AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

The Journal of
Regional
Analysis
& Policy

JRAP 39(2): 155-173. © 2009 MCRSA. All rights reserved.

The Regional Impact of Discriminatory Trade Liberalization on Colombian Agriculture

Ricardo Arguello
Cornell University -USA and Universidad del Rosario - Colombia

Abstract. This study provides an assessment of the potential impact of trade liberalization on the regional structure of Colombian agriculture. For this, a two-step methodology is implemented. First, the effects of discriminatory trade liberalization are estimated by means of a multi-region general equilibrium model. Second, relevant price and quantity changes are transmitted to a simple transportation model that simulates the likely changes that trade liberalization will bring upon the spatial structure of agriculture. Results indicate that changes in the spatial structure of agricultural production in Colombia are not negligible and are instrumental for policy design on several fronts.

1. Introduction

As many other developing countries, Colombia has been progressively liberalizing its trade regime. While the general effects of trade liberalization on the economy have been assessed in several instances (Arguello and Valenzuela, 2006; Botero, 2005; Duran et al, 2006; Martin and Ramirez, 2005; and Pardo et al., 2005), only recently has an attempt been made to ascertain its likely effects at the regional level (Haddad, et al., 2008).

This research intends to do so for the agricultural sector. Specifically, its objective is to evaluate the potential impact of the implementation of a series of trade agreements undertaken by Colombia (including the already signed but not yet implemented trade accord with the US) on the regional structure of most of its agricultural sector. Regional structure refers to the composition of crops cultivated by region as well as the extent of areas cultivated. Geography is explicitly incorporated in the analysis, as distances between production regions and markets are taken into account.

For this, a two-step methodology is implemented. First, the effects of discriminatory trade liberalization are estimated by means of a multi-region general equilibrium model. Second, relevant price and quantity changes are transmitted to a simple transportation model that simulates the likely changes that trade liberalization will bring upon the spatial structure of agriculture.

Results indicate that potential changes in the spatial structure of agricultural production in Colombia are not negligible. First, significant changes, both positive and negative, in harvested areas and output will have an impact on producers at the local level. Second, they may bring significant impacts on regional income brought about by both changes in harvested areas and changes in production costs. Third, they may change the relative importance of production regions from both the individual products perspective and in overall agricultural activity, impinging upon the way production regions are linked to markets and affecting their growth perspectives.

The results are instrumental for policy design on several fronts. First, they allow for the identification of products that are winners and losers from trade liberalization and for tracking changes in harvested areas, production volumes, and the value of production at the production region level. Second, they allow the assignment of hierarchies to production regions in terms of their vulnerability before trade liberalization. This ordering is not trivial, since it depends not only upon the particular mix of products that a region has, but also on its relative competitiveness vis a vis other regions, as it regards productions costs, yields, and proximity to markets. Third, they allow producers to identify options (or the lack thereof) for switching from products that are losers to products that are winners within a production region.

The paper is organized as follows. Section two is a brief literature review. Section three presents and discusses the methodology, while section four describes the data. Section five describes the spatial structure of Colombian agricultural supply and demand. Section six outlines the general economic effects of trade liberalization and shows the variables linking the two models. Section seven describes the spatial effects of trade liberalization. Finally, section eight provides conclusions and policy implications.

2. Literature review

To the best of my knowledge this is the first attempt to assess the likely impacts of trade liberalization on the spatial structure of Colombian agriculture.[1] Also, from the methodological standpoint I know of no other research that has previously taken the approach used here. However, there are plenty of examples in the literature that focus on the regional or spatial effects of different economic shocks on several dimensions of welfare or economic activity. It is possible to distinguish two main approaches for this: regionalized computable general equilibrium models (CGEs) and some form of integrated CGE and microsimulation techniques.

As mentioned by Lofgren and Robinson (1999), since the mid 1990s there has emerged a growing number of regionally disaggregated CGEs to address the need to consider the spatial impact of economic policy in the face of evidence that suggests that regional effects may substantially differ from the national average. For instance, Harris (1999) uses a multiregional CGE to assess the distributional impacts of macro shocks in the Mexican economy. Haddad and Hewings (2004) use an interstate CGE of the Brazilian economy to evaluate the effects of decreasing transportation costs.

The integrated CGE-microsimulation approach has been used in a myriad of applications, especially regarding the poverty impacts of trade liberalization. Its regional or spatial dimension varies according to the nature of the underlying household data. Two examples of this approach are provided by Coady and Harris (2001) and Fujii and Roland-Host (2008).

[1] The above-mentioned study by Haddad et al. (2008) uses a regionalized applied general equilibrium model with 33 regions and 7 sectors. Agriculture is treated as a single sector and land is not included as a production factor.

It is important to distinguish between regionally disaggregated and spatially disaggregated results. While the former allow estimating impacts for subnational disaggregations, this does not necessarily imply being able to take into account activities' location or to explicitly consider distance. The treatment of spatial phenomena in CGE models has its limitations. As Haddad (2004) mentions, it is possible to model the transportation technology by means of the iceberg transportation cost hypothesis, by assuming that transport services are provided though a special optimizing transport sector or by introducing a satellite module for the transportation system. Alternatively, it can be modeled as a spatial network CGE (Lofgren and Robinson, 1999). In spite of making possible an explicit treatment of certain dimensions of geography, none of these options allow for considering the exact location of economic activity. The methodology used in this research allows disaggregation at both the regional and spatial levels, including exact location, provided data availability.

3. Methodology

As mentioned, a two-step process is used to estimate the potential spatial effects of trade liberalization on the Colombian agricultural sector. First, a computable general equilibrium model is used to estimate the economic effects of trade liberalization. Second, appropriate price and quantity changes arising from the first step are brought into a transportation model that simulates the potential impact that these changes may entail on crop location and area harvested at each location. This section describes the procedure employed and details some of the most relevant methodological issues.

3.1 The CGE model

The static version of the GTAP model is used for simulating the impact of trade liberalization on the Colombian economy. This multi-region constant-returns-to-scale model allows for a detailed implementation of Colombia's trade agenda. The model runs on version 6 of the GTAP database (as documented in Dimaranan and McDougall, 2005) and has 2001 as base year. The 87 regions contained in the database are regrouped into 20 regions, defined in such a way as to allow an appropriate simulation of trade agreements signed or under negotiation by Colombia. Analogously, the 57 sectors belonging to the database are regrouped into 32 sectors following two criteria: first, keeping an adequate detail of the agricultural sector; and second, maintaining a certain degree of homogeneity in the level of protection within a sector.

Trade protection data in the database were amended to better reflect a set of preferences granted within the Western Hemisphere (including preferences already implemented by Colombia and its trade partners in the context of trade agreements in force by 2001) as well as other particular trade protection features such as the Andean Price Band System that entails the application of variable levies for a set of agricultural products. A set of 23 trade liberalization episodes directly or indirectly related to Colombia are implemented in the simulation. The only scenario simulated is one in which all trade agreements considered are implemented and full tariff elimination is achieved for all sectors.[2] Therefore, the scenario describes the result of the most important trade liberalization initiatives and depicts the end result of these processes. Only tariff elimination is taken into account, and no consideration is given to non-tariff barriers.

