Greener Acres or Greener Waters? Potential U.S. Impacts of Agricultural Trade Liberalization

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This paper examines the elimination of all agricultural policy distortions in all trading countries and agricultural production decisions in the United States, as well as subsequent environmental quality in the presence and absence of nondegradation environmental standards. The results suggest that trade liberalization has the potential to increase domestic production and boost agricultural returns by as much as 8.5 percent. Consumer surplus would likely fall, and the discharge of nutrients, sediment, and pesticides would likely increase. However, environmental policies can limit these adverse environmental impacts and mute the potential decrease in consumer surplus, while leaving increased returns to agricultural production.

Key Words: agriculture, trade reform, environment, nondegradation

Legislation of the United States requiring formal environmental reviews, or environmental assessments, of major federal activities significantly affecting the environment dates back thirty years. Within the last decade, nongovernmental organizations (NGOs) and other interested parties have called for extending these environmental reviews to trade agreements (e.g., World Wildlife Federation 2001). In fact, U.S. law requires an environmental review of all new trade agreements beginning in 2001 (U.S. Executive Order 13141, 1999). Such an environmental review would likely be required for multilateral trade liberalization in the context of the World Trade Organization (WTO) negotiations in Doha, Qatar, in 2001. There the WTO affirmed its commitment to "correct and prevent restrictions and distortions in world agricultural markets." Further, the WTO committed itself to "comprehensive negotiations aimed at…substantial improvements in market access; reductions of, with a view to phasing out, all forms of export subsidies; and substantial reductions in trade-distorting domestic support" (WTO 2001).

While it is not clear what consequences might result from the environmental review of such trade agreements, they may include multilateral environmental agreements. There are approximately 200 multilateral environmental agreements (MEAs) in place today, of which 20 contain trade provisions (United Nations Environment Programme 2000). Trade agreements may themselves raise environmental quality by increasing income—environmental quality is income elastic. However, linking environmental side-agreements to trade agreements may be an economically efficient method for avoiding adverse environmental impacts of trade or for minimizing the impacts of trade on environmental agreements. For example, the Office of the U.S. Trade Representative (USTR) states in its first environmental review of a free trade agreement that "trade agreements can provide positive opportunities for enhancing environmental protection" (USTR 2003). However, even without MEAs linked to trade policy, environmental reviews of policy will also consider the impacts of trade policy on current and future environmental policies. In the aforementioned environmental review, the USTR states that a core

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obligation of free trade agreements is a "commitment not to weaken or reduce the protections afforded by environmental laws in order to attract trade or investment." In light of the 2001 Doha-WTO trade talks, we consider how adjustments to agricultural trade liberalization might influence or be influenced by national or regional environmental policies such as the Clean Water Act.

Background

Economic theory typically concludes that trade liberalization increases overall economic welfare. Although free trade is optimal from the viewpoint of world welfare, it is not necessarily so from the viewpoint of a single country unless the country is small (Bhagwati and Panagariya 1996). For a large country, with appropriate taxes and subsidies, a welfare level higher than that associated with autarky can be attained. Devising Pareto-improving policy becomes difficult, though, in the presence of negative externalities associated with production, especially in the absence of well-defined property rights, which can lead to the underpricing of natural resources. In such situations, the policymaker must balance welfare improvements from trade against its environmental consequences when setting taxes, subsidies, or standards.

The question posed in this paper is, what are the agri-environmental outcomes of liberalization, since outcomes can be positive (decreased environmental damage and increased producer and consumer surplus) or negative (increased environmental damage and decreased surplus)? While a broad theoretical and empirical literature examines trade and the environment, this literature focuses primarily on the manufacturing sector (Frankel and Rose 2002, Antweiler, Copeland, and Taylor 2001). Fewer quantitative studies have examined the environmental implications of agricultural trade liberalization (Abler and Shortle 1992, Williams and Shumway 2000). These analyses typically assume a change in the underlying trade conditions as a given, and estimate potential production and input changes for a subset(s) of the agricultural sector. As environmental impacts are not explicitly modeled in these studies, environmental inferences are extrapolated from the estimated changes in production and input use.

The literature extending trade analysis to include environmental policies is likewise brief. Both Anderson (1992) and López (1994) find that, if countries fail to institute effective environmental policies, the environmental effects of freer trade can be negative. On the other hand, if effective environmental policies are in place, freer trade will generally increase total benefits to society (Anderson 1992). Diao and Roe (2003) provide intuition on how trade and environmental policies might interact to produce a "win-win" situation, illustrating how declining farm incomes following trade reform in Morocco could be cushioned when coupled with an environmental policy—water market reform in this case. Nonetheless, taken as a whole, the limited number of existing studies in conjunction with their limited scope do not allow us to draw generalizations on the environmental impacts in the United States due to agricultural trade liberalization enacted in isolation or in tandem with environmental policies. Further, previous analyses do not disaggregate production and environmental impacts regionally—an important step, as small environmental impacts in the national aggregate may be significant regionally.

