



Is Regulatory Harmonization Efficient?
The Case of Agricultural Biotechnology Labelling

Lee Ann Jackson

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Adelaide University
Adelaide 5005 Australia

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Lee Ann Jackson
Centre for International Economic Studies and
School of Economics
University of Adelaide
cies@adelaide.edu.au

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Abstract

This research uses a general equilibrium framework to examine the impacts of labeling policies on genetically modified (GM) agricultural products in the international trading system. The research focuses on the case of the policy debate between the United States and the European Union. Numerical calibrations of the general equilibrium model using 1998 data are used to examine four scenarios: both countries labeling, neither country labeling and the two cases when countries pursue mixed strategies. Results indicate that the benefits of countries pursuing mixed strategies outweigh the benefits of harmonized labeling policies. Countries that introduce labeling regulations restrict access to their agricultural markets. However, the benefits consumers obtain from having access to information about GM content compensate for the trade inefficiencies introduced by differing national labeling regulations.

Introduction

Escalating international conflict surrounding agricultural biotechnology products reflects on-going struggles over food safety policies within the international trading system. Since the Uruguay Round trade negotiations in 1986-94 limited the use of tariffs and subsidies, countries have sought alternative mechanisms for protecting their national agricultural systems from international competition. Countries may implement food safety regulations that restrict trade due to justifiable food safety concerns. However they can also use these same regulations to camouflage protectionist intentions. Traditional food safety issues include agricultural pesticides and livestock disease control, but the development of agricultural biotechnology in the late 20th century created an entirely new type of agricultural production – one for which existing regulatory regimes were unprepared. Countries differ in their basic categorization of genetically modified (GM) products which inevitably leads to divergent regulatory approaches, including what type, if any, of labeling is required for GM products. The international trade community is waiting to see how the World Trade Organization (WTO) will address the existence of diverse national labeling systems.

This paper compares the efficiency of agricultural biotechnology labeling systems within an international trade context. The paper focuses on United States and European Union labeling of GM products to highlight the differences between harmonized and heterogeneous label systems. National policies reflect underlying assumptions about how biotechnology differs from existing technologies. Since US agricultural biotechnology policy is based on the assumption that GM products are essentially equivalent to traditional products, existing US regulations are used to control the introduction and marketing of these products. In the US three agencies control regulation of biotechnology. The Environmental Protection Agency attends to the potential pesticide and herbicide impacts of biotechnology products. The United States Department of Agriculture controls the introduction of these species into the environment through test plots. The Food and Drug Administration monitors and regulates the potential food safety of these products. Local

governments also may enact legislation regulating field trials of biotechnology crops or the use of specific biotechnology products (Chen and McDermott 1998).

In contrast, many EU citizens seem to feel that GM products differ substantively from existing traditional products. Hence, while the US operates within existing regulations to regulate biotechnology, the EU has enacted new regulations to target biotechnology products. The EU regulations treat GM products differently from traditional crops because the process of producing GM products is different, not because the final products are different (Chen and McDermott 1998). For example, the EU regulatory system for transgenic products is based on the precautionary principle which states that if a particular product could lead to devastating health or environmental outcomes, then a country is justified in taking action to limit the introduction of these products within their borders. The US objects to the EU regulatory system for GM products for a variety of reasons, including long product approval time lines, lack of transparency of the regulatory process and unexpected changes in approval procedures (Perdikis and Kerr 2000).

The US-EU conflict raises potential new challenges for the WTO. The WTO acts as a rule-enforcing institution that monitors levels of world trade and provides a mechanism for dispute settlement among countries. The legal structure of the WTO supports the right of countries to provide health, safety and environmental regulations to protect their citizens and the environment. At the same time, world trade law in the WTO explicitly recognizes that countries also use these policies as a type of non-tariff barrier and has established guidelines to monitor this type of trade-distorting behavior. Agreements within the legal code for the WTO provide mechanisms for identifying and addressing the intentional use of food safety regulations as trade barriers. Since its creation, WTO dispute settlement panels (DSP) have examined three cases involving the SPS (or SPSS) agreement: a dispute over food quarantine measures between Japan and the US, a dispute over Canadian salmon exports to Australia, and a dispute between the US and the EU over dairy products produced by cows treated with growth hormones. Through the DSP the world trade regime provides guidance for determining when policy convergence ensures optimal outcomes and when the benefits of national sovereignty outweigh the potential trade efficiency losses (see Ostry 1999 for a discussion of the new tensions faced by the WTO).

Who benefits from the adoption of GM labeling regulations and how does the structure of the international trading system affect the impact of these regulations? The answer requires an understanding of the complex economic interactions among consumer preferences, the economic structure of the national agricultural industries, and international trade relationships. Suppose a country that has previously co-mingled GM and traditional products chooses to enforce segregation of these products. Given information about GM content, consumers may choose to avoid GM products because they perceive them to be potential food safety risks. Agricultural producers will face new cost structures, which will in turn alter their use of labor and other factors of production. The trade impacts of this segregation will depend upon whether trading partners are also demanding segregation of GM from traditional products. If countries are pursuing opposite strategies (one choosing to require segregation and the other allowing co-mingling) the economic outcomes will differ from the cases when both countries segregate or both countries co-mingle.

The model described here provides insight into these complex relationships and indicates that harmonized labeling systems do not necessarily improve economic efficiency. Section two provides a brief survey of some literature related to labeling and general equilibrium models. Section three presents the model and describes how the basic general equilibrium model can be altered to capture specific characteristics of labeling and non-labeling economies. Section four discusses the results of numerical simulations, particularly related to the welfare payoffs of various labeling systems. The simulations indicate that, with reasonable assumptions about costs of segregation and consumer preferences for non-GM products, heterogeneous labeling systems lead to higher international welfare than homogeneous systems. Section five concludes with a discussion of the implications for the WTO of these results.

Literature

Traditional consumption theory assumes that all products are homogeneous and consumers only care about the quantity of product consumed. In order to develop a model examining impacts of labels a more textured consumption model is needed. Lancaster (1966) suggests a model to explain how consumers value qualitative product characteristics. Lancaster describes a complex utility function based on characteristics such as color or nutritional content, which leads consumers to choose between similar but different products. The literature on the economics of advertising draws on this approach, highlighting the fact that consumer valuation of product quality depends upon a combination of search, experience and credence characteristics. Search characteristics refer to characteristics such as color which consumers can determine by inspection before purchasing. Experience characteristics are qualities revealed after purchasing, such as taste. Credence characteristics refer to quality characteristics that are not revealed after purchasing. The GM content of non-labeled food products fall into this last category (Nelson 1970).