3.2 The transportation model

This model follows the structure of basic transportation models (Dantzig, 1963; Dantzig and Thapa, 1997; Hillier and Lieberman, 2001). It links a set of production regions with a set of markets through a transportation network comprising distances between pairs of regions, markets and transport fares. Most transport models minimize the total transport cost involved in sending products from production regions to markets. This model maximizes total net revenue; that is, the difference between what markets pay for products shipped to them and what it costs to produce these products in specific locations and deliver them. This way, competition between production regions is not solely based upon location but also on efficiency in production.

Two variants of the transportation model are used: a pre-(CGE)simulation transportation model, that "rationalizes" the base year spatial structure of agricultural production; and a post-simulation transportation model that allows the production-and-trade system to react before the trade shock. The pre-simulation transportation model maximizes net revenue for a production-and-trade-system build on base year data. Its objective function is given by:

$$\begin{aligned} MAX_{tf(j,z,m)} NR = \textstyle\sum_j \sum_z \sum_m [(DP(j,m) \div EXR) \\ - AUC(j) - TC(z,m)] \times tf(j,z,m) \end{aligned} \quad (1)$$

where NR denotes the net revenue function, DP is final demand price, EXR is the exchange rate, AUC is annual unit production cost, TC is per unit transportation cost, and tf is a trade flow. Indexes j, z, and m denote products, production regions, and markets, respectively.

This objective is subject to supply and demand constraints:

$$\textstyle\sum_m tf(j,z,m) \le QP(j,z) \quad (2)$$

$$\textstyle\sum_z \sum_p tf(p,z,m) = \sum_p QD(p,m) \quad (3)$$

Equation (2) is the supply constraint and simply ensures that, for a given production region z and product p, the summation of trade flows going from there to all markets cannot be more than the amount of product the region produces (QP). The demand constraint, equation 3, ensures that quantity demanded of a product in a market (QD) must be exactly matched by the summation of all trade flows of the product coming from all producing regions to this market. As implied, in this case the index p denotes the demanded product. A demanded product, p, is a set of produced products, j, of the same kind (oranges, for instance). The distinction between several products j of the same kind, p, relates to the fact that each of them has different annual unit costs, as technologies and input and factor prices vary by producing region. Therefore, the model uses a mapping between produced goods, j, and consumed goods, p.

As follows from the above, the model generates a set of trade flows from production regions to markets which maximizes net revenue for the production-consumption system embodied in the base year data. In the absence of trade flows in the original data, due to lack of information, the model provides an "economic rationale" for generating them and having a complete production-and-trade system for the base year. A discussion of the post-simulation transportation model is postponed for the next section. A general description of the two variants of the transportation model is provided in Appendix 1.

3.3 Linking the two models and simulating trade liberalization effects

Given the way the GTAP database sectors span over individual products, only a fraction of them are captured in the transportation model database. The 34 products actually covered by the transportation model represent 88.1% of total agricultural production with a potential for being relocated. Tradable products whose location is heavily concentrated and that, due to the industrial structure in place, will unlikely suffer

[2] The only exception to this is the case of the agricultural sector within the Mercosur-Andean Community FTA, where only the Andean Common External Tariff is phased out while the variable levy arising from the Andean Price Band System remains in place.

any kind of relocation because of trade shocks were excluded from the analysis. Examples of this are export bananas, sugar cane, and cut flowers. The whole list of products and their production levels is presented in Appendix 2.

An initial data consistency requirement between the two databases is imposed. For each GTAP sector, the set of comprised individual products must have, in the aggregate, the same (or reasonably close) shares for domestic consumption and exports that the GTAP sector has in the SAM. This assures that the relative changes in quantities produced, domestically sold, and exported are consistently transmitted from the CGE simulation results to the post-simulation transportation model. If this consistency criterion, with an appropriately defined flexibility level, is not met, there would be need to adjust the databases to satisfy it. In the case at hand, the criterion is satisfied.

The variables that transmit the effects of trade shocks from the CGE to the transportation model are a set of price and quantity percentage changes. Price changes affect both the "supply" and "demand" sides of the transportation model. On the supply side, production costs are affected through unskilled labor, skilled labor, fuels, chemical products, and machinery and equipment price changes. It is assumed that technologies are of the fixed coefficients type. On the demand side, the effect is entirely embodied in changes in demand prices. Quantity changes basically affect the demand side. These are reflected in domestic demand and export volumes which, in turn, determine changes in production levels (consistency of the latter is assured thanks to the initial data consistency requirement mentioned above).

Given that production costs data is micro level, and therefore local prices are used for valuing inputs and factor usage, lack of data availability makes it impossible to generate aggregate cost structures for the GTAP sectors. Therefore, no attempt was made to ensure consistency between technical coefficients in the micro data and in the SAM. Given that there is no feedback between the two models (i.e., no convergence is sought between both models results), this feature, although a limitation of the procedure, is not critical for the validity of the results.

For allocating the sectoral (CGE) response to the trade shock among individual products, the following procedure is used. For each set of individual products (included and not included in the transportation model database) that integrate a GTAP sector, products are classified as exportable, importable or non-tradable. The allocation of quantity changes is done first for exportables as it regards changes in exported volumes. For this, use is made of supply elasticities for each individual product, and price changes are found that guarantee that the aggregate weighted change in exported volumes matches that arising from the simulation results coming from the CGE for the corresponding sector. The same set of price changes is used to determine changes in domestic consumption of exportables, but this time using own-price demand elasticities for getting them.

Next, allocation is done for non-tradables. In this case, it is assumed that price changes for the GTAP sector directly apply to each individual product, so the corresponding own-price demand elasticities allow for estimating changes in quantities demanded domestically. Last, changes are allocated to importables. Using the own-price demand elasticities for each product, price changes are found that assure that the total aggregate weighted change in domestic demand for the whole sector matches that coming from the CGE simulation. The set of percentage price changes obtained above is used for adjusting price levels in the transportation model database.

No consideration is given here to cross-price or income effects as these have already been taken into account in the CGE model. The procedure outlined above is just a device for disaggregating at the product level the sectoral effects that arise from the trade shock. A thorough description of the procedure is presented in Appendix 3.

On the supply side, allocation of the CGE effects to individual products has a spatial implication. This is due to production costs associated with each technology changing according to the relevant price changes and technologies associated with production regions. However, on the demand side, allocation of the CGE effects has no spatial implication per se given that it is done in a product-based and not in a market-based manner. In this research no attempt is made to allocate price changes among markets, due to the fact that there is no available information on demand elasticities per product and market that could be used for this purpose. Therefore, the same price change is applied to all markets and this feature of the spatial dimension of the problem is lost.

Once the general equilibrium effects on quantities and prices have been allocated at the product level, the transportation model database can be updated to reflect them. This implies having new annual unit production costs data for all production-region/produced-good pairs, and new demand levels and demand prices for all market/product-demanded pairs. No new transportation costs are assigned since transport costs are assumed linear in distances travelled and all production-region/destination-market combinations for all products use the same type of transportation – an assumption consistent with Colombian reality.

A slightly different version of the transportation model (the post-simulation transportation model) is run using the new data base. It generates, again, a set of trade flows between production regions and markets that maximizes net revenue for the new production-and-demand system. The objective function of the model is given by:

$$MAX_{tf1(j,z,m)} NR1 = \sum_j \sum_z \sum_m [(DP1(j,m) \div EXR) - AUC1(j) - TC(z,m)] \times tf1(j,z,m) \quad (4)$$

where *NR1* is the net revenue function, *DP1* is the new demand price for each product in each market, *EXR* is the exchange rate, *AUC1* is the new annual unit production cost, *TC* is the unit transportation cost, and *tf1* is the new trade flow of product *j*, from production region *z* to market *m*. As before, *j*, *z*, and *m* index products, production regions, and markets, respectively.