A stylized, graphical representation (Figure 1) of trade liberalization and agricultural externalities for an exporting country with a comparative advantage in the production of a composite agricultural commodity serves to illustrate our basic points. The initial world price and domestic production level is $\{P_0, Q_0\}$, and production of the negative agricultural externality is E_0. The initial emission function (G_0) is determined by the interaction of scale, technique, and composition effects (Cole, Rayner, and Bates 1998) and can be assumed to be non-decreasing in commodity production (illustrated as linear for the sake of this discussion).

Now assume that trade liberalization is achieved through trade policy change (e.g., tariffs), which would bring the new price-quantity combination to $\{P_1, Q_1\}$. While this liberalization increases domestic producer surplus and reduces domestic consumer surplus, it also leads to an increase in the domestic agricultural externality to E_1. How might potential increases in agricultural pollution interact with current environmental regulations or be viewed under a free trade agreement environmental review? A first-best trade

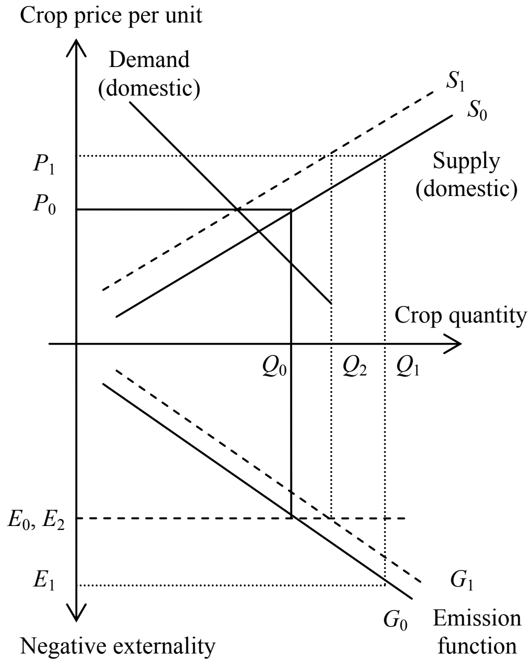

Figure 1. Stylized Relationship Between Trade Liberalization and Agricultural Externalities

model would seek to maximize consumer surplus plus producer surplus plus environmental benefits. However, to reflect better actual policy, we assume a second-best harmonization in which environmental standards are in place that restrict environmental impacts associated with trade liberalization. This is consistent with the USTR's "commitment not to weaken or reduce the protections afforded by environmental laws in order to attract trade or investment."

The U.S. Environmental Protection Agency (EPA) has found that agriculture in the United States is the leading source of pollution in 48 percent of impaired river miles, 41 percent of impaired lake acres, and 18 percent of impaired estuarine areas surveyed (EPA 2002a). Therefore, it is likely that agriculture's adjustments to agricultural trade liberalization could have observable environmental effects in the United States. We examine how national and regional nondegradation standards for water quality may interact with agriculture's adjustments to agricultural trade liberalization. The EPA adopted nondegradation provisions in 1975, requiring states to develop these policies as part of the state's water quality standards (EPA 2004). These standards essentially require states to protect existing uses and water quality conditions to support such uses and are among the strongest regulatory powers in the Clean Water Act (River Network 2004).[1]

Nondegradation provisions of the Clean Water Act are implemented through the National Pollutant Discharge Elimination System (NPDES), which controls point source discharge of pollutants. The courts have ruled that nondegradation standards do not allow the EPA to regulate nonpoint source discharge of agricultural pollutants (U.S. Court of Appeals for the Tenth Circuit 2001). That said, of the 21,845 impaired waterbodies detailed on the EPA 303d list, 43 percent are attributable solely to nonpoint sources, and an additional 47 percent have both nonpoint source and point source contributions (EPA 2002b). For each impaired waterbody, states must develop a comprehensive pollutant management plan, which specifies the maximum amount of a pollutant that a waterbody can receive from point and nonpoint pollutant sources and how the necessary reductions will be achieved. As part of their management plans, states can and do impose nonpoint source controls [see, for example, nondegradation standards for nonpoint sources in the Lake Superior Basin (EPA 2000)].