In this paper, agricultural products have two characteristics that are important to consumers: taste and "quality." Taste can be thought of as the classic consumption good characteristic. The taste of GM and traditional agricultural products are identical and consumers gain more utility by consuming more. Quality is directly related to the GM content of foods. As GM content increases, quality decreases. Hence, including quality in the utility function captures consumers' ambivalence towards GM foods. Some consumers perceive GM crops to be risky in a food safety sense, thus they prefer unmixed non-GM products. However, unless producers are segregating their crops, they do not have access to information about production methods. Thus, an externality exists, because consumers care about quality, but when products are mixed can not control how much they consume of each type (GM or non-GM crops). This consumption structure is introduced into a general equilibrium model in order to capture the price and output impacts in an international trade context.

Recently Anderson, Nielsen and some coauthors also examined the global general equilibrium impacts of segregating GM crops from traditional products. (see Anderson and Nielsen 2001, Anderson and Nielsen 2002, Anderson et al 2001, Anderson et al 2002, Nielsen and Anderson 2001a, Nielsen and Anderson 2001b, Nielsen et al 2000). Their analyses provide a preliminary view of how benefits and costs of GM policies are distributed throughout the world. They explore the benefits to developing countries of pursuing segregation of GM from traditional products, so that they may have access to markets where GM-critical consumers are eager to buy unmixed traditional products. In general their results indicate that adoption of GM crops by even a subset of countries produces substantial welfare gains and that import bans for GM crops in countries where consumers do not prefer "GM-free" products harm both domestic consumers and producers. Nielsen and Anderson (2000) emphasize this last point, demonstrating that when consumer preferences rather than regulatory mandates create markets for non-GM products, the efficiency of solutions is improved.

Nielsen, et al (2000) focus on quantifying the impact of consumers' changing attitudes toward GM products on world trade patterns, with an emphasis on the implications for developing countries welfare. In order to capture the shift in consumer attitudes towards GM products, it is assumed that GM and non-GM crops are increasingly poor substitutes in demand. They find that price differentials are substantial, but that these results are tempered by consumption and production effects. Differences in the prices of GM and non-GM products in developing countries are primarily a result of productivity changes, rather than changes in preferences in the developed world.

The model presented in the next section differs from these models in that it focuses primarily on describing the economic system within two countries (the US and the EU) rather than on large scale regional impacts. In addition the model does not assume GM-induced productivity growth. Rather the model uses data from a single year to calibrate four separate policy scenarios: both countries labeling, neither country labeling, and the two cases where countries choose different labeling strategies. The model structure provides results that focus on the implications of labeling policy harmonization rather than on the global distribution of the benefits of GM adoption and regulation. These results are intended to inform the debate within the international trade community about the use of labels as non-tariff barriers and the role of the WTO in monitoring these types of national policies.

The Model

The GE model described below examines the economic impacts of labeling decisions made by two trading partners. The model can describe two types of economies: an economy with labeling and an economy without labeling. Two critical features of the model capture the unique system of economic interactions related to GM labeling. First, adding labeling regulations changes the processors' production technology so that agricultural production of segregated crops requires additional labor. Because the labeling economy segregates one agricultural product into two separate products (traditional and GM products), it includes one more final good than the non-labeling economy. Second, as mentioned in section 2, the model assumes that consumers care about two product characteristics associated with GM products: quantity and quality.

This section first presents the basic structure of production and consumption in the labeling and non-labeling economies. Then the structure of the trade model is presented, including three cases: both countries labeling, neither country labeling, and the case where countries pursue opposite labeling strategies. Details of the model can be found in appendix.

Production

In order to facilitate the calibration of the GE model to existing economic data, production in each economy is split between industrial (sector 1) primary agricultural production (sectors 2, 3, and 6) and marketed agricultural production (sectors 4, 5, and 7).

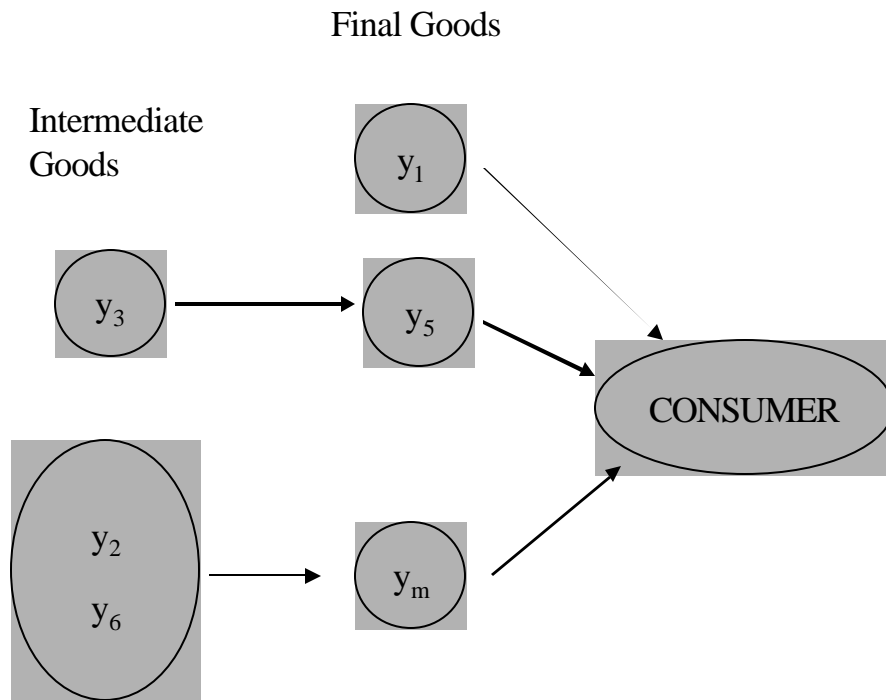
- 1 = industrial good
- 2 = primary traditional C/S
- 3 = primary non-C/S
- 4 = marketed C/S
- 5 = marketed non-C/S
- 6 = primary GM C/S
- 7 = marketed GM C/S

The three types of marketed agricultural production represent traditional corn and soy products (C/S), GM C/S products, and all other agricultural production. Primary agricultural inputs, which are used in the production of the marketed agricultural good, and not consumed directly by consumers, may be classified similarly. Specifically, good 2 is an intermediate input in the production of good 4, good 3 is an intermediate input in the production of good 5 and good 6 is an intermediate input in the production of good 7.

Production is structured as a simple Viner-Ricardo economy. There are eight factors of production: labor and seven others corresponding to the seven sectors in the economy. Labor (v_L) moves freely within the economy and sector labor demand is defined as v_{Lj} for sector j . Each sector also uses one fixed factor, v_1 through v_7 , which might be inputs such as land or sector specific capital. The fixed factors are assumed to be exogenously determined, while labor distribution is endogenous to the model.