This objective is subject to a set of four constraints:

$$\sum_m tf1(qddown, z, m) \leq QP(qddown, z) \quad (5)$$

$$\sum_m tf1(qdup, z, m) \leq QP(qdup, z) + DELTAQD(qdup, z) \quad (6)$$

$$\sum_m tf1(qdup, z, m) \geq QP(qdup, z) \quad (7)$$

$$\sum_z \sum_p tf1(p, z, m) = \sum_p QD1(p, m) \quad (8)$$

Constraints (5), (6), and (7) are supply constraints. Equation (5) applies only for products whose markets (for the product domestically supplied) have shrunk due to the trade shock. In this case the constraint is similar to the one used in the pre-simulation model. The second and third supply constraints apply to products whose markets have grown after the trade shock. Equation (6) assures that the total quantity shipped of a product from a production region cannot increase more than what the whole market (domestic plus exports) has increased (parameter *DELTAQD* represents the total increase in market demand volume). Hence, it is possible for a region to increase production so as to be able to fully satisfy the increase in total demand. Lastly, equation (7) assures that the total amount of a product that is shipped from a production region cannot decrease with respect to the pre-simulation production level. This implies that, for products whose market size increases, a production region cannot expand if it means a decrease in another region producing the same product, an assumption that is consistent with the vision that the original (base year) set of cultivated areas represents a spatial equilibrium. The last constraint, equation (8), is a demand constraint. It ensures that no market is under- or over-supplied with respect to each particular product.

In summary, there are two main differences between the pre- and post-simulation transportation models. First, the database is amended in the second case to reflect changes in unit production costs, quantities domestically demanded, quantities exported, and market prices. Second, the set of constraints for the post-simulation model is modified so as to ensure that there is competition among production regions that is consistent with both the assumption that base year data represents a spatial market equilibrium and the general equilibrium changes induced by trade liberalization. Figure 1 shows the way the whole simulation procedure works.

4. Data

The transportation model database has three main modules, corresponding to supply, demand, and transportation. It has been assembled by the author based on information elaborated by a team of researchers working in a project on Colombian agriculture, as documented in Arguello (2005).

The supply module comprises 18 production regions, covering most of the Colombian agricultural area, whose boundaries have been defined following two criteria: first, relative homogeneity in terms of their agro-ecological characteristics; and second, coincidence with established commercial circuits (Molina, et al., 2004). These regions produce a set of 34 products (not all products are produced in all regions), assumed homogeneous in consumption.

There is also a set of 141 technologies available for producing these products. A technology is a particular combination of resources (and resource prices) that leads to different yields and production costs. There are products that have only one technology, while others may have several. A product that is grown in a particular region is cultivated only under one technology, but technologies may be employed in more than one region. This information is based on available cost data produced by different national organizations and reviewed to assure its consistency (Samaca, 2004).

The demand module has eight markets, seven domestic and an export market. Domestic markets have been defined roughly following consumption patterns and geographic proximity and correspond to consumption regions. This ensures relative homogeneity in consumer prices and transportation costs within each domestic market. Quantities demanded in these

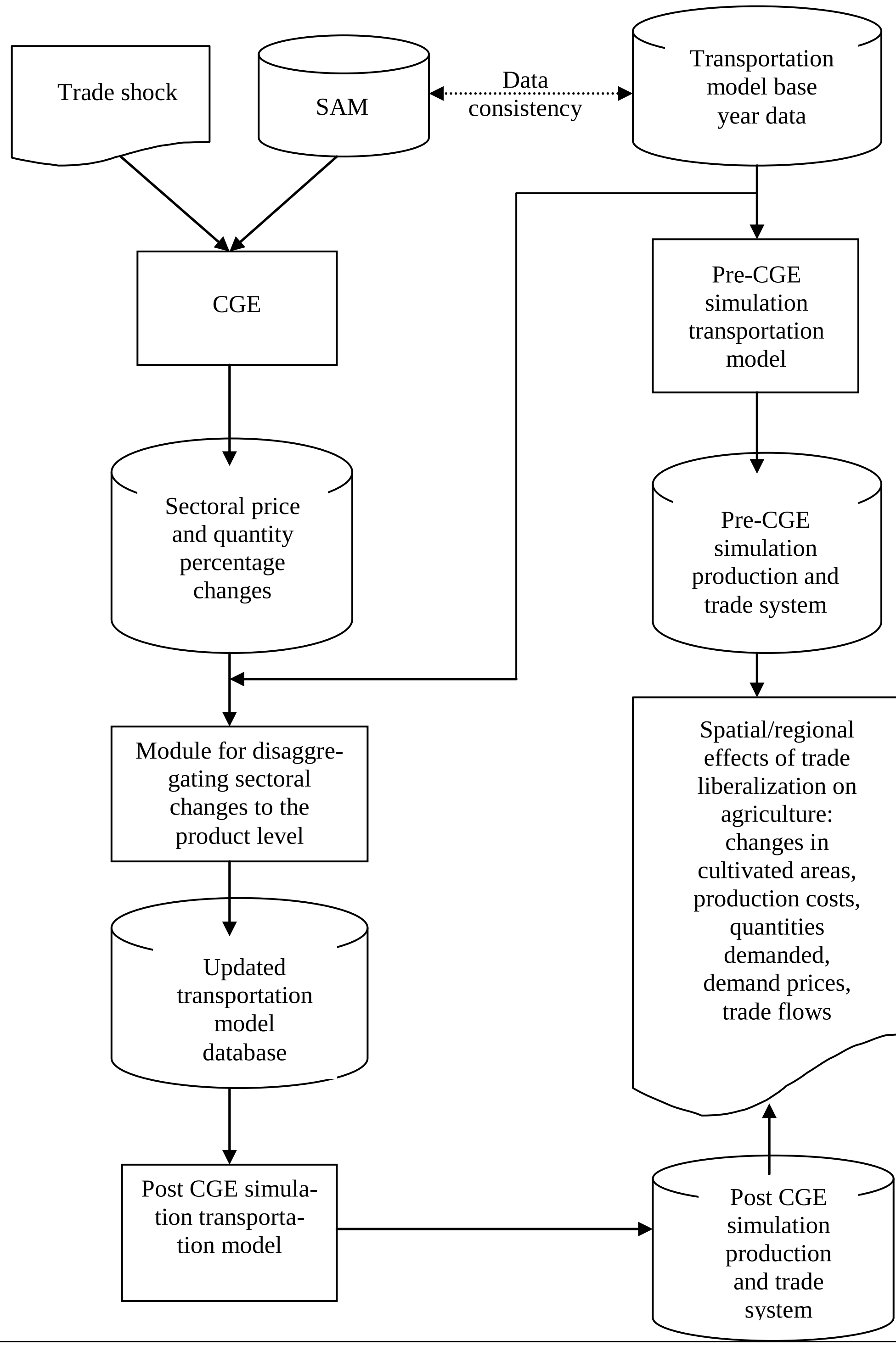

Figure 1. Diagram of the simulation procedure

markets amount to total urban and rural demand at the interior of the geographic area that defines the corresponding market and are estimated based upon Income and Expenditures Household Surveys. In the case of crops that are basically used as industrial inputs, such as oil palm kernel, quantities demanded are estimated from the Colombian Manufacturing Survey. Prices correspond to wholesale prices in the main urban market within each consumption region (Tellez, 2004). Quantities in the export market come from national statistics and, for simplicity, a single export port is assumed to operate.

