Social Welfare and Environmental Degradation
in Agriculture: The Case of Ecuador

by

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Abstract

        A non-linear optimization model which maximizes total Ecuadorian social welfare, defined as the sum of consumers' and producers' surpluses for the four major crops (corn, bananas, rice and African palm) is developed to evaluate the tradeoff between welfare and environmental degradation in Ecuador. It was found that a total welfare loss of US$122 million (a 11 percent reduction - from US$ 1.112 billion to US$ 989.66 million) would be expected from a 30 percent reduction in the total pesticide load on the environment in the production of the four major crops. The distributional impacts of the welfare loss were found, however, to be significantly skewed toward the loss of consumers' surplus. Specifically, a 30 percent reduction of total pesticide load on the environment would result in a reduction of 3.86 percent of producers' total surplus while consumers would be expected to loose 19.46 percent of their total surplus.

Key words: welfare tradeoff, environmental impacts, non-linear optimization

Introduction

        Located on the Northern portion of the West Coast of South America, Ecuador is a predominantly agricultural developing country. Despite the discovery of significant oil reserves in the 1970s, the agricultural sector is today the major contributor to the country's Gross Domestic Product (GDP) and total exports (17 percent and 45 percent respectively in 2001), and the largest generator of employment (employing 31 percent of the work force). Agriculture is also the only economic sector that experienced positive and stable growth in the last decade (Ministerio de Agricultura y Ganaderia, 2001). With an exceptional variety of ecological habitats, a quite diverse production of agricultural commodities takes place on an array of regions that include the coastal plains facing the Pacific Ocean, temperate high mountain Andean valleys, and low lands of the Amazon basin. The agricultural policy reforms of the early 1990s and the opening of the country to international trade have contributed to the development of a more competitive and modern agriculture (Whitaker, 1996 and Valdes, et. al., 1996). In recent years, however, climatic events such as the devastating "El Niño/La Niña" of the late 1990s, have awaken awareness about the fragility of Ecuador's natural resource endowments and the need for the protection/conservation of these resources.
        Banana production, for which Ecuador has exceptional climatological conditions, has reached impressive levels in terms of cultivated area and technology used making Ecuador the world largest exporter with a share of world exports of 37 percent in 2001. Another "tradable" commodity with continuing growth in the lower lands is "African palm" in which the country has become the largest producer in the Americas. Traditional crops such as corn and rice, are still adjusting to the new economic policies, but continue to represent an important sub-sector of Ecuador's agricultural production employing large proportions of the rural population.

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In any given year, the production of corn, rice, African palm and bananas in Ecuador represent up to 50 percent of the country's agricultural GDP, and employ 40 percent of the agricultural labor force (SICA, 2002). The modernization of Ecuadorean agriculture and the need to enhance competitiveness, through increased productivity, have encouraged the use of technological packages relatively intense in the use of pesticides and other chemical inputs. At the same time, another source of rural development, "ecological tourism," is strongly taking off in Ecuador. Foreign tourists attracted by the ecological reserve of the Galapagos Islands are also discovering the exceptional beauty of the other natural regions of Ecuador including the coastal beaches, mountain valleys, waterfalls, and rain forests. Thus, eco-tourism is becoming an important option to enhance the economic welfare of rural areas, but it requires a delicate balance between environmental protection and economic development.

The awareness of the potential environmental degradation related to modern agricultural systems and the consideration of alternative rural development activities, have opened important policy discussions within the Ecuadorean society. Currently, the Government of Ecuador is willing and desirable to evaluate alternative policy options addressing the tradeoff between welfare and environmental degradation. These efforts include those to reduce the potential environmental damage inflicted to natural resource endowments by the use of modern technologies in agricultural production which require the intense use of chemical inputs. The objective of this study is to evaluate the tradeoff between social welfare and environmental degradation in Ecuador. It is anticipated that the rigorous methodology developed in this study will prove to be useful in the formulation of sound and economically feasible policies for the Ecuadorean agricultural sector in the future.