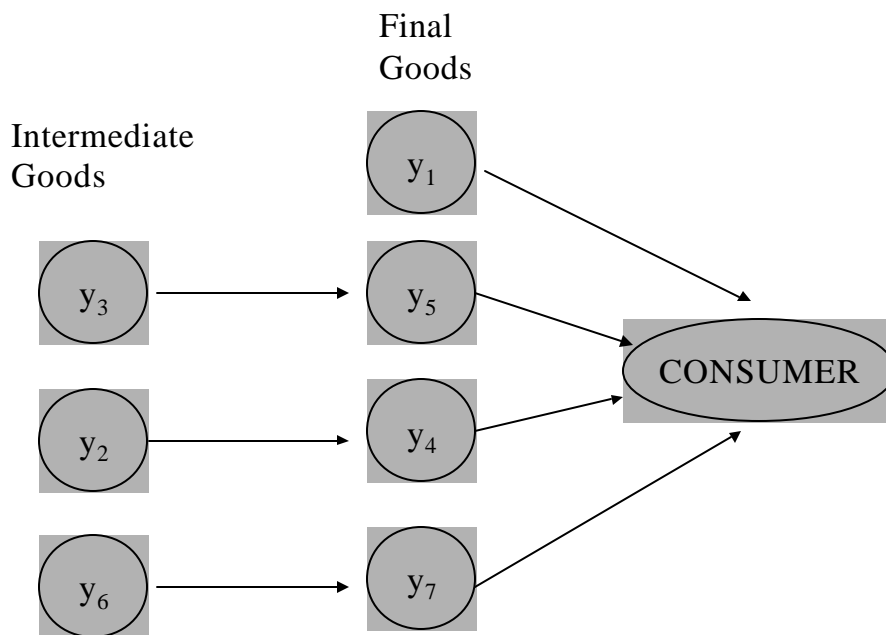
When an economy is not segregating GM from non-GM products, farmers sell primary agricultural products mixed together to the

agricultural marketers. The agricultural marketers in turn sell a final C/S product (y_m) for a single price. Hence, in the non-segregated case, the economy does not include a final good sector for non-GM C/S products (see figure).



Structure of a Non-Labeling Economy

In contrast when a country requires labeling of GM products, primary agricultural producers use labor to segregate the traditional from the GM agricultural varieties. Agricultural marketers purchase segregated inputs and produce a GM and a non-GM final good. Each of these products has a unique price (see figure).



Structure of a Labeling Economy

The model's equilibrium solution is based upon the definition of sectoral value-added functions which, given the assumptions made

on production functions, have properties identical to traditional GDP functions (See appendix). These sectoral value-added functions can be used to define sector labor demand ($v_{Lj}(w, p_j, v_j)$ for $j=1, \dots, 7$), intermediate good supply ($y_j(w, p_j, v_j)$ for $j=2, 3$, and 6), and intermediate good demand ($\tilde{y}_{mj}(w, p_j, v_j, p_{mj})$ for $m=j=2, 3$, and 6 where p_j refers to the price of the final marketed good associated with the m intermediate agricultural good). Given the definitions for sectoral value added functions in the nonsegregated case,

$$v_{Lj}(w, p_j, v_j) = \frac{\partial G_j(w, p_j, v_j)}{\partial w} \text{ for } j=1, 2, 3, \text{ and } 6$$

$$v_{Lj}(w, p_j, p_{mj}, v_j) = \frac{\partial G_j(w, p_j, p_{mj}, v_j)}{\partial w} \text{ for } j=4, 5, \text{ and } 7$$

$$y_j(w, p_j, v_j) = \frac{\partial G_j(w, p_j, v_j)}{\partial p_j} \text{ for } j=2, 3, \text{ and } 6$$

$$\tilde{y}_{mj}(w, p_j, p_{mj}, v_j) = \frac{\partial G_j(w, p_j, p_{mj}, v_j)}{\partial p_{mj}} \text{ for } j=5, \text{ and } 7$$

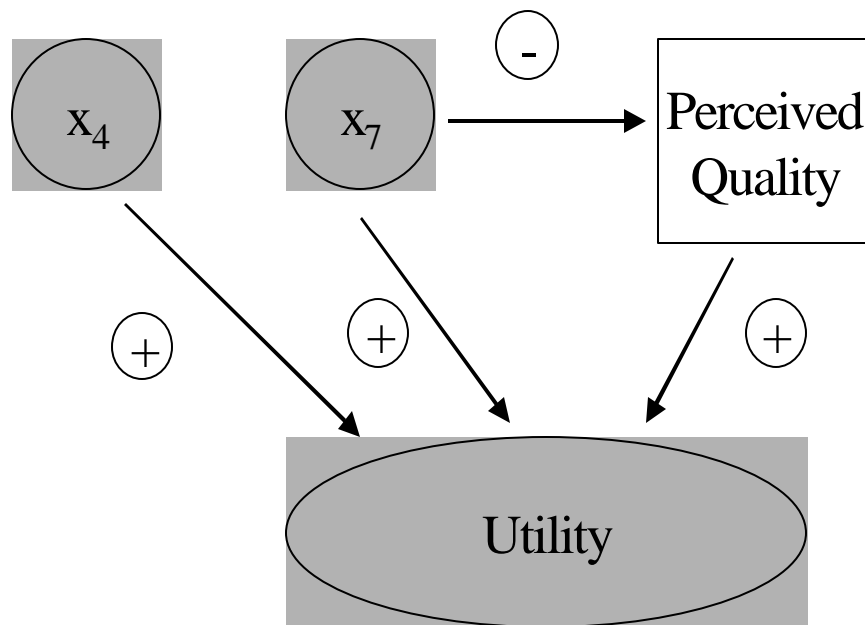
$$\tilde{y}_2(w, p_7, p_2, v_4) = \frac{\partial G_4(w, p_7, p_2, v_4)}{\partial p_2}$$

where the subscript "mj" refers to the intermediate good m used in the production of final good j. In the segregated case,

$\tilde{y}_2 = \tilde{y}_2(w, p_4, p_2, v_4) = \frac{\partial G_4(w, p_4, p_2, v_4)}{\partial p_2}$. Section provides the formal definition of equilibrium for the three versions of the trade model.

Consumption

Segregation and labeling decisions will also affect the structure and analysis of utility. Consumers in this model care about total food consumption as well as perceived food quality. With labeling, consumers have complete information about the GM content of agricultural products and have access to pure traditional crops (See figure). If they choose they can avoid consuming GM crops in order to avoid penalizing perceived food quality. As consumption and perceived quality increase, utility increase. However, consumers perceive a decrease in food quality with consumption of GM products (x_7). In figure the +/- signs by the arrows indicate these relationships.



Structure of Consumption

In the non-labeling economy, consumers cannot avoid GM crops, because these crops are co-mingled with traditional crops. While they perceive decreased food quality as they consume more of the mixed product, their utility increases with increased consumption of products and perceived quality.