Production, domestic demand, and export quantities data are matched in the base year so that total production exactly equals total domestic demand plus exports for each product. Therefore, as has been mentioned, data for the base year is assumed to represent a spatial market equilibrium, and the transportation model is just a device for giving an "economic rationale" to this equilibrium and for setting the basis for the whole production-and-trade system that reacts before price and quantity changes arising from the CGE simulation.

Lastly, the transportation module includes transport costs that are the linear outcome of transport fares per weight unit and distance. Transport fares vary by market of destination, irrespective of the origin of the merchandise, according to data calculated by the Colombian Ministry of Transportation based upon transport cost surveys (Colombian Ministry of Transportation). Only one transport modality is considered (light trucks) due to the fact that it is the most commonly used for mobilizing agricultural products. For calculating distances between production regions and markets, baricentric points are identified for each production region and distances were taken from these points to the location of the main urban market for each production-region/domestic-market pair. Regarding the export market, distances from each production region were calculated using the average distance from the production baricenter to the two main Colombian ports (one on the Atlantic Ocean and one on the Pacific Ocean).

5. Spatial structure of Colombian agricultural supply and demand

Excluding plant fibers, cut flowers, and livestock and animal products, Colombian agricultural raw production reached almost 51 million metric tons in 2001, representing 86.5% of total Colombian agricultural production. The set of 34 products included in the transportation model database roughly represent 99.4% of the 51 million metric tons. However, disregarding export bananas and sugar cane this share decreases to around 30%. Recalling that export bananas and sugar cane are crops with practically no chance of relocation, the set of products selected for the study represent the bulk (88.1%) of products that may suffer some form of relocation arising from the simulated trade shock.

As shown in Table 1, among the 18 production regions, the Alto Magdalena region has the highest share of production volume for the set of products included in the model. It is followed by the Sabanas and the Andina Central regions, with the three of them accounting for 53.1 percent. In general, intensity indexes (measured as cultivated area as a percentage of total arable land) show that there is relatively ample room for extending agricultural activities, at least from the standpoint of the set of products covered here. The exceptions to this are the Andina Central region, that is being overexploited, and the Eje Cafetero region, with an intensity index close to 96%.

Table 1. Physical production shares for the 18 production regions in the model

Production Region	Production Share	Production Region	Production Share
Alto-Magdalena	19.2	Andina-Antioquia	3.0
Sabanas	17.5	Orinoquia	2.0
Andina-Central	16.3	Piedemonte	1.9
Andina-Santander	7.5	Andina-Norte	1.9
Meta	6.7	Andina-Nariño	1.7
Medio-Magdalena	5.4	Uraba	1.5
Sierra	5.0	Pacifica-Nariño	1.2
Eje-Cafetero	4.5	Altiplano	0.9
Valle	3.1	Andina-Cauca	0.6

Source: Transportation Model Database, 2001.

Regrouping the 34 products according to the GTAP database classification, there are six groupings in the transportation model database: rice (one product), cereals (two products), fruits and vegetables (26 products), oil crops (two products), sugar (one product), and other crops (two products). Appendix 4 provides the list of products belonging to each product grouping. The highest share in physical production belongs to fruits and vegetables (70.8%), followed by rice (10.7%) and cereals (10%). The remaining groups have the following shares: oil crops, 4.3%; sugar, 1.2%, and other crops, 3%. From the standpoint of each product grouping, production tends to be relatively concentrated in a few regions. Table 2 shows the relevant information.

As the base year represents the initial spatial equilibrium, the composition of consumption exactly matches that of production in terms of product

Table 2. Main production regions' shares in physical production by product group

Rice		*Cereals*		*Fruits and Vegetables*	
Region	Share	Region	Share	Region	Share
Alto-Magdalena	35.1	Sabanas	34.1	Andina-Central	22.1
Meta	27.6	Alto-Magdalena	14.9	Alto-Magdalena	18.5
Sabanas	15.3	Sierra	10.7	Sabanas	17.4
Orinoquia	10.2	Medio-Magdal.	8.1	Andina-Santan.	8.9

Oil Crops		*Sugar*		*Other Crops*	
Region	Share	Region	Share	Region	Share
Meta	40.6	Andina-Central	39.1	Eje-Cafetero	24.3
Medio-Magdal.	25.0	Alto-Magdalena	32.8	Alto-Magdal.	18.0
Sierra	17.3	Andina-Santander	11.4	Andina-Sant.	16.8
Pacifica-Nariño	8.2	Andina-Antioquia	6.8	Valle	10.4

Source: Transportation Model Database, 2001

groupings as well as of individual products. Export markets are of significance only for fruits and vegetables, oil crops, and other crops, representing 1.2%, 8.5%, and 86.5%, respectively, of total volume demanded. On the other hand, among the eight markets considered, domestic demand tends to concentrate in the Centro region where most of the population of the country is located. However, its degree of dominance over quantities demanded varies by product grouping, reflecting regional variation in consumer tastes and the location of manufacturing demand in the case of inputs. The Centro region represents 29.5% of total demand; the Caribe region represents 16.4%, the Pacifico region 15.2%, and the Antioquia region 13.6%. The rest of the regions account for the remaining 25.3% of total demand. Table 3 shows markets' shares in demand by product grouping.

Lastly, distances between production regions and regional markets vary considerably. The average distance is 735 kms with a minimum value of just 12 kms and a maximum of 1,832 km. The region with the lowest average distance to markets is Eje Cafetero (located toward the geographical center of the country), while the region with the highest average distance is Pacifica Nariño (located in the extreme southwestern part of Colombia).

Table 3. Markets' shares in quantities demanded by product grouping

Market	Rice	Cereals	Fruits and Vegetables	Oilcrops	Sugar	Other Crops
Antioquia	12.4	16.7	14.0	11.9	10.0	3.0
Caribe	24.2	21.7	15.1	20.9	1.8	0.6
Centro	32.9	26.0	30.3	29.5	44.9	4.1
Eje Cafetero	4.8	1.0	8.5	4.2	4.5	2.1
Llanos-Amazonia	2.0	3.7	8.3	3.8	1.7	0.5
Pacifico	18.1	22.9	14.1	16.6	13.6	2.3
Santanderes	5.6	8.1	8.6	4.7	23.4	1.0
Exports	0.0	0.0	1.2	8.5	0.0	86.5

Source: Transportation Model Database, 2001

6. Trade liberalization effects

Results from the CGE simulation show that the Colombian economy is bound to negligibly lose welfare. The loss amounts to 0.1% of GDP and is largely determined by deterioration in terms of trade. While allocative efficiency gains are positive, they are insufficient to compensate for terms of trade losses. Table 4 shows the general impact of trade liberalization in the Western Hemisphere on the Colombian economy, detailing the contribution of the agreements that directly impinge upon Colombian protection structure. It also presents a decomposition of welfare results between allocative efficiency and terms of trade effects. Welfare is measured in dollar terms (of 2001) as the equivalent variation.