Optimization Model Structure

The first step in the analysis and evaluation of agricultural production optimality and its associated environmental impacts in Ecuador, was to develop an optimization model to maximize total Ecuadorian social welfare from the production and consumption of the four major crops. Once this was accomplished, the environmental implications associated with the baseline optimal solution from the model were derived. Then, alternative model scenarios' solutions associated with the reduction of the total pesticide load on the environment in the production of the four major crops were derived and used to evaluate the tradeoff between welfare and environmental degradation. The model was set up as a non-linear optimization model which maximizes total social welfare (the sum of consumers' and producers' surpluses) in Ecuador for the four major crops. This model internalized the domestic welfare impacts of the imports and exports of these crops. The crops considered in the model were corn, bananas, rice and African palm. Rice, however, was split into winter and summer rice production because of significant differences on the way production of rice practices take place in these two seasons.

Given the patterns of consumption and production of the four crops analyzed, Ecuador was assumed to be a "small" country (i.e., its level of production, consumption and trade do not have a significant impact on the formation of world prices) in the corn, rice and African palm oil markets. However, given Ecuador's importance in the production and trade of bananas, Ecuador was assumed to be a "big" country (i.e., its level of production, consumption and trade has a significant impact on the formation of world price) in the bananas market. Because of significant differences in production practices and productivity of the four crops considered

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across Ecuador, the country was divided into four production regions: low costal area, high costal area, highlands and the eastern territory. Also, because of significant differences in the degree of sophistication with respect to technologies used in the production of the four crops in Ecuador, producers were classified into three possible levels of technology used: traditional, semi-sophisticated, and highly-sophisticated producers.

The overall structure of the optimization model developed is as follows:

$$W = \sum_{j=1}^{5} \int_{P^*_j}^{\infty} Q^d_j(P_j)\,dP_j + \sum_{j=1}^{5} \int_{0}^{P^*_j} Q^s_j(P_j)\,dP_j \tag{1}$$

Subject to:

$$Q^s_j = \sum_{r=1}^{4} \sum_{t=1}^{3} A_{jrt}\, Y_{jrt} \tag{2}$$

$$L_r \geq \sum_{j=1}^{5} \sum_{t=1}^{3} A_{jrt} \tag{3}$$

$$TL \geq \sum_{j=1}^{5} \sum_{r=1}^{4} \sum_{t=1}^{3} A_{jrt} \tag{4}$$

$$Q^d_j = Q^s_j + M_j - X_j \tag{5}$$

and

$$P_j,\ Q^s_j,\ Q^d_j,\ A_{jrt},\ M_j,\ X_j,\ \geq 0 \tag{6}$$

where: the "j" subscript indicates the crop, the "r" subscript indicates the production region, the "t" subscript indicates level of technology used in production, P_j represents the price per ton for crop "j" (P_j^* represents the equilibrium price for crop "j" which maximizes welfare), Q_j^d represents the demand function for crop "j"in tons, Q_j^s represents the supply function curve for crop "j"in tons, A_{jrt} represents the number of hectares in the production of crop "j" produced in region "r" using technology "t", Y_{jrt} represents the yield in tons per hectare of crop "j" produced in region "r" using technology "t", L_r represents the maximum amount of cropland available for crop production in region "r", TL represents the maximum amount of cropland available for crop production of the crops considered in the whole country, M_j represents imports in tons of commodity "j", and X_j represents exports in tons of commodity "j." Equation (1) depicts the objective function of the model and represents the definition of the total welfare function (W) which is found by adding individual welfare components by crop which in turn are composed of both, consumers' and producers' surpluses in each one of the markets of the crops considered. Equation (2) represents the supply function per crop. Equation (3) represents cropland availability by region. Equation (4) represents the total cropland availability constraint for the country as a whole. Equation (5) represents the demand function per crop which considers both, imports and exports. Conditions in (6) represent the non-negativity constraints of the model.