Assume that both countries have the same technologies, and preferences apart from production method or quality. Countries differ in their factor endowments, their labeling strategies, and their preferences for quality. Consumers in each country have quasi-homothetic preferences and thus may differ in the amount of GM content they consume (Diao and Roe 1996). Arguments of the utility functions are the vector of demand for final goods (x) and quality (Q) (see following paragraph for definition of Q). Utility may be written

$$U_i = U_i(x, Q)$$

where $U_i(\cdot)$ is strictly increasing in all arguments. The maximization of $U_i(\cdot)$ with respect to income constraints gives the Marshallian demand functions $D_j(p, m)$ where p is the price of final goods and m is income.

Quality is embodied in the food consumers eat. It affects utility through the consumption of x_4 and x_7 , rather than entering the utility function as a separate choice variable. Consumers can not directly perceive the quality by tasting or looking at the product, for example. Thus, consumers experience a negative externality when they consume mixtures of GM products and traditional products, because they care about GM consumption but cannot control their intake of these products.

In the labeling case, the quality function may be represented as

$$Q = Q(x_7)$$

This function is a continuously decreasing, linear function of x_7 . Consumers may choose between consuming unmixed traditional crops or GM crops. The level of quality is solely determined by the consumption of x_7 , thus the consumption externality is eliminated. In contrast, in the non-labeling case, quality may be represented as

$$Q = Q(x_m)$$

where x_m represents demand for the non-labeled mixed product ($x_4 + x_7$). This function is a continuously decreasing, linear function of x_m . The level of quality is determined by the consumption of combined x_4 and x_7 , hence consumers experience a consumption externality.

Competitive Equilibrium with Trade

Three cases with trade will be considered: both countries labeling, neither country labeling, and one country labeling/one country not labeling. Since the labeling decision slightly alters the composition of the model, the equilibria definitions are also slightly different. Each equilibrium is defined below. The definitions are given in terms of sectoral value added functions in order to highlight the subtle functional differences among the three cases.

Let the second country be identified by an asterix. Then, a competitive equilibrium for the trade model is a set of prices and wages (p, p^*, w, w^*) , commodity bundles (y, y^*) , and a set of input allocations (v, v^*) , with quality levels (Q, Q^*) such that (1) all agents treat prices parametrically; (2) given prices, producers maximize profits; (3) given prices, consumers maximize their utility given their budget constraints; (4) in each country, the demand for inputs are equal to the endowments; (5) in each country the demand for intermediate goods equals the supply of intermediate goods, (6) world demand for each final good is equal world supply, and (7) Walras' law holds.

Neither Labeling

An equilibrium in this case is $(w, w^*, p_1, p_2, p_2^*, p_3, p_3^*, p_5, p_6, p_6^*, p_7)$, such that the labor markets and intermediate good markets clear for each country and world markets for final goods clear. In this equilibrium p_1, p_5 , and p_7 are world prices for traded final goods where p_7 is the price for the mixed final agricultural product.. Note that p_4 does not exist because neither country is segregating their GM products from their traditional products.

Assuming an internal solution, and normalizing $p_1 = 1$, equations - necessary equilibrium conditions. Labor market clearing conditions are

$$-\sum_{j=1, \dots, 7} \frac{\partial G_j(\cdot)}{\partial w} = v_L \quad \#$$

$$-\sum_{j=1, \dots, 7} \frac{\partial G_j^*(\cdot)}{\partial w^*} = v_L^* \quad \#$$

Market clearing conditions for intermediate goods are

$$\frac{\partial G_2(\cdot)}{\partial p_2} + \frac{\partial G_4(\cdot)}{\partial p_2} = 0 \quad \#$$

$$\frac{\partial G_3(\cdot)}{\partial p_3} + \frac{\partial G_5(\cdot)}{\partial p_3} = 0 \quad \#$$

$$\frac{\partial G_6(\cdot)}{\partial p_6} + \frac{\partial G_7(\cdot)}{\partial p_6} = 0 \quad \#$$

$$\begin{aligned}\frac{\partial G_2^*(.)}{\partial p_2^*} + \frac{\partial G_4^*(.)}{\partial p_2^*} &= 0 & \# \\ \frac{\partial G_3^*(.)}{\partial p_3^*} + \frac{\partial G_5^*(.)}{\partial p_3^*} &= 0 & \# \\ \frac{\partial G_6^*(.)}{\partial p_6^*} + \frac{\partial G_7^*(.)}{\partial p_6^*} &= 0 & \#\end{aligned}$$

In addition the world market clears for final goods 5 and m,

$$\begin{aligned}D_5(.) + D_5^*(.) - \frac{\partial G_5(.)}{\partial p_5} - \frac{\partial G_5^*(.)}{\partial p_5} &= 0 & \# \\ D_m(.) + D_m^*(.) - \frac{\partial G_m(.)}{\partial p_7} - \frac{\partial G_m^*(.)}{\partial p_7} &= 0 & \#\end{aligned}$$

where $D_j(.)$ represents demand for good j by country 1 and $D_j^*(.)$ represents demand for good j by country 2. Similarly, $\frac{\partial G_j(.)}{\partial p_j}$ represents supply of final good j for country 1 and $\frac{\partial G_j^*(.)}{\partial p_j}$ represents supply of final good j for country 2.

Both Labeling

An equilibrium in this case is $(w, w^*, p_1, p_2, p_2^*, p_3, p_3^*, p_4, p_5, p_6, p_6^*, p_7)$ such that intermediate good and factor markets clear in both countries and the world markets for final goods clear. Note that with labeling a separate price (p_4) exists for marketed traditional products. Assume an internal solution, and normalize $p_1=1$. $G_5(.)$ represents the sectoral value-added function for primary agricultural producers who are segregating GM from traditional crops and is substituted for $G_2(.)$ and $G_6(.)$ for both countries. Labor market clearing conditions are

$$\begin{aligned}- \sum_{j=1,3,3,4,5,7} \frac{\partial G_j(.)}{\partial w} &= v_L \\ - \sum_{j=1,3,3,4,5,7} \frac{\partial G_j^*(.)}{\partial w^*} &= v_L^*\end{aligned}$$

Market clearing for conditions for intermediate goods are

$$\begin{aligned}\frac{\partial G_5(.)}{\partial p_2} + \frac{\partial G_4(.)}{\partial p_2} &= 0 \\ \frac{\partial G_3(.)}{\partial p_3} + \frac{\partial G_5(.)}{\partial p_3} &= 0 \\ \frac{\partial G_5(.)}{\partial p_6} + \frac{\partial G_7(.)}{\partial p_6} &= 0 \\ \frac{\partial G_2^*(.)}{\partial p_2^*} + \frac{\partial G_4^*(.)}{\partial p_2^*} &= 0 \\ \frac{\partial G_3^*(.)}{\partial p_3^*} + \frac{\partial G_5^*(.)}{\partial p_3^*} &= 0 \\ \frac{\partial G_6^*(.)}{\partial p_6^*} + \frac{\partial G_7^*(.)}{\partial p_6^*} &= 0\end{aligned}$$

In addition the world market clears for final goods ($j=4,5,7$)

$$D_j(.) + D_j^*(.) - \frac{\partial G_j(.)}{\partial p_j} - \frac{\partial G_j^*(.)}{\partial p_j} = 0$$

where $D(.)$ represents demand for country 1 and $D^*(.)$ represents demand for country 2. Similarly, $\frac{\partial G_j(.)}{\partial p_j}$ represents supply of final good j for country 1 and $\frac{\partial G_j^*(.)}{\partial p_j}$ represents supply of final good j for country 2.