Table 4. Welfare effects from trade liberalization in the Western Hemisphere on the Colombian economy*

Trade Agreement	Allocative efficiency	Terms of trade	Welfare (EV**)
FTA with the US	46.7	-16.7	30.0
FTA Mercosur-Andean C.	2.1	-22.9	-20.8
G-3 FTA	-6.7	-2.6	-9.2
Andean Community FTA	0.5	0.7	1.2
Multi Fiber Agreement	-6.3	-28.5	-34.7
Other agreements	-11.4	-34.6	-46.1
Total effect	24.9	-104.6	-79.6

*US$ million, 2001; **Equivalent Variation.
Source: CGE simulation.

As follows from the table, only the FTA with the US and the full implementation of the Andean Community FTA (trade liberalization with Peru) yield positive welfare results for Colombia. While the FTA with the US results in positive allocative effects and negative terms of trade effects, the full implementation of the Andean Community FTA, although of lesser magnitude, yields positive effects in the case of both welfare components. The remaining trade liberalization processes generate negative welfare effects for the Colombian economy. Among these, only the FTA Mercosur-Andean Community yields positive allocative effects.

Table 5 shows the contribution of agricultural sectors to overall welfare results. It includes detailed welfare effects only for the set of sectors of interest for this research and the total for the whole agricultural sector. Figures in the first and second columns represent allocative efficiency and terms of trade effects in 2001 US$ millions. The third column corresponds to the share of each sector line in overall welfare results.

Table 5. Contribution of agricultural sectors to welfare results

Sector	Allocative Efficiency	Terms of Trade	Share in Total Welfare
Paddy Rice	8.0	-0.3	9.6
Cereals	11.8	-1.1	13.4
Fruits and Vegetables	-0.6	-5.7	-8.0
Oil Crops	6.0	0.3	7.9
Sugar	1.9	-4.2	-2.9
Other Crops	0.8	26.9	34.7
Total Agriculture	128.7	-5.2	155.1

First and second columns in 2001 million dollars. Figures in the third column are percentages.
Source: CGE simulation.

Moving to changes in prices and in quantities produced, domestically-demanded, and exported, Table 6 presents the relevant figures in percentage terms. The second column refers to domestic demand for domestically produced goods. The fourth column shows percentage changes in physical production for each sector. It is the result of the weighted sum of percentage changes in demand for domestically produced goods and exports. The last column shows percentage changes in market prices. Only the set of sectors that are included in the transportation model database are shown.

Table 6. Percentage changes in total demand, production, and prices for agricultural sectors from the CGE simulation

Sector	Domestic Demand	Exports	Production	Prices
Paddy Rice	-11.9	0.0	-11.9	-3.5
Cereals	-13.2	0.0	-13.2	-3.8
Fruits and Vegetables	-0.1	3.7	0.6	-1.1
Oil Crops	-12.9	-19.9	-12.9	-3.7
Sugar	-1.0	10.8	0.8	-2.7
Other Crops	-0.9	22.1	14.3	1.6

Source: CGE simulation.

Rice and cereals, which among the sectors of interest are mainly importables, show decreases in domestic demand, production, and prices, as average tariffs protecting them fall due to trade liberalization. Fruits and vegetables, sugar, and other crops, all of which are overwhelmingly exportables, show increases in volume that are commensurate with the relative size of reductions in average tariffs faced by Colombia. The case of oil crops is unique in that exports decrease. This is due to both the relatively high increase in imports, which depress domestic prices, and the fact that most exports go to markets in which Colombia faces no tariffs in the pre-simulation period and, hence, has no market access gains.

7. The spatial impact of trade liberalization

As a result of trade liberalization, market prices for unskilled labor, skilled labor, fuels, chemical products, and machinery and equipment fall in the range between 0.2% and 1.61%. As a consequence, on the supply side unit production costs for the whole set of 141 technologies fall 1.1% as an average.

On the demand side, individual percentage changes in quantities produced and exported and in prices, are obtained following the procedure described above. These quantity and price changes are reflected at the spatial level through changes in areas cultivated, production volumes, and production values by region, modifying the structure of Colombian agriculture.

These changes may arise from different sources. First, the composition of regional production in terms of product types may cause changes as regions with large shares of importables over exportables tend to lose as demand for domestic production must decrease due to tougher competition from imports. On the contrary, regions with large shares of exportables must gain as trade liberalization tends to increase export volumes. Second, the extent to which markets are liberalized for both imports and exports for each region affects changes. Tariff reductions are uneven among importables (because of initial levels of tariffs) so it can be expected that regions whose importables are more liberalized will be hit harder by foreign competition. On the contrary, exportables benefiting from higher tariff reductions will tend to expand production the most, and regions with large shares in cultivated areas for these products will tend to gain.

The third source of changes is regional comparative advantage manifested both in terms of production costs and proximity to markets. Regions employing technologies with heavier use of factors and inputs whose market prices decline the most due to trade liberalization tend to benefit the most. Also, even though transport costs remain unchanged in the model, location is important for regional comparative advantage. Regions located closer to markets whose size increases will tend to benefit, while regions located more distant may not. Similarly, regions located closer to markets whose size decreases will tend to show lower or no losses, while regions located far away will certainly tend to lose as market shrinkage will affect them the most due to higher transport costs.

Even though these rules of thumb for assessing the direction of expected changes are clear cut, their interaction is not. The extent to which they may offset or reinforce each other's effects is uncertain from the outset so only simultaneous consideration of them allows appraising their impact at the regional level.

Table 7 shows changes in harvested areas accruing to each region. All but two production zones (Andina Cauca and Eje Cafetero) show changes in net harvested areas. However, seven of the remaining 16 production zones show decreases in harvested areas that represent less than a 3% change with respect to the base year. Therefore, the spatial effects of trade liberalization concentrate on nine production zones.

The highest increase in harvested area, both in absolute and relative terms is found for the Medio Magdalena region (a 122.1% increase). The highest decrease is found in the Orinoquia region. In terms of the intensity with which production regions are cultivated, the above changes imply that the Andina Central region will be more heavily over cultivated (showing an over use of more than 25%).

It is also relevant to see how the spatial structure of physical production changes. The difference between spatial changes in harvested areas and production is due to both differences in productivity among production zones and differences in extraction rates among products. Production changes are presented in Table 8 below. Total production volume decreases by nearly 354,800 tons, a 1.7% decrease. The production zone with the largest increase in harvested area, Medio Magdalena, also shows the largest increase in production (a 15.5% increase). The biggest decreases in production volumes are in zones with relatively low initial shares of total production, mainly in Orinoquia, Uraba, and Piedemonte.