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Procedures and Results

The non-linear optimization model depicted in equations (1) to (5) and conditions in (6) was solved using GAMS (Generalized Algebraic Modeling System, Brooke, et. al., 1998). All the parameters in the optimization model related to the supply side, specifically, land use by crop, region and technology of production used were obtained from the recently completed Agricultural Census for Ecuador (SICA, 2002). Also, domestic and international demand related information used in the optimization model were obtained from the latest research/studies conducted by SICA experts including: for corn - Barrionuevo (2002); for bananas - Vasquez (2002); for rice - Recalde (2002); and for African palm - Arevalo (2002). For those interested readers, a documented copy of the GAMS model developed in this study is available from the authors. The baseline solution for the model is depicted in Table 1. As depicted in that table, optimal total welfare for the four crops considered is US$ 1.112 billion, of which US$ 600 million correspond to producers' surplus and US$ 512 million correspond to consumers' surplus. Table 1 also depicts producers' and consumers' surpluses as well as the optimal levels of production, equilibrium prices, exports and imports by crop which maximize total welfare. That is, Ecuador's welfare associated with the four crops analyzed would be maximized if the production, prices, exports, and imports depicted in Table 1 are followed. The solution depicted in Table 1 was found to be close, in relative terms, to what the actual conditions are in Ecuador with respect to production, prices, exports and imports of each of the commodities analyzed. Thus, the model developed here was found to closely replicate actual conditions in Ecuador. Therefore, it can be used to effectively evaluate the possible impacts of policies affecting these commodities.

Given the interest in evaluating the environmental impacts of agricultural production in Ecuador, the first step was to find out what the environmental impacts associated with the baseline optimal solution of the optimization model were. In order to accomplish this, the Environmental Impact Quotient (EIQ) methodology developed by Kovach, et. al., 1992 was followed. The EIQ is a calculation of the environmental impact of the most common pesticides (insecticides, acaricides, fungicides and herbicides) used in commercial agriculture. Specifically, the formula used to derive the EIQ value of individual pesticides takes into account for both the short and long term impacts of pesticides on humans, ground water, soil, and the impacts on aquatic, avian and insect life (Kovach, et. al., 1992). The functional form of the formula used is:

$$EIQ = FWC + CC + EC \qquad\qquad (7)$$

Where: FWC represents the farm worker component which is defined as C*[(DT*5)+(DT*P)]; CC represents the consumer component which is defined as [(C*(S+P)/2*SY)+L]; and EC represents the ecological component which is defined as {(F*R) + [(D*(S+P)/2*3) + (Z*P*3) + (B*P*5)]/3}. Within those components: DT is dermal toxicity; C is chronic toxicity; SY is systemicity; F is fish toxicity; L is leaching potential; R is the runoff or surface loss potential; D is bird toxicity; S is soil half-life; Z is bee toxicity; B is beneficial arthropod toxicity; and P is surface plant half-life.

The farm worker component is defined as the sum of applicator exposure (DT*5) plus picker exposure (DT*P) times the long term health effect or chronic toxicity (C). Chronic

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toxicity of specific pesticide is calculated as the average of the ratings from various long tern laboratory studies conducted on small mammals. These tests are designed to determine the potential reproductive, teratogenic, mutagenic, and oncogenic effects of pesticides. The farm worker applicator exposure is determined by multiplying the dermal toxicity (DT) rating to small mammals times a coefficient of 5 to account for the increased risk associated with handling concentrated pesticides. The picker exposure is equal to the dermal toxicity (DT) times the rating for surface plant half-life (the time required for one-half of the chemical to break down). This factor takes into account the weathering of pesticides that occurs in agricultural systems and the days to harvest restrictions that may have placed on certain pesticides.

