

Divergent Environmental Regulations and Trade Liberalization

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The market and nonmarket consequences of environmental regulations and of trade liberalization under different regulatory regimes are explored in the context of the NAFTA through simulation modeling of the North American sheep and lamb markets. Producers are able to shift much of the cost of regulation to domestic and foreign consumers and thus gain from regulation. In the cases investigated, nonmarket effects are unlikely to reverse the sign of market gains or losses, and "level playing field" regulations may or may not be preferred.

Les conséquences économiques et environnementales de la réglementation en matière d'environnement et de la libéralisation des échanges dans le contexte de l'accord de libre-échange nord-américain sont examinées en modélisant le marché nord-américain de l'agneau et du mouton. Les producteurs réussissent à transférer aux consommateurs nord-américains la plupart des coûts dus à la réglementation et donc à en retirer des gains. Dans les cas étudiés, il est peu probable que les impacts environnementaux changent les gains en perte et vice-versa. Une réglementation n'affectant pas la compétitivité des partis ne serait pas nécessairement préférable.

INTRODUCTION

In the debates surrounding proposals to liberalize trade within North America via the Canada–U.S. Trade Agreement (FTA) and the North American Free Trade Agreement (NAFTA), the potential for conflict between trade and environmental policies was raised. In an international trade context, the sensibility that more output is not invariably preferred to less translates into questions regarding interactions between trade and environmental policies and outcomes.

Prominent in these discussions is the issue of policy differences. "Vive la difference!" may be a rallying cry for some, but calls for a so-called "level playing field" are apt to be heard where there are differences in environmental regulations among trading partners. In the United States, for example, Senator Frank Lautenberg proposed an

amendment "to make the failure to adopt effective pollution standards an unfair trade practice." This was justified on the basis that "countries which allow the exploitation of their environment are reaping the benefits of lower production costs" (*Congressional Record*: S4817). Where countries' effective environmental policies are the same, trade liberalization is unlikely to trigger charges of environmental dumping and loss of competitiveness, despite any discrepancies in the inherent costs of compliance. Rather, it is the differences in regulation among trading partners that give rise to a set of concerns. In many important respects, the situation and issues mirror those pertaining to other policies and technical standards: Do the policy differences serve as intentional or unintentional trade barriers? Does the policy provide a hidden subsidy to (or tax on) local produc-

ers? Will further easing of tariffs undermine the effectiveness of existing policies? Is policy harmonization, as is increasingly the case in the European Union, desirable from a welfare standpoint? Or is the public good better served by mutual recognition of each country's own standards?

There is still much to be learned about the interplay between trade liberalization and environmental protection measures, both in general terms and with respect to particular policies and industries. This paper explores the effect of environmental policies in an open economy framework and of trade liberalization when there are production externalities. To this end, we formulate a partial equilibrium model that includes producer response to environmental policies for North American trade in a selected sector. The model is calibrated to actual trade flows and then is employed to explore quantitative trade, environmental and welfare effects of NAFTA liberalization under a variety of environmental policy assumptions. Our main findings are generally consistent with those of other empirically based studies of the relationship between trade liberalization and environmental policies: North American trade liberalization has the expected market effects with or without environmental policies in place, and environmental policies retain their effectiveness following trade liberalization. Also, as expected, environmental effects serve as a partial offset to market-based gains from trade liberalization for the exporter and enhance the gains (or reduce losses) for the importing countries.

SPECIFIC OBJECTIVES

The two main objectives of this paper are to explore the effect of environmental policies in an open economy framework and to investigate the effect of trade liberalization when there are production externalities. The first objective responds to the concern that environmental policies serve as a tax on producers in the imposing country. Our focus within this broader objective is divergent policies. In the markets studied we pose two questions:

- To what extent do environmental restrictions affect the expected market outcomes?
- Does a level playing field — in the sense of equal restrictions — increase social welfare relative to divergent policy situations?