Table 7. Changes in harvested areas at the production zone level

Production Zone	Harvested Area Percentage Change	Initial Share of Harvested Area	Final Share of Harvested Area	Initial Intensity	Final Intensity
Altiplano	-1.1	0.5	0.4	6.9	6.8
Alto-Magdalena	-0.2	19.3	18.1	47.2	47.1
Andina-Antioquia	-0.3	4.8	4.5	27.2	27.1
Andina-Cauca	0.0	2.7	2.6	37.3	37.3
Andina-Central	13.6	13.3	14.2	110.5	125.4
Andina-Nariño	-0.2	1.8	1.7	15.1	15.0
Andina-Norte	-25.0	1.5	1.1	9.1	6.8
Andina-Santander	-1.5	8.5	7.8	34.7	34.2
Eje-Cafetero	0.0	11.4	10.7	95.7	95.7
Medio-Magdalena	122.1	4.8	10.0	11.4	25.3
Meta	-1.7	6.1	5.6	21.3	20.9
Orinoquia	-55.6	1.6	0.6	5.0	2.2
Pacifica-Nariño	-2.7	1.6	1.5	6.4	6.2
Piedemonte	-17.5	1.6	1.2	5.1	4.2
Sabanas	21.0	8.1	9.2	13.4	16.2
Sierra	-3.8	5.7	5.1	8.6	8.3
Uraba	-44.6	1.0	0.5	8.5	4.7
Valle	-4.1	5.7	5.1	35.5	34.1

Source: Transportation model simulation.

Table 8. Changes in volume of production at the production zone level

Production Zone	Physical Production Percentage Change	Initial Share of Production Volume	Final Share of Production Volume
Altiplano	-1.2	0.9	0.9
Alto-Magdalena	-0.3	19.2	19.5
Andina-Antioquia	-0.1	3.0	3.1
Andina-Cauca	0.0	0.6	0.6
Andina-Central	1.3	16.3	16.8
Andina-Nariño	-1.5	1.7	1.7
Andina-Norte	-7.5	1.9	1.8
Andina-Santander	-0.2	7.5	7.6
Eje-Cafetero	0.1	4.5	4.6
Medio-Magdalena	15.5	5.4	6.3
Meta	-1.1	6.7	6.7
Orinoquia	-59.9	2.0	0.8
Pacifica-Nariño	-6.2	1.2	1.1
Piedemonte	-18.4	1.9	1.6
Sabanas	2.6	17.5	18.3
Sierra	-6.3	5.0	4.7
Uraba	-42.1	1.5	0.9
Valle	-8.0	3.1	2.9

Source: Transportation model simulation.

For completeness, Table 9 shows changes in the value of production per zone. Production is valued using annual unit production costs. Therefore, it is assumed that producers operate with zero benefits and that trade margins accrue to agents that do not belong to any production zone.

On average, changes in the value of production are relatively close to changes in the volume of production (-6.71% vs. -7.42%), but their variability roughly doubles the one corresponding to volumes. In all, the adjustment in the regional structure of the value of production is less than the one taking place in the regional structure of harvested areas.

These results indicate that potential changes in the spatial structure of agricultural production in Colombia arising as a consequence of trade liberalization are not negligible and may have important implications in several dimensions. First, they entail significant changes, both positive and negative, in harvested areas that will have an impact on producers and employment at the local level. Second, they may have significant impacts on regional income brought about by both changes in harvested areas and changes in production costs. Third, they may shift the relative importance of production zones from both the individual products perspective and for overall agricultural activity, impinging upon the way public resources must be allocated through existing or new supporting programs.

Table 9. Changes in production value at the production zone level

Production Zone	Production Value Percentage Change	Initial Share of Production Value	Final Share of Production Value
Altiplano	-2.4	1.2	1.2
Alto-Magdalena	-1.6	21.6	21.6
Andina-Antioquia	-1.5	4.7	4.7
Andina-Cauca	-1.0	1.9	1.9
Andina-Central	6.6	12.8	13.8
Andina-Nariño	-1.5	1.9	1.9
Andina-Norte	-24.0	2.5	1.9
Andina-Santander	-1.7	8.6	8.5
Eje-Cafetero	-0.9	8.0	8.1
Medio-Magdalena	85.9	3.5	6.6
Meta	-4.4	8.0	7.8
Orinoquia	-79.2	3.0	0.6
Pacifica-Nariño	-6.2	1.1	1.1
Piedemonte	-29.7	1.4	1.0
Sabanas	8.0	8.4	9.2
Sierra	-6.0	5.3	5.0
Uraba	-49.9	1.1	0.6
Valle	-11.1	5.1	4.6

Source: Transportation model simulation.

8. Conclusions and policy implications

This research estimates the likely impact of discriminatory trade liberalization on the agricultural sector from a regional/spatial perspective. For this, an approach linking a computable general equilibrium model with a transportation model is proposed and implemented. Results center around three dimensions: changes in harvested areas, changes in physical production levels, and changes in the value of production. The results highlight the following conclusions.

Changes in the spatial structure of agriculture may be significant in the three dimensions explored. Total harvested areas may increase by 6.6%, implying percentage changes at the production region level ranging from 122.1% to negative 55.6%. There is a negative change in total production volume of 1.7%, which translates in individual regions' changes between 15.5% and negative 60%. Lastly, the total value of production decreases 1.47%, with individual regions' changes from 85.9% to negative 79.2%.

Gains and losses, in terms of percentage changes in the three dimensions, tend to concentrate in relatively few regions. Six regions take the bulk of losses while three regions reap almost all benefits (leaving the remaining nine regions with relatively small impacts). This is an important result for policy design.

From another perspective, potentially damaging environmental effects may take place in the Andina Central region as a consequence of harvested area expansion. According to the estimates, harvested area could increase to over 25% above available arable land.

The richness of these results illustrate the complexity that policies to ease the transition from the old to the new agricultural environment should have to be effective. There is clearly the need for these policies to have a product dimension, designed along the lines of each product's particular situation in terms of its competitiveness. Identifying winners and losers among the products may help in focusing policies on agents linked to them, whether for easing their transition or for helping their taking advantage of the new opportunities.

However, policies also need a regional/spatial dimension as production regions encompass a mix of products that are winners or losers and the net result for a region depend not only upon its particular mix but also on factors such as its relative competitiveness vis a vis other regions, its proximity to markets, etc. Having an estimate of the expected relative impact of trade liberalization on a particular production region is instrumental for policy design. This is so from the point of view of the tradeoffs that a production region faces, given its particular product mix, as well as from the point of view of the magnitude of these impacts as compared to those from other regions. In both senses, the results of this research provide valuable information for policy design.

References

Arguello, R. (technical coordinator). 2005. Cuantificación de los Beneficios y Costos de la Reconversión de la Agricultura Colombiana. Informe Final. Corporación Colombia Internacional, contrato DNP.

Argüello, Ricardo, and Ernesto Valenzuela. 2006. Implicaciones en Acceso a Mercados. Ch. 3 in *Las Negociaciones Hemisféricas y la Comunidad Andina: Evaluación de Impacto,* ed. Secretaría General de la Comunidad Andina, Comunidad Andina and Banco Interamericano de Desarrollo, Lima, April.

Botero, Jesus. 2005. Estimación del impacto sobre el empleo de los tratados de libre comercio en Colombia; análisis de equilibrio general computable. *Serie estudios y perspectivas*, No. 8, Oficina de la Cepal en Bogota, July.

Coady, D. and R. Harris. 2001. A Regional General Equilibrium Analysis of the Welfare Impact of Cash Transfers: An Analysis of Progresa in Mexico. IFPRI, *TMD Discussion Paper* No. 76, Washington, D.C., June.

Colombian Ministry of Transportation, www.mintransporte.gov.co.

Dantzig, George. 1963. *Linear Programming and Extensions.* Princeton, NJ: Princeton University Press.

Dantzig, George and M.N: Thapa. 1997. *Linear Programming 1: Introduction*. New York: Springer.