The consumer component is calculated as the sum of consumer exposure potential $(C*(S+P)/2*SY)$ plus the potential ground water effects (L). Ground water effects are included into the consumer component because it is more of a human health issue (drinking contaminated water) than a wildlife issue. Consumer exposure is calculated as chronic toxicity (C) times the average for residue potential in soil and plant surfaces $(S+P)/2$ times the systemic potential rating (SY) of the pesticide (the pesticide's ability to be absorbed by plants).

The ecological component is composed of the potential impacts on aquatic and terrestrial effects, and it is calculated as the sum of the potential effects on fish $(F*R)$, and the average impacts on birds $(D*(S+P)/2*3)$, bees $(Z*P*3)$ and beneficial arthropods $(B*P*5)$. The environmental impact on pesticides on aquatic life is determined by multiplying the chemical toxicity to fish (F) times the runoff potential of the specific pesticide (the runoff potential takes into account the half-life of the chemical in surface water).

The impacts on pesticides on terrestrial systems is found by calculating the average impact of the toxicity of the chemicals to birds $(D*(S+P)/2*3)$, bees $(Z*P*3)$ and beneficial arthropods $(B*P*5)$. Because terrestrial organisms are more likely to occur in commercial agricultural settings than fish, more weight is given to the pesticidal effects on these terrestrial organisms. Also, it is important to point out that because arthropod natural enemies spend most of the life within agroecosystem communities (while birds and bees are somewhat transient) their exposure to pesticides is expected to be greater, this is the reason why their exposure is multiplied by a factor of 5 instead of a factor of 3. For additional details on the calculation of EIQ's for over 120 pesticides please see the Kovach, et. al., 1992.

In this study, based on the detailed crop budgets developed for all crops in all regions and under all technology scenarios for Ecuador, along with published EIQ's for all the pesticides used in the production of the four crops analyzed (of course weighted for both the frequency and amount of active ingredient used) EIQs field use ratings were derived for each crop by region and by type of producer. For example, for the case of corn production in the highlands region for the traditional, semi-sophisticated and highly-sophisticated producers possibilities the associated levels of EIQs field use ratings were 79.64, 128.75 and 180.74, respectively. The higher the EIQ field use rating is, the higher the chemical load on the environment would be. Once the EIQs field use ratings were derived for all production possibilities considered in the model, a Degradation of the Environment Index (DEI) using the most environmentally degrading production possibility as the unit was constructed. The most environmentally degrading production possibility was found to be the production of bananas with an EIQ field use rating of 4,731.84. It is important to point out, that pesticide use in the production of bananas across all regions and across all levels of technology was found to be the same in Ecuador. This is because regardless of location or type of producers, bananas' producers use the same pesticide

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package/practices. Thus, the DEI used for bananas production was set equal to 1 and, for example, for corn production in the highlands region at the highly-sophisticated level of technology utilization the DEI was calculated to be 0.0382 (180.74/4,731.84). That is, one hectare in the production of bananas contributes over 96% more to environmental degradation (pesticide load on the environment) than one hectare in the production of corn in the highlands under the highly-sophisticated level of technology.

Given the DEI information generated above, an additional constraint which added DEIs across production of all crops was included in the optimization model. Overall, the total DEI in Ecuador associated with the optimal baseline solution depicted in Table 1 was found to be 175,613 DEI units, or approximately 831 million EIQ field use rating units (831 million EIQ field use rating units = 175,613 * 4,731.84). This level of pesticide load on the environment provides a point of departure to find out what the impacts on welfare would be if a reduction of this load is desired. Given the interest of the Ecuadorian government in finding out more about what the tradeoffs are between environmental degradation and social welfare, the optimization model was solved for six alternative scenarios in which a 5, 10, 15, 20, 25, and 30 percent reduction of DEI was imposed on the optimization model.