The horizontal line E_2 in Figure 1 represents such a nondegradation restriction. Enforcing this restriction, while permitting the trade liberalization treaty to move forward, increases costs to farmers as they change production practices to limit the externality. This will shift supply inwards to S_1 and decrease production from Q_1 to Q_2. The new emissions function (G_1) describes the new interaction between technique, scale, and composition effects. Returns to agricultural production under trade liberalization with environmental standards may be lower with respect to trade liberalization with no restrictions, but may still be higher than in the base case of no trade liberalization. Whether or not the environmental standards are welfare-enhancing overall depends on the value of ($E_1 - E_0$) compared to change in consumer surplus and returns to agricultural producers. Our goal is to develop an empirical model

[1] Similar provisions are also found in section 4(b) of the Wilderness Act and section 101(b)(1) of the Clean Air Act.

that allows interactions between multiple commodities, inputs, production practices, and externalities, for a trade liberalization scenario that is actually under consideration.

Methodology

We extend previous empirical approaches by explicitly modeling the environmental impacts of endogenous regional production, consumption, and price changes for all major U.S. agricultural sectors in response to an exogenous trade liberalization scenario. Production adjustments are viewed in terms of technique, scale, and composition effects, which have specific regional, agri-environmental implications. We extend the model to include nondegradation standards and assess the implications for consumer surplus and expected producer gains from trade liberalization.

Simulation Model for U.S. Agriculture

To estimate the endogenous adjustments to changes in underlying trade conditions, we use a multi-commodity, regional model [the U.S. Regional Agricultural Sector Model (USMP) (House et al. 1999)] that incorporates agricultural commodity, supply, demand, and the environment to simulate potential adjustments in production and prices to policy (see, for example, Johansson and Kaplan 2004). The USMP uses a positive math programming approach (Howitt 1995) to calibrate production levels and enterprises to regularly updated production practice surveys (Padgitt et al. 2000), the USDA multi-year baseline (USDA 2003) and the National Resources Inventory (USDA 1994). Simulations are manifest across 10 main production regions (r) and 45 sub-regions (u) (see Figure 2), further delineated by erosion class (highly erodible and non-highly erodible). The model includes 22 inputs and the production and consumption of 42 agricultural commodities and processed products (Table 1), which are integrated into the flow of final commodity demand and stock markets. The USMP considers domestic consumption, net trade, processing, and government stock demands. The model differentiates more than 5,000 crop production enterprises according to cropping rotations, tillage practices, and fertilizer rates. More than 90 livestock and poultry production enterprises are delineated at the region level by species.

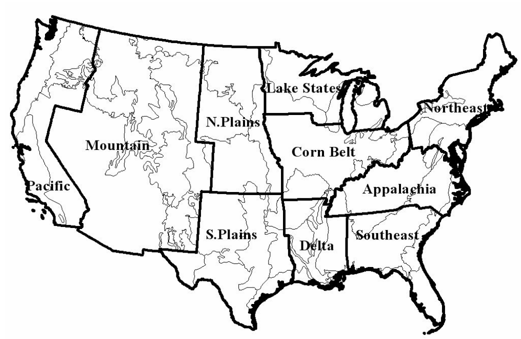

Figure 2. U.S. Regional Agricultural Sector Model (USMP) Spatial Coverage: Intersection of 10 USDA Farm Production Regions and 25 USDA Land Resource Regions

The agriculture sector is assumed to be a spatially competitive market equilibrium system, but partial in the sense that it does not compete with other sectors (e.g., manufacturing) for factors of production (e.g., land or labor). The model allows for production scale effects, some composition effects, such as a changing product mix, and technique effects, in response to changes in economic incentives. For instance, nitrogen fertilizer use can be reduced by decreasing acreage planted (scale effect), by shifting to production of crops that use less nitrogen fertilizer (composition effect), or by reducing nitrogen fertilizer application rates (technique effect). Estimated price and production changes are simulated for commodity production at the regional level and integrated into the flow of final commodity demand and stock markets.

This is accomplished using a constrained optimization approach, maximizing consumer and producer surplus, consistent with a free market, medium-run, spatial equilibrium, $\mathcal{L}$:

$$(1)\ Max\ \mathcal{L} \equiv \mathbf{Z'A^d} - \frac{\mathbf{Z'B^dZ}}{2} - \mathbf{P'A^s} - \frac{\mathbf{P'B^sP}}{2} - \mathbf{Y'W_Y} - \mathbf{INP'_vA^s} - \frac{\mathbf{INP'_VB^sINP_V}}{2} - \mathbf{INP'_FW_{INP}};$$

subject to

$$(2)\qquad \mathbf{pp'_{cr}X_{cr}} + \mathbf{pp'_{liv}X_{liv}} + \mathbf{pp'_yY} - \mathbf{Z} \geq 0$$