Duran, Jose, Carlos de Miguel, and Andres Schuschny. 2006. Andean Countries and USA: how much can be expected from FTAs?. ECLAC, UN, Santiago.

Fujii, T. and D. Roland-Host. 2008. How Does Vietnam's Accession to the World Trade Organization Change the Spatial Incidence of Poverty? World Bank, Policy Research Working Paper 4521, Washington, D.C., February.

Haddad, E. 2004. Linking Inter-Regional CGE Models with Geo-Coded Transportation Network Infrastructure Models. *TD Nereus* 04, University of Sao Paulo

Haddad, E. and G. Hewings. 2004. Handling Market Imperfections in a Spatial Economy. A CGE Approach. *TD Nereus* 10, University of Sao Paulo.

Haddad, E., J. Bonet, G. Hewings, and F. Perobelli. 2008. Spatial Aspects of Trade Liberalization in Colombia: A General Equilibrium Approach. Banco de la República de Colombia, *Borradores de Economía* No. 515.

Harris, R. 1999. The Distributional Impacts of Macroeconomic Shocks in Mexico: Threshold Effects in a Multi-Region CGE Model. IFPRI, *TMD Discussion Paper* No. 44, Washington, D.C., January.

Hillier, F. and G. Lieberman. 2001. *Introduction to Operations Research* (7th ed.). New York: McGraw Hill.

Lofgren, H. and S. Robinson. 1999. Spatial Networks in Multi-Region Computable General Equilibrium Models. IFPRI, *TMD Discussion Paper* No. 35, Washington, D.C., January.

Martin, C. and J.M. Ramirez. 2005. Impacto económico de un acuerdo parcial de libre comercio entre Colombia y Estados Unidos. *Serie estudios y perspectivas*, No. 7, Oficina de la Cepal en Bogota, July.

Molina, J. et al. 2004. Componente Regional. Regionalización y Jerarquización: Aspectos Metodológicos. In: Ricardo Arguello (coord.) Cuantificación de los Beneficios y Costos de la Reconversión de la Agricultura Colombiana. Informe de Avance. Corporación Colombia Internacional, contrato DNP.

Pardo, O., A. Perdomo, C. Delgado, and C. Lozano. 2005. Colombia y el TLC: Efectos sobre la distribución del ingreso y la pobreza. *Archivos de Economía*, No. 289, Departamento Nacional de Planeación – DNP, Bogota, August.

Samaca, H. 2004. Componente Costos de Producción. Sistema de Costos de Producción. In: Ricardo Arguello (coord.) Cuantificación de los Beneficios y Costos de la Reconversión de la Agricultura Colombiana. Informe de Avance. Corporación Colombia Internacional, contrato DNP.

Tellez, C. 2004. Componente Inteligencia de Mercados. Identificación de Productos. In: Ricardo Arguello (coord.) Cuantificación de los Beneficios y Costos de la Reconversión de la Agricultura Colombiana. Informe de Avance. Corporación Colombia Internacional, contrato DNP.

Appendix 1. Description of the transportation model

A. Pre-CGE simulation transportation model

Sets

J	Crops
Z	Production regions
M	Markets
P(J)	Products (34 products defined over 141 crops –technologies)

Parameters

C(J)	Cycle (years) for crop j
AC(J)	Cycles per year (number per year) for crop j
Y(J)	Yields per cycle (tons per ha per cycle) for crop j
CP(J)	Total production cost per cycle (Col$ per ha per cycle) for crop j
ER(J)	Extraction rate for crop j
TR(M)	Transport cost rate per market m (Col$ per km per ton)
HA(J,Z)	Harvested area (in ha) for crop j in region z
D(Z,M)	Distance between production region z and market m (km)
QD(J,M)	Initial quantity demanded of crop j in market m (tons per year)
DP(J,M)	Initial demand price of crop j in market m (Col$ per ton)
EXR	Exchange rate (Col$ per US$)
AY(J)	Annual yields for crop j (AY(j) = Y(j) / C(j)) (tons)
QP(J,Z)	Annual quantity of crop j produced in region z (QP(j,z) = AY(j) * HA(j,z) * ER(j)) (tons)
UCC(J)	Unit cost per cycle for product j (UCC(j) = (CP(j) / EXR) / Y(j)) (US$ per ton)
AUC(J)	Annual unit cost for crop j (AUC(j) = UCC(j) * AC(j)) (US$ per ton per year)
TC(Z,M)	Unit transport cost between region z and market m (TC(z,m) = (TR(m) / EXR) * D(z,m)) (US$ per ton per km)

Variables

tf(J,Z,M)	Trade flow of product J from region Z to market M (tons)
NR	Net revenue

Equations

Objective function: $MAX_{tf(j,z,m)}\, NR = \sum_j \sum_z \sum_m [(DP(j,m) \div EXR) - AUC(j) - TC(z,m)] \times tf(j,z,m)$

Constraints:

Supply: $\forall j,z$

$$\sum_m tf(j,z,m) \leq QP(j,z)$$

Demand: $\forall p,m$

$$\sum_z \sum_p tf(p,z,m) = \sum_p QD(p,m)$$

B. Post-CGE simulation transportation model

Sets

J	Crops
Z	Production regions
M	Markets
P(J)	Products (34 products defined over 141 crops –technologies)
QDDOWN(J)	Crops with lower new demand
QDUP(J)	Crops with higher new demand

Parameters

C(J)	Cycle (years) for crop j
AC(J)	Cycles per year (number per year) for crop j
Y(J)	Yields per cycle (tons per ha per cycle) for crop j
CP1(J)	Post CGE simulation total production cost per cycle (Col$ per ha per cycle) for crop j
ER(J)	Extraction rate for crop j
TR(M)	Transport cost rate per market m (Col$ per km per ton)
HA(J,Z)	Harvested area (in ha) for crop j in region z
D(Z,M)	Distance between production region z and market m (km)
QD(J,M)	Initial quantity demanded of crop j in market m (tons per year)
QD1(J,M)	Post CGE simulation quantity demanded of crop j in market m (tons per year)
DP1(J,M)	Post CGE simulation demand price of crop j in market m (Col$ per ton)
EXR	Exchange rate (Col$ per US$)
AY(J)	Annual yields for crop j (AY(j) = Y(j) / C(j)) (tons)
QP(J,Z)	Annual quantity of crop j produced in region z (QP(j,z) = AY(j) * HA(j,z) * ER(j)) (tons)
UCC1(J)	Post CGE simulation unit cost per cycle for product j (UCC(j) = (CP(j) / EXR) / Y(j)) (US$ per ton)
AUC1(J)	Post CGE simulation annual unit cost for crop j (AUC(j) = UCC(j) * AC(j)) (US$ per ton per year)
TC(Z,M)	Unit transport cost between region z and market m (TC(z,m) = (TR(m) / EXR) * D(z,m)) (US$ per ton per km)
DELTAQD(J,Z,)	Post CGE simulation change in total quantity demanded of crop j available for region z (DELTAQD(j,z) = sum(m, QD1(j,m) - QD(j,m))

Variables

tf1(J,Z,M)	Post CGE simulation trade flow of product j from region z to market m (tons)
NR1	Post CGE simulation net revenue

Equations

Objective function:

$$MAX_{tf1(j,z,m)}\ NR1 = \sum_j \sum_z \sum_m [(DP1(j,m) \div EXR) - AUC1(j) - TC(z,m)] \times tf1(j,z,m)$$