The second objective arises from the concern that nonmarket effects will negate the benefits from trade liberalization. The classic welfare results that support economists' arguments regarding the desirability of free trade rest on the assumption that market prices reflect the full costs of production and that market welfare represents social welfare. Relaxation of this assumption calls into question the desirability of free trade (Pethig 1976). A secondary concern is whether or not environmental policies can remain effective following trade liberalization.

The empirically based simulation model is constructed to yield results that allow us to address the specific questions outlined above. While the methodology is necessarily applied to a particular set of related markets, this research is not intended as an in-depth analysis of those markets *per se*. We use the market situation as it existed in 1990 as the basis for comparison and then perform two sets of simulations. In the first, unilateral and bilateral imposition of environmental regulations are modeled as the basis for addressing questions regarding their market and nonmarket effects. In the second, trade liberalization is simulated across regulatory scenarios in order to look at the market and nonmarket tradeoffs from tariff removal under a variety of conditions. Formal hypothesis tests are beyond the scope of this type of model, yet the results are capable of yielding insights conditional upon the assumptions and parameterization. Sensitivity of the results to the specific parameterization is investigated.

THEORETICAL AND EMPIRICAL ANTECEDENTS

Over the past two decades, a series of theoretical explorations of trade and environmental interactions has yielded a wealth of

propositions whose factual significance has yet to be conclusively established. Depending upon the particular assumptions employed and/or parameters involved, it can be demonstrated that trade liberalization can help, harm or have little net effect upon the natural environment. Similarly, environmental regulations can be shown to alter geographic patterns of production and trade, or not, depending upon the assumptions employed.

Concerning the issue of environmental regulations' influence on the location of production, the possibility for significant effects can be demonstrated theoretically, but empirical verification has not been forthcoming. Some early theoretical studies such as Siebert et al (1980) and Pethig (1976) established a potential link between environmental regulations and reduced international competitiveness, with corresponding changes expected in production and trade flows. However, to date, little empirical support has been found for such competitive effects (von Moltke 1993; Jaffee et al 1993). Similarly, evidence that differences in environmental compliance costs have caused direct or indirect shifts in the location of production of "environmentally intensive" goods appears to be inconclusive at most. Low (1993) and others (e.g., Tobey 1993; Jaffee et al 1993) have found little statistical evidence that divergent environmental regulations play a significant contributory role in industrial migration decisions, or that so-called "environmental dumping" is more than an anecdotal phenomenon.

One recent example of an empirical study should serve to give the typical flavor of such efforts. Grossman and Kreuger (1993) examined potential environmental effects of the NAFTA, concentrating primarily on U.S.-Mexico issues. Their analysis of the relationship between per capita gross domestic product (GDP) and air pollution suggested that NAFTA-induced increases in per capita GDP are likely to improve Mexico's environmental protection efforts. Grossman and Krueger also were unable to find statistical evidence of industrial flight to Mexico to

avoid high U.S. pollution abatement costs. On the contrary, the relevant coefficient had the opposite sign to what was expected and was statistically significant. The authors surmised that compliance costs are too small relative to total costs to drive the decision between U.S. and Mexican production locations. Using a computable general equilibrium model together with data on U.S. toxic releases, Grossman and Kreuger generated predictions about post-NAFTA electricity generation and toxic releases in the partner countries, concluding that changes in the scale and composition of manufacturing may lead to a worsening of industrial pollution and increased electricity generation in all three countries. Nevertheless, the authors speculate that Mexico's comparative advantage lies in relatively less polluting sectors such as agricultural and labor-intensive manufactures, so that North American trade liberalization may yield an overall reduction in pollution for that country.