(commodity balancing);

$$(3)\qquad \mathbf{pp'_{inpcr}X_{cr}} + \mathbf{pp'_{inpliv}X_{liv}} - \mathbf{INP_V} \leq 0,\ \forall r$$

Table 1. Inputs and Outputs for Simulation Model

Inputs		Outputs		
Regional	National	Crops	Livestock	Processed
cropland	nitrogen fertilizer	corn	fed beef for slaughter	soybean meal
pastureland	potassium fertilizer	sorghum	nonfed beef for slaughter	soybean oil
	potash fertilizer	barley	beef calves for slaughter	livestock feed mixes
	lime	oats	beef feeder yearlings	dairy feed supplements
	other variable costs	wheat	beef feeder calves	swine feed supplements
	public grazing land	cotton	cull beef cows	fed beef
	custom farming operations	rice	cull dairy cows	nonfed beef
	chemicals	soybeans	cull dairy calves	veal
	seed	silage	milk	pork
	interest on operating capital	hay	hogs for slaughter	broilers
	machinery and equipment repair		cull sows for slaughter	turkeys
	veterinary and medical costs		feeder pigs	eggs
	marketing and storage			butter
	ownership costs			American cheese
	labor and management costs			other cheese
	land taxes and rent			ice cream
	general farm overhead			nonfat dry milk
	irrigation water application			manufacturing milk
	energy costs			ethanol
	insurance			corn syrup

Note: The U.S. Regional Agricultural Sector Model (USMP) accounts for production of the major crop (corn, soybeans, sorghum, oats, barley, wheat, cotton, rice, hay, silage) and confined livestock (beef, dairy, swine, and poultry) categories, comprising approximately 75 percent of agronomic production and more than 95 percent of confined livestock production (USDA 1997). We do not consider potential applications of manure to rangeland, vegetable, horticulture, sugar, peanut, or silviculture operations.

(regional input balancing);

$$(4)\quad \alpha_{p,u}\left(\sum_b \delta_{b,u} s_{p,b,u} RAC_{b,u}^{-\rho_{p,u}}\right)^{-\frac{1}{\rho_{p,u}}} - C_{p,u} \le 0,\ \forall p,u$$

(regional crop balancing);

$$(5)\quad \alpha_{b,u}\left(\sum_t \delta_{b,t,u} X_{b,t,u}^{-\rho_{b,u}}\right)^{-\frac{1}{\rho_{b,u}}} - RAC_{b,u} \le 0,\ \forall b,u$$

(regional rotation balancing); and

$$(6)\quad \mathbf{Z}, \mathbf{Y}, \mathbf{X}_{\mathbf{cr}}, \mathbf{X}_{\mathbf{liv}}, \mathbf{INP}_{\mathbf{V}}, \mathbf{INP}_{\mathbf{F}}, \mathbf{RAC}, \mathbf{C} \ge 0$$

(nonnegativity constraints).

Matrix **Z** represents demand for produced commodities (matrix **P**), across markets and regions. Matrices **A** and **B** are the intercept and slope coefficients for product and market demand (superscript "d") and supply (superscript "S"), respectively. Matrices $\mathbf{X_{cr}}$ and $\mathbf{X_{liv}}$ represent cropping and livestock activities across regions and management practices. Vectors **Y** and $\mathbf{W_y}$ represent processing activity levels and net costs of process, respectively. Matrix **INP** represents variable (subscript "V") and fixed (subscript "F") inputs into production. $\mathbf{W_{INP}}$ represents cost per unit of fixed inputs. The output parameters per share of crop, livestock, and processing activities are represented by matrices $\mathbf{pp_{cr}}$, $\mathbf{pp_{liv}}$, and $\mathbf{pp_y}$, respectively. The input parameters per share of crop and livestock production activities are represented by matrices $\mathbf{pp_{inpcr}}$ and $\mathbf{pp_{inpliv}}$, respectively. Substitution among the cropping activities is represented using nested constant elasticity of transformation (CET) functions [(4) and (5)]. The crop and rotation balancing equations ensure that supply of land ($C_{p,u}$) in sub-region (u) is allocated to a crop (p) and is at least as great as the demand for it, given by the sum of rotational acres ($RAC_{b,u}$) multiplied by the share of each crop grown in that rotation ($s_{p,b,u}$) subject to nonlinear CET distribution ($\delta_{b,u}$), shift ($\alpha_{p,u}$), and substitution ($\rho_{p,u}$) calibration parameters. Similarly, the allocation of land to various tillage practices (t) used in a crop rotation (b) must be no greater than the amount of land in that rotation, also subject to CET distribution ($\delta_{b,t,u}$), shift ($\alpha_{b,u}$), and substitution ($\rho_{b,u}$) calibration parameters.