Upon solving the six models, under the assumption that reductions of the total pesticide load on the environment would be desired, it was found that because of the extremely high relative contribution of bananas production to the degradation of the environment in Ecuador (see Table 1), it would be optimal to significantly reduce the production of bananas. Specifically, on the one hand, at all levels of DEI reduction analyzed, equilibrium prices, production, imports, and consumers and producers surpluses of corn, rice, and African palm were not affected. On the other hand, however, equilibrium price, production, exports, and consumers' and producers' surpluses associated with bananas were found to be increasingly impacted by the DEI reduction levels analyzed. Figures 1 to 4 depict the impacts on bananas' equilibrium price, production and exports, and the impacts on consumers' and producers' surpluses and on total welfare across DEI reduction scenarios.

From the baseline to the 30 percent reduction of DEI scenario, Figures (1) to (4) show that: (a) the equilibrium price of bananas would increase 15.29 percent (from US$ 137.63/ton to US$ 158.68/ton); (b) both total production and exports of bananas would decrease slightly above 33 percent (production from slightly above 5 million tons to 3.34 million tons, and exports from slightly above 2 million tons to 1.34 million tons); (c) surplus to bananas' producers would decrease 7.9 percent (from US$ 293.21 million to US$ 270.03 million - total producers' surplus from all crops would decrease from US$ 600.39 million to US$ 577.21 million); (d) surplus to consumers from all crops would decrease 19.47 percent (from US$ 512.15 million to US$ 412.45 million - it is important to note that all the consumer's surplus reduction would take place in the bananas' market representing a loss of two-thirds of the initial surplus to consumers in that market of US$ 149.53 million); and (e) total surplus would decrease 11.04 percent (from US$ 1.112 billion to US$ 989.66 million).

Conclusion

At this point, an important question to ask would be: Given the four major crops analyzed, is the tradeoff of 11 percent of total surplus for a 30 percent reduction in the total load of pesticides on the environment economically and politically feasible in Ecuador? The answer

to this question is critically dependent upon: (a) what the potential gains of a decrease in the load of pesticides on the environment would be on other economic activities, such as eco-tourism which is increasingly becoming very important in Ecuador; and (b) the overall and distributional impacts that this type of policy would have on both, producers' and consumers' welfare. Furthermore, regional considerations in terms of where at, regionally speaking within Ecuador, would be a priority for environmental damages from agriculture to be reduced is critical in the decision making process because of the associated regional economic consequences that these type of decisions could have. Given the importance that these issues currently play and are expected to continue to play in the enhancement and development of the Ecuadorian agricultural sector in the future, many of these issues are currently being addressed with the optimization model developed in this study. It is felt that both, the model developed and the procedures followed in this study represent a valuable attempt to evaluate the tradeoff between social economic welfare and environmental degradation issues. It is hoped that this effort proves useful in the formulation of agricultural policies in the Ecuadorian agricultural sector in the near future.

References

Arevalo, F. Ecuadorian Domestic and International Demand and Supply Information for African Palm - Personal Communication. SICA - Systema de Información y Censo Agricola - Project Ecuador. http//www.sica.gov.ec, 2002.

Barrionuevo, N. Ecuadorian Domestic and International Demand and Supply Information for Corn - Personal Communication. SICA - Systema de Información y Censo Agricola - Project Ecuador. http//www.sica.gov.ec, 2002.

Brooke, A., D. Kendrick, A. Meeraus, R. Raman, and R. Rosenthal. GAMS: A User's Guide. GAMS Development Corporation, Washington, DC, 1998.

Kovach, J., C. Petzoldt, J. Degni, and J. Tette. A Method to Measure the Environmental Impact of Pesticides. New York's Food and Life Sciences Bulletin Number 139. New York State Agricultural Experiment Station - Geneva, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca, New York, 1992.

Ministerio de Agricultura y Ganaderia, República del Ecuador. El Sector Agropecuario Frente al ALCA, Quito, Ecuador, 2001.

Recalde, O. Ecuadorian Domestic and International Demand and Supply Information for Rice - Personal Communication. SICA - Systema de Información y Censo Agricola - Project Ecuador. http//www.sica.gov.ec, 2002.