Mixed Labeling Strategies

Assume that country one is not segregating traditional and GM crops, while country two is segregating GM and traditional crops and labeling each type of crop. Several assumptions are made in relation to this mixed strategy trade model. Since countries are trading final goods, segregated traditional varieties are also available in country one. Hence, utility functions are the same for consumers in each

country.

Also, assume that consumers in country 2 treat the co-mingled crops from country 1 the same as GM crops produced in country two, rather than as a separate type of commodity. This assumption is based on the idea that country 2 consumers primarily care about having access to the non-GM product. Any product with GM content is considered to be of lower quality. In the same vein, the price of co-mingled crops from country 1 and the price for pure GM crops from country two is p_7 (see Figure XX).

An equilibrium in this case is $(w, w^*, p_1, p_2, p_2^*, p_3, p_3^*, p_4, p_5, p_6, p_6^*, p_7)$ such that intermediate goods and factor markets clear in each country and world markets for final goods clears. Assuming an internal solution, and normalizing $p_1=1$, the labor market clearing conditions are

$$- \sum_{j=1, \dots, 7} \frac{\partial G_j(\cdot)}{\partial w} = v_L$$

$$- \sum_{j=1, 3, 4, 5, 7} \frac{\partial G_j^*(\cdot)}{\partial w^*} = v_L^*$$

Market clearing conditions for intermediate goods are:

$$\frac{\partial G_2(\cdot)}{\partial p_2} + \frac{\partial G_4(\cdot)}{\partial p_2} = 0$$

$$\frac{\partial G_3(\cdot)}{\partial p_3} + \frac{\partial G_5(\cdot)}{\partial p_3} = 0$$

$$\frac{\partial G_6(\cdot)}{\partial p_6} + \frac{\partial G_7(\cdot)}{\partial p_6} = 0$$

$$\frac{\partial G_2^*(\cdot)}{\partial p_2^*} + \frac{\partial G_4^*(\cdot)}{\partial p_2^*} = 0$$

$$\frac{\partial G_3^*(\cdot)}{\partial p_3^*} + \frac{\partial G_5^*(\cdot)}{\partial p_3^*} = 0$$

$$\frac{\partial G_6^*(\cdot)}{\partial p_6^*} + \frac{\partial G_7^*(\cdot)}{\partial p_6^*} = 0$$

World market clearing conditions for final goods are

$$D_4(\cdot) + D_4^*(\cdot) - \frac{\partial G_4(\cdot)}{\partial p_4} = 0$$

$$D_5(\cdot) + D_5^*(\cdot) - \frac{\partial G_5(\cdot)}{\partial p_5} - \frac{\partial G_5^*(\cdot)}{\partial p_5} = 0$$

$$D_7(\cdot) + D_7^*(\cdot) - \frac{\partial G_m(\cdot)}{\partial p_7} - \frac{\partial G_7^*(\cdot)}{\partial p_7} = 0$$

where $D_j(\cdot)$ represents the demand for j in country 1 and $D_j^*(\cdot)$ represents demand for j in country 2. Similarly, $\frac{\partial G_j(\cdot)}{\partial p_j}$ represents supply of final good j for country 1 and $\frac{\partial G_j^*(\cdot)}{\partial p_j}$ represents supply of final good j for country 2. In this case $\frac{\partial G_m(\cdot)}{\partial p_7} = \frac{\partial G_4(\cdot)}{\partial p_7} + \frac{\partial G_7(\cdot)}{\partial p_7}$

The Data

The model uses 1998 US and EU data from a variety of sources in order to calibrate the model to reflect the scale of the various economies and sectors (see appendix). Data for the rest of the world is incorporated into calculations of world final good market clearing conditions. This year was the first in which GM crops represented a significant percentage of world agricultural production. In addition, 1998 is the most recent year with complete data for both the US and the EU. Because the data represents a single point in a continuum of GM adoption and acceptance the results from the model must be interpreted as an indication of potential scale of policy impacts, rather than a definitive prediction. The data are used to develop Social Accounting Matrices (see Appendix). These matrices are in turn used to calibrate the general equilibrium model.

The elasticities for production functions come from the following data sources. Labor elasticity for manufacturing (α) was calculated from the Economic Report of the President (1999) as share of value of production to wages. The elasticity on the fixed resource is then simply $(1-\alpha)$. The labor elasticity (β) for primary agriculture was calculated from Agricultural Outlook numbers (January-February 2000). The total value of primary agricultural production (table 9-21) and the total farm wages, calculated from the number of hired farmworkers and median weekly earnings (table 9-19), are used to calculate β . Labor elasticity (δ_1) in processed agriculture was calculated from the

Bureau of Economic Analysis productivity data set while the elasticity of intermediate inputs in processed agriculture comes from Gopinath and Roe (1996) that estimates that primary agriculture represents 26% of the value of processed agriculture.

The elasticities for the utility function are estimated using the SAM for each country. The elasticity for good 1 (e_1) is the residual from the elasticities on the mixed C/S product (e_m), the elasticity for non C/S products (e_n), and the elasticity on the perceived quality (ep). In these simulations the US consumer is assumed not to place any value on the quality of C/S consumed ($ep_{US} = 0$). The EU, on the other hand, gains utility from increased quality of C/S products although quality is a smaller component of demand than the C/S component ($0 < ep_{EU} < e_m$). Because data on quality preferences did not exist at the time of this modeling exercise, this parameter (ep_{EU}) is synthesized and sensitivity analyses are conducted to ensure that the chosen parameter is reasonable.

In the model with segregated products, all elasticities are the same as in the non-segregated model but an additional elasticity is used to calculate the joint-output function that represents the segregation process for C/S primary agricultural production. Empirical evidence suggests that cultivating GM crops has non-trivial cost reducing effects however data on industry segregation costs are limited (see ERS 2000, ERS 2001a). Since, definitive data concerning the production costs are sparse, this elasticity (s) is synthesized. Sensitivity analyses are performed to ensure that the changing this elasticity does not alter the direction of changes in prices and outputs in the general equilibrium model.