The nonlinear CET equations imply that there is a declining marginal rate of transformation between land used in one crop rotation and land used to produce the same crop as part of another rotation, and between one tillage activity in a particular rotation and land used in other tillage activities used with the same rotation. This implies that changes in land allocated to various production enterprises will not occur in a bang-bang fashion, but will smoothly adjust to changes in relative returns across production enterprises. The transformation elasticities are specified so that model supply response at the national level is consistent with domestic supply response in the USDA's Food and Agriculture Policy Simulator (Westcott, Young, and Price 2002) and with trade response in the USDA Economic Research Service (ERS)/Penn State model (Stout and Abler 2003).

For this analysis, we examine environmental parameters historically of concern for water quality and U.S. agri-environmental policy: pesticide use, soil erosion, and nutrient (nitrogen and phosphorus) losses to water. Changes in the levels of these parameters are estimated using the Environmental Policy Integrated Climate (EPIC) model (Mitchell et al. 1998). For each crop production activity, the EPIC model simulates erosion (sheet, rill, and wind), nutrient and pesticide cycling as a function of crop management (rotation, tillage, and fertilizer rates) given historic weather, hydrology, soil temperature, and topography data.

Trade Liberalization

The U.S. agricultural trade surplus is currently expected to be about $1 billion for 2005 (Brooks, Whitton, and Carter 2005). Historically, bulk grains have been the largest share of U.S. exports; however, since 2000, higher value animals and animal products have formed the largest share of U.S. exports (USDA 2004). The largest share of food imports is fresh fruit and vegetable products. Given that average global protection is higher for grains and animal commodities than for fruit and vegetables, we would expect trade liberalization to generally favor U.S. producers by resulting in increased world prices for these products (Burfisher et al. 2001), as depicted in a stylized fashion in Figure 1. We simulate changes in U.S. production levels and prices likely to prevail after all trade restrictions on agricultural products are lifted between WTO member nations using the ERS/Penn State WTO model (Table 2). This model is an applied partial equilibrium, multiple-commodity, multiple-region model of agricultural policy and trade, which simulates the agriculture sector's response to a scenario in which all countries eliminate their border protections and trade-distorting domestic support for all commodities (Stout and Abler 2003). It is a gross trade model accounting for exports and imports of each commodity in every region, but it does not distinguish a region's imports by their source or a region's exports by their destination.

The core set of policies "liberalized" across all countries in this model include both specific and *ad valorem* import and export taxes/subsidies, tariff-rate quotas (TRQs), and producer and consumer subsidies.[2] Also tariffs, fixed payments per unit of output and per unit of intermediate output, as well as any direct and whole-farm payments that are based on area or that otherwise affect crop mix were eliminated. Decoupled subsidies, such as production flexibility contracts, are not linked to production of specific crops, and therefore do not factor into this set of simulation models. For example, the model removes U.S. loan rates for crops and marketing orders for dairy products. For Japan, the model removes "mark-ups" for rice and wheat. Policy coverage for the

Table 2. Changes in U.S. Production and Prices for Selected Commodities Following Trade Liberalization (%)

	Percent Change	
Commodities	Production	Price
rice	-1.20	13.20
wheat	-0.10	4.80
corn	2.40	16.50
other coarse grains	1.70	13.50
soybeans	-0.70	7.50
cotton	0.00	4.50
beef and veal	-0.10	10.60
pork	0.00	7.50
poultry meat	1.60	13.00
butter	-15.00	-12.00
cheese	-0.60	-1.90
non-fat dry milk	-15.00	-1.60
fluid milk	1.70	-1.20
whole dry milk	-31.60	-13.40
other dairy	1.90	-1.10

Source: Derived from the USDA ERS/Penn State WTO model.

[2] For a discussion of agricultural trade liberalization options see Burfisher et al. (2001).

European Union (EU) is also extensive. The model also removes intervention prices (which entail government purchases and then export subsidies), variable import levies, compensatory payments, acreage set-asides, and base-area bounds (which limit the total area of grains and oilseeds by cutting off payments if the base-area bound is reached). In addition, EU production quotas for raw milk and sugar are removed.

Full elimination of all trade-distorting policies (as defined according to the WTO) can be viewed as an upper bound on possible U.S. production changes due to a WTO/Doha trade liberalization agreement, as the final extent of elimination of trade-distorting policies under a WTO/Doha trade agreement is impossible to predict. Arguably, then, the most fruitful path for quantitative analysis is to examine the scenario of full elimination of trade distortions, which would likely result in the largest production and environmental impacts.