Constraints:

Supply1: $\forall qddown, z$

$$\sum_m tf1(qddown, z, m) \leq QP(qddown, z)$$

Supply2: $\forall qdup, z$

$$\sum_m tf1(qdup, z, m) \leq QP(qdup, z) + DELTAQD(qdup, z)$$

Supply3: $\forall qdup, z$

$$\sum_m tf1(qdup, z, m) \geq QP(qdup, z)$$

Demand: $\forall p, m$

$$\sum_z \sum_p tf1(p, z, m) = \sum_p QD1(p, m)$$

Appendix 2. Colombian agricultural production (in thousand tons) and product classification for the transportation model

Products					
Not included in the transport model		Fully included in the transport model		Partly included in the transport model	
Product	Production	Product	Production	Product	Production
Wheat	27.5	Rice (Milled Equivalent)	1,590.8	Sugar Cane	33,400.0
Barley	6.1	Maize	1,191.9	Bananas	1,375.3
Rye	0.0	Sorghum	212.4	Fruits, Other	1,624.9
Oats	4.0	Cassava	1,980.1		
Millet	0.0	Potatoes	2,873.9		
Cereals, Other	0.0	Yams	255.5		
Sweet Potatoes	0.0	Beans	124.2		
Roots, Other	73.0	Peas	0.0		
Treenuts	0.0	Pulses, Other	32.0		
Groundnuts (Shelled Eq)	2.2	Soyabeans	55.7		
Sunflowerseed	0.0	Palmkernels	118.5		
Rape and Mustardseed	0.0	Tomatoes	398.3		
Cottonseed	74.0	Onions	412.5		
Coconuts - Incl Copra	99.1	Vegetables, Other	805.1		
Sesameseed	3.8	Oranges, Mandarines	237.6		
Olives	0.0	Lemons, Limes	0.0		
Oilcrops, Other	0.0	Citrus, Other	0.0		
Grapefruit	0.0	Plantains	2,928.1		
Apples	0.0	Pineapples	313.6		
Dates	0.0	Coffee	656.2		
Grapes	16.4	Cocoa Beans	43.7		
Tea	0.0				
Spices	0.0				
Pepper	0.0				
Pimento	0.0				
Cloves	0.0				
Spices, Other	0.0				
Share in total	0.6	Share in total	28.0	Share in total	71.5
Share in mobile	1.9	Share in mobile	88.1	Share in mobile	10.1

Appendix 3. Description of the procedure for allocating sectoral changes to individual products

1. *Initial data consistency requirement:*

$ShrD_{GTAP} \approx ShrD_{TM}$ and $ShrX_{GTAP} \approx ShrX_{TM}$ (1)

where $ShrD_{GTAP}$ and $ShrX_{GTAP}$ are the share of demand for domestically produced goods and the share of exports for a GTAP sector and $ShrD_{TM}$ and $ShrX_{TM}$ are the corresponding shares for the set of products included and not included in the transportation model database that belong to the GTAP sector, and

$$ShrD_{TM} = \sum_i ShrD_{TM_i} + \sum_j ShrD_{TM_j} \quad (2)$$
$$ShrX_{TM} = \sum_i ShrX_{TM_i} + \sum_j ShrX_{TM_j} \quad (3)$$
$$\sum_i ShrD_{TM_i} + \sum_j ShrD_{TM_j} + \sum_i ShrX_{TM_i} + \sum_j ShrX_{TM_j} = 1 \quad (4)$$

where i is the set of products belonging to the GTAP sector that are included in the transportation model database and j is the set of products belonging to the GTAP sector that are not included in the transportation model database.

2. *Individual Products Classification*

For each group of products, classification among exportables, importables, and non-tradables is done on the basis of the net trade position of the individual product.

3. *Allocating Changes from the CGE to Individual Products*

Allocation is done first for exportable products. The consistency rule that must be followed is:

$$dqx_{GTAP} \times ShrX_{GTAP} = \sum_i dqx_i \times ShrX_i + \sum_j dqx_j \times ShrX_j \quad (5)$$

and

$$\sum_i dqx_i \times ShrX_i = \sum_i \varepsilon_i \times dp_i \times ShrX_i \quad (6)$$
$$\sum_j dqx_j \times ShrX_j = \sum_j \varepsilon_j \times dp_j \times ShrX_j \quad (7)$$

where dqx is the percentage change in quantity exported, ε is the product's supply elasticity, dp is the percentage change in price, and the rest is as defined above.

For exportables, the following must also hold:

$$dqd_i = \mu_i \times dp_i \quad (8)$$
$$dqd_j = \mu_j \times dp_j \quad (9)$$

where dqd is the percentage change in quantity demanded in the domestic market, and μ is the product's demand elasticity.

Non-tradables are assumed to get the same quantity and price changes as the GTAP sector as a whole. Therefore, the following must hold:

$$dqd_{GTAP} = dqd_l = dqp_k, \forall l, k \qquad (10)$$

$$dp_{GTAP} = dp_l = dp_k, \forall l, k \qquad (11)$$

where *l* is the set of non-tradables included in the transportation model database and k is the set of non-tradables not included.

Lastly, percentage price changes are found for the set of importable products, such that:

$$\begin{aligned} dqd_{GTAP} \times ShrD_{GTAP} &= \sum\nolimits_i dqd_i \times ShrD_i \\ &+ \sum\nolimits_j dqd_j \times ShrD_j \\ &+ \sum\nolimits_l dqd_l \times ShrD_l + \sum\nolimits_k dqd_k \times ShrD_k + \sum\nolimits_g dqd_g \times ShrD_g + \sum\nolimits_h dqd_h \times ShrD_h \qquad (12) \end{aligned}$$

where g is the set of importables that are included in the transportation model database and h is the set of importables not included, and

$$\sum\nolimits_g dqd_g \times ShrD_g = \sum\nolimits_g \mu_g \times dp_g \times ShrD_g \qquad (13)$$

$$\sum\nolimits_h dqd_h \times ShrD_h = \sum\nolimits_h \mu_h \times dp_h \times ShrD_h \qquad (14)$$

where μ is the demand elasticity and the rest of variables are as defined above.

As mentioned in the text, the corresponding price and quantity changes at the individual product level apply to all domestic markets equally.

Appendix 4. List of products included in the transportation model database and their corresponding GTAP product groupings

GTAP Code	GTAP Name	Products Included	Product Code
1	Paddy rice	Rice	Rice
3	Cereals	Corn, Sorghum	Corn, Sorg
4	Fruits and vegetables	Avocado, Hot pepper, Garlic, Green beans, Bananas, Onions, Shallots, Citrus fruits, Strawberry, Red beans, Physalys, Sour sop, Guava, String beans, Lulo, Mango, Passion fruit, Black berry, Potato, Papaw, Pineapple, Plantain, Tomato, Tree tomate, Cassava, Carrot	Avoc, Hpep, Garl, Gbea, Bana, Onio, Shal, Citr, Stra, Rbea, Phys, Ssop, Guav, Sbea, Lulo, Mang, Pass, Bber, Pota, Papa, Pine, Plan, Toma, Tarb, Cass, Carr
5	Oil seeds	Oil palm, Soy beans	Palm, Soyb
6	Sugar	Molasses	Mola
8	Other crops	Cocoa, Coffee	Coco, Coff