Policy simulations

Model simulations explore the impact of four possible policy scenarios. The base-case scenario, the situation in which both the US and the EU are segregating crops, was chosen because this scenario provides prices for all goods. By comparison, the case where neither country is segregating does not provide prices for segregated products, and therefore cannot be used as the base for calculations of percent price changes. This base-case is then compared to the scenario when neither country is segregating (S1), the scenario when the US segregates and the EU does not (S2), and the scenario when the EU segregates and the US does not (S3). In the simulations, the price of the non-agricultural good (p_1) is chosen as the numeraire. These simulations indicate the scale of the economic impacts of national labeling policies within the international trading system. The simulations in this chapter examine how combinations of national labeling regulatory choices alter prices, outputs and trade flows.

Analysis of differences in p_4 , the non-GM agricultural good, and p_7 , the GM agricultural good, among the various scenarios indicates that when at least one country is segregating the price for the non-GM product is always higher than for the GM product. This price difference reflects the externality effect associated with the consumption of GM products. When both countries are segregating the prices for GM and non-GM products are closer than they are when countries maintain opposite labeling policies (see table). Also, p_4 is higher in both cases where only one country is labeling because the supply of the pure traditional good is less when only one country is

| Percent Change from Base Case | | | | |
|-------------------------------|----------|-------------|-------------|-------------|
| | Both seg | S1 (no seg) | S2 (US seg) | S3 (EU seg) |
| segregating p_4 | 1.6238 | na | 6.0351 | 1.7197 |
| p_7 | 1.5972 | 1.4640 | 0.5861 | 1.3591 |

When the US is segregating and the EU is not, p_4 is 10.3 times

larger than p_7 . [WHY] In contrast, when the EU is segregating and the US is not (S3), the price for traditional products is only 1.3 times as large as the price for the GM product.

Demand Impacts

Labeling schemes which provide consumers with clear information concerning GM product content have direct implications for consumer choice and hence for final demand. When two types of C/S are available on the world market individual countries consume only one type rather than consuming a bundle of unmixed traditional C/S and GM C/S products. Specifically in the base case, S2 and S3 US demand for the non-GM C/S product is zero, while EU demand for the GM C/S product is zero (see table

| | Both seg | S1(no seg) | S2(US seg) | S3(EU seg) |
|--------------------|---------------|---------------|---------------|---------------|
| US C/S | | | | |
| Non-GM | 0 | – | 0 | 0 |
| GM/Mixed | 71.18 | 77.63 | 194.93 | 83.61 |
| EU C/S | | | | |
| Non-GM | 371.75 | – | 99.74 | 351.24 |
| GM/Mixed | 0 | 331.03 | 0 | 0 |
| World Total | 442.93 | 408.66 | 294.67 | 434.85 |

The price relationship of the final goods segregated C/S products

and the quality externality associated with GM products lead to these demand results. When the market contains two C/S products, EU consumers shun GM products in order to avoid the negative consumption externality. On the other hand, US consumers do not

experience externalities associated with consuming GM products. Therefore, when the market includes two C/S products they will choose the cheapest product regardless of GM content. In the case where neither country segregates (S1) the market contains only one C/S product which is a mixture of traditional and GM C/S. EU consumers consume the mixture, but at smaller quantities even though the price for the mixture is less than the price for the unmixed traditional product. US consumers choose more C/S because these products are now cheaper and they are indifferent between two types of products.

Supply impacts

Table presents simulation results for supply changes.

| | Percent Change from Base Case | | | |
|----------------------|-------------------------------|-------------|-------------|---------------|
| | S1 (no seg) | S2 (US seg) | S3 (EU seg) | |
| US | | | | |
| Manufacturing | 0.0004 | -0.0039 | 0.0005 | |
| Non-GM C/S | -0.2363 | 1.8849 | -0.2798 | |
| Non C/S | 0.0005 | -0.0026 | 0.0004 | The model can |
| GM C/S | -0.1606 | -0.5038 | -0.2084 | |
| EU | | | | |
| Manufacturing | 0.0007 | 0.0051 | -0.0005 | |
| Non-GM C/S | -0.0379 | -0.5319 | 0.0493 | |
| Non C/S | 0.0006 | 0.0009 | 0.0000 | |
| GM C/S | -0.4874 | -0.7506 | -0.1115 | |

determine separate supply values for GM and traditional products in cases when these products are mixed in the final good market. Therefore, the table reports results for four final products even for countries that do not segregate.

When both countries segregate (base case) the total supply of C/S products is higher than when neither country is segregating (S1). This result is non-intuitive because when countries segregate they incur production costs which would imply, *ceteris paribus*, that equilibrium supply would decrease. The result reflects the demand structure for these two labeling scenarios and the consumption externality that EU consumers experience when they consume mixed products. As discussed in the previous section in the base case each country produces both unmixed C/S products, but domestic consumers choose only one C/S product. The entire supply of the other C/S product is exported and consumed by foreign consumers. When both countries switch to non-labeling strategies, only one C/S product is available. In this model US consumers do not perceive GM crops to be unsafe, therefore when the products are mixed they will consume more at the lower price. In contrast, EU consumers experience the quality consumption externality, because they can not avoid consuming GM crops. They therefore decrease their consumption of C/S products. The net effect is a decrease in the equilibrium supply of C/S products in S1 as compared to the base case scenario.

In the two scenarios where countries pursue opposite labeling strategies (S2 and S3), a specialized market for traditional C/S products emerges. When the US is segregating and the EU is not (S2), US supply of Non-GM C/S products increases while the supply of GM C/S decreases. US producers are producing pure traditional C/S products and selling them entirely to the European market. US consumers, therefore, depend upon EU production of unsegregated product to satisfy their demand for C/S. In the scenario when the EU is labeling and the US is not (S3), US production of GM and non-GM C/S decreases relative to the base case scenario. The EU producers decrease their production of GM products and increase their production of non-GM C/S products. In this scenario, all the GM products produced in the EU are sold overseas to the US. Therefore, it is still profitable for the EU to produce small amounts of GM products, although they are not being consumed domestically in the EU.

Trade Impacts

Table highlights the changes in composition of exports and imports when segregating alters the availability of particular products. When both countries are segregating (base case) the US has a trade deficit and the EU has a trade

| | | Percent Change from Base Case | | | | |
|-----------|----------------|-------------------------------|-------------|-------------|-------------|---|
| | | Base Case | S1 (no seg) | S2 (US seg) | S3 (EU seg) | |
| US | | | | | | |
| | Exports | 37.4513 | -0.7819 | 1.8849 | -0.5978 | |
| surplus. | Imports | -54.6014 | -0.8586 | 12.0628 | -0.8198 | In this case the US exports the unmixed traditional C/S |
| | Surplus | -17.1501 | -1.0262 | 34.2886 | -1.3047 | |
| EU | | | | | | |
| | Exports | 29.7881 | -0.1064 | 20.8744 | 0.2595 | |
| | Imports | -29.3634 | 0.4466 | 2.3966 | 1.0527 | |
| | Surplus | 0.4247 | -38.3442 | 1298.4457 | -54.5815 | |

product, whereas the EU exports the non C/S and unmixed GM C/S product. When neither country is segregating, the US exports mixed C/S product, while the EU exports mixed C/S and non-C/S product. When the US is segregating and the EU is not segregating, the US only exports the unmixed traditional product and the EU exports the non-C/S product and the mixed C/S product. Finally, in the case where the US is not segregating and the EU is segregating, the US does not export any agricultural products to either the EU or the ROW, while the EU exports at least some portion of each of its agricultural products.