Policy Simulations

In our simplified illustration (recall Figure 1), we depicted a price-taking country that cannot influence world prices. However, the United States is a major supplier of many commodities, and large adjustments to policy change are likely to have implications for world prices. We capture this in the import and export demand equations, which are shifted in the U.S. regional model to replicate as closely as possible the estimated *ex post* price and quantity adjustments following trade liberalization (Table 2). This first simulation is termed scenario *T*, indicating the adjustments to production and agri-environmental impacts following WTO trade liberalization in agriculture. Following this simulation, nondegradation standards are added to the model corresponding to E_2 in Figure 1. Scenario *T+N* represents a trade liberalization scenario where the amount of nitrogen and phosphorus runoff, pesticide use, and sheet and rill erosion are held to *ex ante* national levels. Scenario *T+R* represents a trade liberalization scenario where the amounts of these same pollutants are held to *ex ante* regional levels. These correspond to shifting the emission function to G_1 in Figure 1. Note that import and export demand functions are adjusted in the regional agricultural model to replicate the price and quantity changes estimated by the ERS/Penn State WTO trade model for the initial scenario (*T*). The two scenarios with trade and environmental policy interactions utilize these adjusted demand functions and capture the initial trade impacts of production and price adjustments, but do not explicitly re-model global trade levels and prices using the ERS/Penn State WTO trade model. Therefore, to the extent that U.S. environmental policies will continue to reverberate in global commodity markets, subsequent world price adjustments are not fully captured in our modeling framework.

Agri-Environmental Results and Implications

Economic Impacts

The results suggest that net returns to agricultural production closely follow the pattern illustrated in our simple graphical representation. Returns to production increase under trade liberalization, but consumer surplus falls, reflecting the fact that domestic consumers are facing higher commodity prices following trade liberalization, albeit by a smaller percentage compared to increases in net returns (Table 3). Regionally, the largest value increase in net returns occurs in the Corn Belt, and the largest impacts on consumers occur in the most populous areas, i.e., the Northeast and Pacific regions. Under trade liberalization and nondegradation standards we find that in general returns to production are actually marginally higher (by as much as $120 million). This is primarily due to the increase in no-till cultivation that occurs under the two environmental scenarios, which is likely to be more profitable in the short run compared to conventional tillage under environmental constraints.[3] The decline in consumer surplus is also marginally higher (by $6 million) with environmental restrictions.

Changes in U.S. Cultivation

The largest adjustments to trade liberalization will likely occur when there are no environmental standards imposed (Table 4). Cropped acres might increase by about 1.6 million acres, most of which are likely to be conventionally tilled. For

[3] Even though conventional tillage is not necessarily the most profitable means to cultivate crops for all farmers, it is nevertheless an option used by many farmers, for many reasons (Hopkins and Johansson 2004). For example, our model does not incorporate possible long-run increases in management or chemical costs associated with no-till management, which may explain why some producers continue to use conventional tillage techniques.

Table 3. Changes in Economic Indicators Following Trade Liberalization (million $)

	Region[a]										
Scenario[b]	NE	LS	CB	NP	AP	SE	DL	SP	MTN	PC	US
	Change in net returns to agricultural production										
T	390	333	1,667	435	513	527	471	184	180	-84	4,615
T + N	392	355	1,686	464	509	528	473	196	186	-54	4,734
T + R	391	359	1,685	485	512	528	472	197	187	-77	4,739
	Change in consumer surplus										
T	-2,512	-843	-1,600	-242	-1,112	-1,360	-416	-1,013	-758	-1,801	-11,657
T + N	-2,513	-843	-1,601	-242	-1,112	-1,361	-417	-1,014	-758	-1,801	-11,661
T + R	-2,513	-844	-1,601	-242	-1,112	-1,361	-417	-1,014	-758	-1,802	-11,663

Note: Source for base units taken for year 2010 and discounted to 2004 dollars using a discount rate of 5.02 percent (USDA 2003).

[a] Region definitions: NE (Northeast) = CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, and VT; LS (Lake States) = MI, MN, and WI; CB (Corn Belt) = IA, IL, IN, MO, and OH; NP (Northern Plains) = KS, ND, NE, and SD; AP (Appalachia) = KY, NC, TN, VA, and WV; SE (Southeast) = AL, FL, GA, and SC; DL (Delta) = AR, LA, and MS; SP (Southern Plains) = OK and TX; MTN (Mountain) = AZ, CO, ID, MT, NM, NV, UT, and WY; PC (Pacific) = CA, OR, and WA; US (United States).