SICA - Systema de Información y Censo Agricola - Project Ecuador. http//www.sica.gov.ec, 2002.

Valdes, A., B. Schaeffer, and H. Ramos. Surveillance of Agricultural Price and Trade Policies: A Handbook for Ecuador. Technical Paper No. 314, the World Bank, Washington DC, 1996.

Vasquez, E. Ecuadorian Domestic and International Demand and Supply Information for Bananas - Personal Communication. SICA - Systema de Información y Censo Agricola - Project Ecuador. http//www.sica.gov.ec, 2002.

Whitaker, M.D. Evaluación de las Reformas de las Políticas Agrícolas en el Ecuador, Estudio Síntesis al Volumen I. Instituto de Estrategias Agropecuarias, Quito, Ecuador, 1996.

Table 1. Baseline Results of the Optimization Model for Ecuador, 2002

| | Corn | Bananas | Rice | | | Palm | Total |
			Winter	Summer	Total		
Equilibrium Price (US$/ton.)	150.68	137.63	249.50	297.03		62.25	
National Production (1,000 ton.)	350	5,041	842	635	1,477	2,042	
Exports (1,000 ton.)		2,016					
Imports (1,000 ton.)			148	112	260		
Producers' Surplus (US$ mill.)	24.64	293.21			228.91	53.63	600.39
Consumers' Surplus (US$ mill.)	48.43	149.53			178.64	135.55	512.15
TOTAL Welfare (US$ mill.)							1,112.54
Degradation of the Environment Index (1,000 uni.)	2.74	138.23			28.32	6.32	175.61

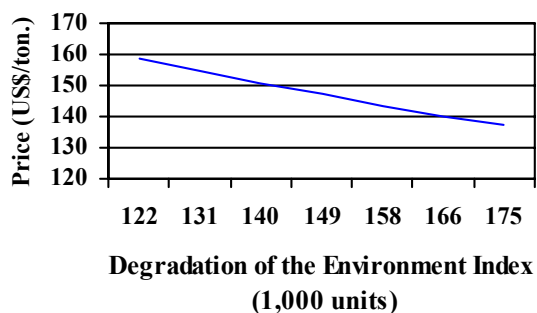Figure 1. Bananas Equilibrium Price
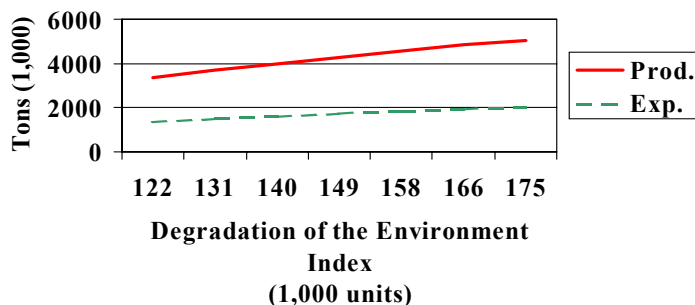

Figure 2. Production and Exports of Bananas

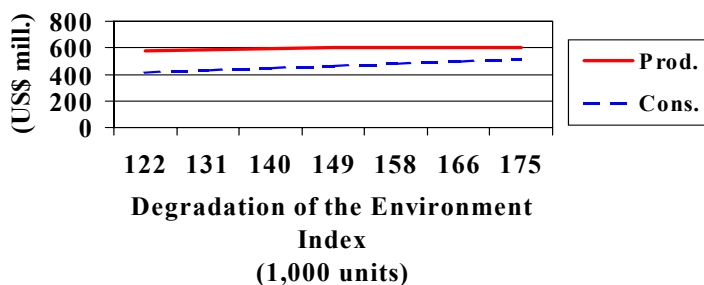Figure 3. Consumers' and Producers' Surpluses

Figure 4. Total Welfare

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