A comparison of the export and import equilibrium values for the other scenarios indicates that when the US is not segregating (S1 and S3) the US experiences trade surpluses while the EU experiences trade deficits. In contrast, in the case where the US is segregating and the EU is not segregating (S2) trade volumes change significantly more than in the other two cases. The large positive percentage change in EU trade surplus in S2 reflects the small trade surplus value for the base case. In this case each country produces products that are exported and consumed entirely by their trading partners. For example, the US exports all the unmixed traditional product it produces, while the EU exports all of its mixed product. Because countries are producing products that are entirely for foreign consumption, trade volumes increase.

Welfare Impacts

In order to examine the complete impact on a nation, a money metric of welfare is calculated. This measure is the sum of the change in income produced by changes in labeling strategies and the equivalent variation measure of price changes caused by labeling

| | | Percent Change from Base Case | | |
|-----------|--------------|-------------------------------|-------------|-------------|
| | | S1 (no seg) | S2 (US seg) | S3 (EU seg) |
| behavior. | US | -11.22 | 398.46 | 84.77 |
| | EU | 9.25 | -198.86 | 11.14 |
| | Joint | -1.97 | 199.60 | 95.21 |

These welfare measurements provide a picture of the strategic nature of labeling choices in an international trade setting. Table indicates that whether the US is labeling (base case and S2) or not labeling (S1 and S3) the EU prefers to label. Hence the EU's dominant strategy is to label. When the EU is labeling (base case and S3) the US prefers not to label, while when the EU is not labeling (S1 and S2) the US prefers to label. Hence the equilibrium strategy is for the EU to label and the US not to label (S3). In this way, the model reflects the current state of US and EU GM labeling policy.

This equilibrium strategy does not provide the highest joint welfare in the three cases. US and EU benefits are maximized in scenario S2 when the US is segregating and the EU is not. However, in this case while the US experiences large welfare improvements in comparison to the base case scenario, the EU experiences large welfare declines. In theory if the US compensated the EU, both countries could be made better off in the S2 scenario than in the S3 scenario.

This welfare analysis suggests that the benefits of policy harmonization in the case of GM labeling may not be as large as expected. When both countries pursue the same labeling strategy (ie. the base case and S1) total joint benefits are lower than the cases in which countries pursue mixed strategies. When consumers differ in their perception of product characteristics, different national approaches to product regulation do not necessarily lead to decreased world welfare.

Sensitivity Analysis

Sensitivity analysis of the parameters s and ep_{eu} indicate that the welfare results are robust. As s increases beyond .38 the model cannot solve for an equilibrium, however this parameter value would imply extremely large segregation costs. Within a range of realistic values the model provides reasonable solutions. As s increases when the US is not segregating, US welfare improves. When the US is segregating and the EU is not segregating the US welfare decreases relative to the base case as s increases. The EU welfare payoffs have a

more complex relationship with the parameter s . When the US is segregating and the EU is not segregating, as s increases EU welfare improves relative to the base case. However, in the two cases where countries pursue mixed strategies, the EU welfare improves relative to the base case at low levels of s , then declines. The level of s at which this change in direction occurs is different in the two labeling cases. Throughout the range of s examined in the sensitivity analysis, welfare results indicate that US not labeling/EU labeling is the stable labeling equilibrium.

Sensitivity analysis of the ep_{EU} parameter also indicates that the US not labeling/EU labeling is the stable labeling equilibrium over the range of realistic ep_{EU} values. Over the range of ep_{EU} evaluated, EU's dominant strategy is to label. However, as ep_{EU} increases above .01 the EU relative welfare as compared to the base case decreases in each of the three scenarios: S1 (no seg), S2 (US seg) and S3 (EU seg).

Conclusion

The WTO was established based on the assumption that efficient trading systems with limited barriers to trade will improve global welfare. Towards this end the WTO establishes and supports the rights of countries to maintain market access restricted only by negotiated barriers sanctioned by the WTO. At the same time, the WTO's legal structure supports countries' rights to restrict access to their markets due to health and safety issues as stated in the SPS Agreement. In the case of GM products these two rights conflict. Countries that introduce labeling regulations to address consumer concerns about food safety are restricting access to their agricultural markets for countries that do not require labeling. While conflicting labeling requirements may curtail market access between trading partners, the research reported here indicates that, when the full economic effects are considered, policy heterogeneity can benefit countries more than policy harmonization.

The model presented here highlights the fact that policies addressing one type of inefficiency can introduce other inefficiencies. Without labeling, the US has full market access, but EU consumers are forced to consume mixtures of products, when they would prefer to consume unmixed traditional products. With labeling EU consumers can avoid the GM products which they perceive to be of lower quality, but market access for US producers is restricted. Therefore labeling policies address the inefficiency created by the consumption externality, but introduce market inefficiency.

In this context, simply categorizing the label as a non-tariff barrier does not recognize the complexity of the GM trade issue. Typically, non-tariff barriers are technical regulations and industrial standards that refer to the same product but that differ among countries. The GM product policy dilemma stems from a fundamental conflict over how national policies categorize GM products. The EU justifies labeling because EU policies treat GM products as fundamentally different than traditional products. In contrast, US policies treat GM products as if they are substantially equivalent to existing products and US consumers consider these products to be interchangeable. These countries have chosen labeling policies that are consistent with their overall system of policies governing GM products. From the US's frame of reference these labels act as non-tariff barriers. From the EU's perspective these labels provide an appropriate classification for two different types of products.

What are the primary concerns with the use of labeling policies in the international trading system? The WTO supports the use of national policies to address safety and environmental concerns but acknowledges that explicit food safety rationales may camouflage protectionist intent. Policy makers are concerned that divergent labeling policies, even if they capture true consumer preferences will cost the global economy by introducing economic inefficiencies. The results presented here indicate that divergent policies can lead to higher joint welfare than harmonized labeling policies. Although EU labeling may limit market access when the US is mixing traditional and GM products, in general equilibrium shifts in production and consumption lead to outcomes that benefit both economies as compared to the cases where countries harmonize their policies.