[b] Scenario definitions: *T* = global agricultural trade reform only; *T + N* = trade reform and national non-degradation environmental policy; *T + R* = trade reform and regional non-degradation environmental policies (all estimated monetary values are in 2004 dollars).

the most part, technique and composition adjustments can mitigate environmental parameters at low cost or at a profit. For example, the increase in acres using no-till residue management increases by a larger percentage with environmental restrictions than without. The amount of additional acres coming into production after trade liberalization also falls slightly with the imposition of national- and regional-level nondegradation policies for nutrients, pesticides, and erosion, which implies more intensive management of cropping enterprises.

Water Quality Parameters

Overall, in percentage terms, changes in the amount of nitrogen discharge, phosphorus discharge, and erosion predicted by the model are generally less than one percent (with pesticide use increasing by 1.4 percent), indicating that agricultural trade liberalization may likely have little overall impact on the environment. Nevertheless, changes in total acres and acreage under the various tillage practices do help explain some of the environmental changes that might occur under various trade liberalization scenarios (Table 5).

If additional acres are brought into production following trade liberalization, the amount of nitrogen and phosphorus runoff, pesticide use, and erosion will increase if there are no environmental policies to restrict their discharge. For example, the largest change in planted acres occurs in the Northern Plains region across all scenarios. The changes in nutrient discharge are largest in this region. Nitrogen lost to water resources might increase in this region by as much as 35 million pounds in the absence of nondegradation policies. However, even if a region does not necessarily have a large increase in planted acres, it can still experience increasing runoff due to changes in tillage and crops. Even though planted acreage increases by about one percent in the Appalachia region, pesticide use increases by nearly 6 percent.

With environmental standards, it is possible to reduce the potential increases in national and regional runoff at minimal cost. For example, in the Northern Plains, net returns may increase (over and above trade-only increases) by between $30 and $55 million under nondegradation standards. This is accomplished by adjusting the regional distribution of corn, sorghum, wheat, and soybean operations, and by using no-till practices.

Moreover, while the value of these environmental changes is not known with certainty, they have value to society. For example, a conservative estimate of the value of reducing sheet and rill erosion is $2 per ton (Ribaudo et al. 1990).

Table 4. Changes in Tillage Practices Following Trade Reform (millions of acres)

	Region[a]										
Scenario[b]	NE	LS	CB	NP	AP	SE	DL	SP	MTN	PC	US
	Conventional										
T	0.1	0.0	0.3	0.2	-0.1	0.0	0.0	0.0	0.1	0.0	0.7
T+ N	0.1	-0.1	0.6	0.1	0.0	0.0	0.0	-0.2	0.3	-0.1	0.7
T+ R	0.1	0.0	0.6	-0.2	0.0	0.0	0.1	-0.1	0.2	0.0	0.7
	Mold-board										
T	0.0	0.1	0.2	-0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.3
T+ N	0.0	0.1	-0.1	-0.3	0.0	0.0	0.0	0.1	0.0	0.0	-0.2
T+ R	-0.1	0.1	-0.3	-0.3	0.0	0.0	0.0	0.2	0.0	0.0	-0.5
	Mulch										
T	0.0	0.1	0.2	-0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.4
T+ N	-0.1	-0.3	-0.4	0.1	-0.2	0.0	0.0	0.1	-0.1	0.0	-0.8
T+ R	-0.1	-0.2	-0.4	0.2	0.0	0.0	0.0	0.1	0.0	0.0	-0.5
	No-till										
T	0.0	-0.1	-0.3	0.8	0.0	0.0	-0.1	0.0	0.0	0.0	0.5
T+ N	0.0	0.3	0.4	1.0	0.0	0.0	-0.2	0.0	0.0	0.0	1.5
T+ R	0.0	0.2	0.4	0.9	0.0	0.0	-0.1	0.0	0.0	0.0	1.4
	Ridge-till										
T	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
T+ N	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
T+ R	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
	All tillage types										
T	0.1	0.1	0.4	0.7	0.1	0.0	-0.1	0.1	0.1	0.0	1.6
T+ N	0.0	0.1	0.4	0.7	-0.1	0.0	-0.2	0.0	0.1	-0.1	1.0
T+ R	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.1	0.1	0.0	0.9

Note: Source for base units taken for year 2010 (USDA 2003).

[a] Region definitions: NE (Northeast) = CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, and VT; LS (Lake States) = MI, MN, and WI; CB (Corn Belt) = IA, IL, IN, MO, and OH; NP (Northern Plains) = KS, ND, NE, and SD; AP (Appalachia) = KY, NC, TN, VA, and WV; SE (Southeast) = AL, FL, GA, and SC; DL (Delta) = AR, LA, and MS; SP (Southern Plains) = OK and TX; MTN (Mountain) = AZ, CO, ID, MT, NM, NV, UT, and WY; PC (Pacific) = CA, OR, and WA; US (United States).

