplus changes	*0.23* *(0.19, 0.40)*	*0.34* *(0.32, 0.48)*	*0.36* *(0.298, 0.41)*
Consumers of susceptible variety	-0.92 (-1.02, -0.92)	-1.08 (-1.3, -1.06)	-1.21 (-1.40, -0.98)
Consumers of non-susceptible variety	0.93 (0.89, 1.02)	0.99 (0.93, 1.04)	1.04 (1.01, 1.2)
Net consumer surplus changes	*0.01* *(0.13, 0.1)*	*-0.09* *(-0.37, -0.02)*	*-0.17* *(0.39, 0,22)*

Note: Mean values are reported with a 95% confidence interval

The same NTM applied to the EU domestic markets also leads to a reduction in production of the susceptible varieties of about 4% in three scenarios. This may be due to the increasing production cost brought by the NTM. Compared to the reduction of the imports of the susceptible varieties, the relatively smaller reduction of the domestic produced apples implies a better response among European apple producers to the NTM. Possible reasons for the better response can be: 1) earlier and better preparation of the policy changes notice. The particular NTM is implemented as a government mandated standard so there has been more local discussion in the EU on this issues before the implementation of the NTM; 2) less flexibility in exiting the EU apple market. In addition, there is also a larger increase in the supply of the non-susceptible varieties from the EU domestic apple producers (about 16%) compared to the foreign producers. Both the price and demand increases for this variety of apples results in the increased production.

The last nine rows in Table 4.2 show the changes in the producer and consumer surplus for both susceptible and non-susceptible apple varieties. I calculated the welfare changes for both producers and consumers in the EU and ROW, using changes in factor and product prices and quantities in following equations:

$$\Delta CS_i^y = -P_i^y QD_i^y EP_i^y [1+0.5EQD_i^y] \qquad (9)$$

$$\Delta PS_k^y = W_k^y XS_k^y EW_k^y [1+0.5EXS_k^y] \qquad (10)$$

As mentioned before, I have obtained apple price and quantity information for both the EU and its apple trading partners in the ROW from the EUROSTAT and USDA Foreign Agricultural Service's report on apple and pear production in 2011. The factor quantities of the EU and the ROW are calculated based on output quantities following the fixed factor assumptions. The factor prices of the farm input and marketing input are calculated according to the "20% and 80%" rule based on output prices. Both calculations are weighted on market shares. The change in total producer surplus in region *y* is the sum of the producer surplus from each factor market: $\Delta PS^y = \sum_k (\Delta PS_k^y)$ and the change in the total consumer surplus in region *y* is the sum of the consumer surplus across output markets $\Delta CS^y = \sum_i (\Delta CS_i^y)$.

Throughout the three scenarios, the foreign producers lose welfare for the susceptible varieties but gain for the non-susceptible varieties. In the first two scenarios, when the production costs increase by 25% or 30%, the net changes in producer surplus are positive. In other words, the gains from the non-susceptible varieties outweigh the losses from the susceptible varieties for the producers in the ROW region. In the third scenario, the net producer surplus for the ROW region is negative. This indicates that the cost increase and the loss of the EU market for the non-susceptible varieties lead to an outcome with negative welfare for foreign producers under the NTM. The producer surplus changes imply that under the NTM, foreign producers may not stop exporting apples to the EU market. By increasing exports of non-affected apples and decreasing exports of affected apples, foreign apple producers may actually be better off in some circumstances depending on the magnitude of the production cost rise.

As for the EU producers, there are consistent producer surplus losses for producers of the susceptible varieties and gains for producers of the non-susceptible varieties in all the three scenarios. The net producer surplus changes are also consistently positive in all the three scenarios. Because of the better response to the NTM and to the domestic policy changes, the EU apple producers overall are not hurt by the NTM but are better off as they become more competitive in the apple market compared to the

ROW producers.