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Model Definition

Assume that the production functions for final and intermediate goods are strictly increasing, continuously differentiable and homogeneous of degree one in arguments. Specifically, assume they are Cobb-Douglas:

$$\begin{aligned}
y_1 &= A_1 v_{L1}^\alpha v_1^{1-\alpha} \\
y_2 &= A_2 v_{L2}^\beta v_2^{1-\beta} \\
y_3 &= A_3 v_{L3}^\beta v_3^{1-\beta} \\
y_4 &= A_4 v_{L4}^{\delta_1} v_2^{\delta_2} v_4^{\delta_3} \\
y_5 &= A_5 v_{L5}^{\delta_1} v_3^{\delta_2} v_5^{\delta_3} \\
y_6 &= A_6 v_{L6}^\beta v_6^{1-\beta} \\
y_7 &= A_7 v_{L7}^{\delta_1} v_6^{\delta_2} v_7^{\delta_3}
\end{aligned}$$

where A_j represents the scalar for sector j and $\delta_3 = 1 - \delta_1 - \delta_2$.

Profit Maximization

Since each sector uses a sector-specific fixed factor in the production of goods a value-added function exists for each sector (Diewert 1979). Producers in sector j take prices as given and choose labor input (v_{Lj}) to maximize profit. For example, producers in sector two solve

$$\max_{v_{L2}} p_2 (A_2 v_{L2}^\beta v_2^{1-\beta}) - w v_{L2}$$

In addition producers that segregate use additional labor (v_{LS}) to jointly produce y_2 and y_6 . Let "s" represent the cost parameter. Producers that segregate crops solve the following maximization problem, taking prices and wages as given

$$\max_{v_{LS}, v_{L2}, v_{L6}} v_{LS}^s (p_2 (A_2 v_{L2}^\beta v_2^{1-\beta})^{1-s} + p_6 (A_6 v_{L6}^\beta v_6^{1-\beta})^{1-s}) - w(v_{LS} + v_{L2} + v_{L6})$$

Sectoral Value-Added Functions

The solution to each sectors' profit maximization problem can be used to define the sectoral value-added functions (G_j). The sectoral value-added functions are formally the same as the classical GNP function. Specifically, these functions are: 1) defined and non-negative for all $p > 0$ and $v \geq 0$; 2) continuous, linearly homogeneous, convex functions of p for all v ; 3) continuous, linearly homogeneous, non-decreasing concave functions of v for all p ; and 4) positive if $v > 0$.

Given the Cobb-Douglas production functions assumed above, these value-added functions for all sectors may be written

$$\begin{aligned}
G_1 &= v_1 w^{\frac{\alpha}{1-\alpha}} p_1^{\frac{1}{1-\alpha}} [\alpha^{\frac{1}{1-\alpha}} (1-\alpha)] A_1^{\frac{1}{1-\alpha}} \\
G_2 &= v_2 w^{\frac{\beta}{1-\beta}} p_2^{\frac{1}{1-\beta}} [\beta^{\frac{1}{1-\beta}} (1-\beta)] A_2^{\frac{1}{1-\beta}} \\
G_3 &= v_3 w^{\frac{\beta}{1-\beta}} p_3^{\frac{1}{1-\beta}} [\beta^{\frac{1}{1-\beta}} (1-\beta)] A_3^{\frac{1}{1-\beta}} \\
G_4 &= v_4 w^{\frac{\delta_1}{1-\delta_3}} p_2^{\frac{\delta_2}{1-\delta_3}} p_4^{\frac{1}{1-\delta_3}} [\delta_2^{\frac{\delta_2}{1-\delta_3}} \delta_1^{\frac{\delta_1}{1-\delta_3}} (\delta_3)] A_4^{\frac{1}{1-\delta_3}} \\
G_5 &= v_5 w^{\frac{\delta_1}{1-\delta_3}} p_3^{\frac{\delta_2}{1-\delta_3}} p_5^{\frac{1}{1-\delta_3}} [\delta_2^{\frac{\delta_2}{1-\delta_3}} \delta_1^{\frac{\delta_1}{1-\delta_3}} (\delta_3)] A_5^{\frac{1}{1-\delta_3}} \\
G_6 &= v_6 w^{\frac{\beta}{1-\beta}} p_6^{\frac{1}{1-\beta}} [\beta^{\frac{1}{1-\beta}} (1-\beta)] A_6^{\frac{1}{1-\beta}} \\
G_7 &= v_7 w^{\frac{\delta_1}{1-\delta_3}} p_6^{\frac{\delta_2}{1-\delta_3}} p_7^{\frac{1}{1-\delta_3}} [\delta_2^{\frac{\delta_2}{1-\delta_3}} \delta_1^{\frac{\delta_1}{1-\delta_3}} (\delta_3)] A_7^{\frac{1}{1-\delta_3}}
\end{aligned}$$

In the case of the segregating sector, the maximization problem described above yields a segregation sector value added function,

$$G_S = w^{\frac{\beta(1-s)}{(\beta-1)(1-s)}} (X_2 X_6)^{\frac{-1}{(\beta-1)(1-s)}} \left(\langle X_2 \rangle^{\frac{1}{\beta(1-s)-1}} + \langle X_6 \rangle^{\frac{1}{\beta(1-s)-1}} \right)^{\frac{\beta(1-s)-1}{(\beta-1)(1-s)}} H$$

where

$$\begin{aligned}
H &= [\beta^{\frac{\beta}{1-\beta}} (1-\beta)(1-s)^{\frac{1}{(1-\beta)}} s^{\frac{-\beta}{(\beta-1)(1-s)}}] \\
X_j &= p_j (A_j v_j^{1-\beta})^{1-s} \text{ for } j=2 \text{ and } 6
\end{aligned}$$

Data Sources

US Data Sources

| Data Source | Data Extracted |
|--|---|
| Economic Report of the President 1999 | GDP by sector Total wages Labor by sector |
| National Agricultural Statistics Service | GDP to corn and soy |
| Economic Research Service | GDP to GM corn and soy |
| Gopinath and Roe (1997) | GDP to int. agr. goods |
| Foreign Agricultural Trade of the U.S. | C/S exports and imports |
| FAOSTAT and COMTRADE | Agr. exports and imports |
| ERS, FAOSTAT and James (2000) | GM exports and imports |
| Direction of Trade Statistics Yearbook | Total exports and imports |

EU Data Sources

| Data Source | Data Extracted |
|---|--|
| Eurostatistics | GDP Total Total labor Agricultural labor |
| Eurostat Yearbook | Employee compensation |
| http://europa.eu.int/comm/agriculture/agrista/2000/table_en/en315full.pdf | GDP to agriculture |
| Gopinath and Roe (1997) | GDP to interm. ag. goods |
| Economic Research Service | GDP to corn and soy C/S exports and imports |
| FAOSTAT and COMTRADE | Ag. exports and imports |
| ERS, FAOSTAT and James (1999) | GM exports and imports GDP to GM corn and soy |
| Direction of Trade Statistics Yearbook | Total exports and imports |

Social Accounting Matrices

US SAM

US SAM continued

EU SAM

EU SAM continued

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