[b] Scenario definitions: *T* = global agricultural trade reform only; *T+ N* = trade reform and national non-degradation environmental policy; *T+ R* = trade reform and regional non-degradation environmental policies.

Therefore, the benefits of a regional nondegradation constraint on soil erosion could be as high as \$16 million (\$2 x 8 million tons of erosion), which exceeds the reduction in consumer surplus associated with trade liberalization alone versus trade liberalization with environmental constraints (\$6 million).

Conclusions

U.S. law mandates that the federal government perform environmental assessments of all proposed trade agreements (U.S. Executive Order 13141, 1999). Because the federal government has little experience to date in estimating environmental consequences of agricultural trade agreements, our approach can serve as one model for such studies by others.

We also explore how nondegradation standards for agricultural externalities might influence producer adjustments to trade policy. Our results suggest that under a post-Doha trade liberalization scenario, agricultural trade liberalization is likely to affect the environment in a variety of

Table 5. Changes in Environmental Quality Following Trade Reform (millions of units)

	Region[a]										
Scenario[b]	NE	LS	CB	NP	AP	SE	DL	SP	MTN	PC	US
	Nitrogen losses to water (lbs.)										
T	3.7	9.8	19.2	35.2	8.2	0.6	-1.5	3.7	0.8	-0.5	79.2
T+ N	1.3	-4.8	12.8	20.8	-7.2	-0.3	-10.4	-6.0	3.4	-5.6	4.1
T+ R	0.0	-0.8	-0.1	1.8	-0.8	0.1	-0.4	1.0	0.6	-0.2	1.2
	Phosphorus losses to water (lbs.)										
T	0.6	0.2	2.5	2.5	0.9	0.0	-0.3	0.3	0.0	0.0	6.7
T+ N	0.4	0.0	1.7	0.3	-0.7	-0.1	-1.2	-0.4	-0.1	0.0	-0.1
T+ R	0.1	0.1	0.1	-1.8	0.0	0.0	-0.2	0.1	-0.1	0.0	-1.9
	Total pesticide use (lbs. active ingredient)										
T	0.1	0.4	1.3	2.0	1.6	-0.1	-0.1	0.1	0.1	0.0	5.4
T+ N	0.0	-0.3	0.3	1.4	-0.5	-0.1	-0.5	-0.1	0.0	-0.2	0.0
T+ R	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1
	Sheet and rill erosion (tons)										
T	0.5	0.5	4.1	1.3	0.3	0.0	-0.5	0.2	0.0	0.0	6.4
T+ N	0.4	-0.2	2.0	-0.3	-0.5	-0.2	-1.5	-0.3	0.0	0.0	-0.6
T+ R	0.0	-0.1	-0.3	-1.3	-0.1	-0.1	-0.4	0.0	0.0	0.0	-2.4

[a] Region definitions: NE MI, CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, and VT; LS (Lake States) = (Northeast) = KS, IA, IL, IN, MO, and OH; NP (Northern Plains) = MN, and WI; CB (Corn Belt) = AL, KY, NC, TN, VA, and WV; SE (Southeast) = ND, NE, and SD; AP (Appalachia) = OK and TX; AR, LA, and MS; SP (Southern Plains) = FL, GA, and SC; DL (Delta) = CA, OR, and AZ, CO, ID, MT, NM, NV, UT, and WY; PC (Pacific) = MTN (Mountain) = WA; US (United States).
[b] Scenario definitions: *T* global agricultural trade reform only; = *T+ N* trade reform and = national non-degradation environmental policy; *T+ R* = trade reform and regional non-degradation environmental policies.

ways, some positive and others negative. Nondegradation standards at the national or regional level can prevent harmful environmental impacts, while leaving producers' gains to trade relatively unaltered.

Our modeling framework contains many of the agri-environmental indicators that are traditionally the focus of U.S. agricultural policy. However, the set of indicators is by no means complete, nor do we have good estimates of their value to society. Our results indicate that the value of restricting the amount of sheet and rill erosion alone may be greater than the potential costs to consumers and producers when adjustments to agricultural trade liberalization are constrained by nondegradation standards. Future research extensions could incorporate environmental impacts (and valuation thereof) due to changes in greenhouse gas emissions, manure nutrient and bacterial discharges, and emissions of pollutants associated with fuel usage, as well as environmental amenities associated with agricultural production.

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