Consumers of the susceptible varieties lose because of higher prices and also due to the smaller quantity available in the market. The quality improvement of the apples brought by the new MRL doesn't lead to a large impact; more time is needed for consumers to recognize the quality improvements for the susceptible varieties. Consumers of the non-susceptible varieties enjoy a welfare gain because more apples are available in the market. The net welfare changes for consumers who consume both types of apples are positive in the 25% scenario but negative in the other two scenarios. The larger loss among the susceptible varieties may be due to the relatively higher price and larger market share of this particular type of apples in the EU market.

The simulation results are consistent in all the price, quantity, and surplus changes throughout the three scenarios. Based on the results in Table 4.2, the reduction of the MRL for DPA has decreased the imports of the affected varieties of apples from foreign countries and also decreased the EU domestic production of these types of apples. However, because of the highly differentiated structure of the apple markets, trade in apples did not disappear. Instead, the EU imports more other varieties of apple to replace the NTM-affected apples. Meanwhile the EU increases its domestic production of other varieties of apples. The NTM has changed the composition of apple trade flows into the European market and the market shares of different varieties of apples in the EU. In addition to the actual market change, the EU apple producers enjoy a welfare gain under the NTM. The foreign apple producers also do when they experience mostly increases in gain under the NTM. The consumers are expected to enjoy a welfare gain in the long run if they value the quality improvements linked to the NTM.

Above is a specific example of importing country's policy change on agricultural input using the cost-benefit accounting method to quantify the effects of the policy NTM. The method here pays special attention to how the NTM is implemented when it affects an input market directly. It also incorporates the product differentiation character of the particular market. Despite some limitations in the empirical example, it has demonstrated clearly the importance of the process for choosing an appropriate method to quantify a NTM, analyzing the effects of supply and demand, and finally the welfare analysis using the cost-benefit framework.

4.4 Conclusion

Motivated by the gaining importance of NTMs in international trade, particularly in agricultural and food trade, this paper reviews previous studies that used various methodologies of quantifying NTM in agricultural markets. The three most popular methods are summarized: the price wedge, the gravity model, and the cost-benefit accounting framework. Each method is analyzed according to their characteristics, and I provide actual examples from the literature to further demonstrate the details of each method.

A general guideline of how to choose the most appropriate method is then summarized and applied to a real-life example using the cost-benefit accounting framework. The example follows the core concepts of the cost-benefit analysis framework. I build a partial equilibrium model to assess the economic effects of the NTM created by the EU. The cost-benefit accounting framework is flexible to model specific characteristics of different NTMs and different product markets. It could model explicitly the changes of consumer and producer and also specifically capture the product heterogeneity and the input response of the producers' problem.

The cost-benefit accounting framework is the most appropriate approach for this particular example studied in the paper for the output, namely a NTM affecting the input market in a market with product differentiation. However, for policy makers and economists to determine which method is the most suitable to quantify the effects of NTMs in their specific work, they should carefully consider the characteristics of the particular NTM, the related product, and the purpose of the work in order to choose the most appropriate method. Again, three issues need to be considered when choosing a method: 1) the impact of NTMs on trade/ welfare 2) the magnitude and design of the NTMs and 3) the particular characteristics of the products subject to the NTMs.

END NOTES

[1] Codex Alimentarius is a joint body of the UN World Health Organization and Food Agriculture Organization. Codex MRLs are science-based and considered least trade-distorting. Most countries follow the Codex recommendations for MRLs. However, there are a few exceptions: the United States use MRLs regulated principally by the US Environmental Protection Agency with enforcement functions by the US Food and Drug Administration, US Department of Agriculture, and state enforcement agencies (USEPA, 2013). The EU, Australia, and Japan tend to have MRLs that are much more stringent than the Codex MRLs. A few developing countries such as Sri Lanka use lenient MRLs (Li and Beghin 2012).

[2] Demand elasticity, import demand elasticity, and export demand elasticity of the susceptible varieties are generally more elastic than the non-susceptible varieties.

[3] For every 1 dollar spent in producing an agricultural output, 0.2 is used for farm input and 0.8 is used for marketing input (Reed, Elitzak and Wohlgenant 2002).

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