Another set of studies has taken up optimality and social welfare issues. Relatively early, Pethig (1976) took issue with the proposition that countries enjoying relatively large assimilative capacities (environmental endowments) should specialize in the production of environmentally intensive goods, and rigorously showed the necessary and sufficient conditions for a welfare loss from trade given a set of initial assumptions. More recently Krutilla (1991) presented a theoretical approach to identifying first-best and second-best optimal trade and environmental policy combinations when there are production externalities. Feenstra and Rose (1993) explored first- and second-best policies in the context of California's agricultural water requirements and U.S.-Mexico trade liberalization. Some special assumptions (e.g., that water now used to produce crops that are replaced by Mexican imports will be sold to urban consumers, and horizontal supply curves) yielded sizable social welfare gains for California following liberalization. In these works, it can be seen that the welfare implications of free trade cannot be signed *a priori* in the presence of externalities.

The absence of definitive answers to most questions regarding the interaction of trade and environmental outcomes and policies is frequently mentioned in the literature. In Copeland and Taylor's (1995) review of theoretical contributions to the dialogue, it quickly becomes apparent that specific conditions and assumptions about countries, sectors, preferences and institutions determine the eventual conclusions regarding the environmental and welfare outcomes of specialization and trade. Indeed, the body of theoretical results has led to observations that empirical analyses are needed to verify the theoretical propositions and to ascertain which assumptions should be included in the set of those corresponding to particular observed outcomes. Yet, as pointed out by Perroni and Wigle (1994), quantitative support for the various propositions emerging from the theoretical literature on trade and the environment is both scarce and generally not particularly robust. The relationships appear to be sufficiently complex and dependent upon specifics that they confound easy generalizations. Robustness may ultimately be obtained through a preponderance of evidence garnered from multiple studies, each utilizing a somewhat different approach or set of assumptions or applied to a different set of markets.

LIVESTOCK INDUSTRY, POLICIES AND EXTERNALITIES

The livestock industry is selected for this case study because of its readily identifiable and potentially significant environmental externalities, the existence of trade flows within the North American countries and the existence of import tariffs for Canada and Mexico. The extent and nature of livestock externalities and the cost of alleviation vary according to species, intensity of production, and geography. Such considerations make generalizations risky. The live sheep and lamb markets are chosen to represent the issues in the simplest possible way. A relatively minor component of the livestock industry in North America, its modest size

facilitates partial equilibrium analysis and the trade flows are almost entirely contained within the continent. The sheep and lamb markets are bilateral markets restricted primarily by tariffs, further simplifying the modeling. The straightforward trade relations and the comparatively minor government support for these industries allow the United States to focus on the externality effects.

Pollution caused by manure disposal from intensive livestock production is the leading environmental issue in agriculture in many regions. Manure pollutes the environment through leaching of excessive nitrates into groundwater and through runoff, which can cause eutrophication of streams and waterways. European countries, notably within the European Union (EU), have identified nitrates as a significant contributor to water pollution, and livestock as a major contributor to the nitrate problem. Leuck (1993) has investigated the responsiveness of livestock supply in the EU to policies intended to reduce nitrate-related water pollution, and Haley (1993) further examined the policy-production-environmental-trade nexus for EU agriculture.

Within North America, environmental externalities as a consequence of livestock production have also been recognized, although there has not been a policy such as the EU Nitrate Directive to serve as a focal point for public opinion and economic analysis. In Canada and the U.S. regulations regarding the location of livestock production and the storage and spreading of manure are in effect. In Richardson and Mutti's (1976) study of the effects of U.S. environmental controls on international competitiveness, livestock and livestock products ranked with the "pollution-intensive" manufacturing industries in terms of pollution abatement costs and market effects.

Canadian regulation of externalities from agriculture is largely conducted on a provincial basis. Similarly, the *Clean Water Act* in the U.S. directs states to identify and remedy water quality problems such as those caused by manure. Hence there are geo-

graphic policy differences within as well as across countries.¹

Even in the relatively simple cases of sheep and lambs, the externalities have complex interactions, and the indirect consequences of production differ by location. Sheep herds are generally small across Canada, with the largest herds having only a few hundred animals and found with the Hutterite colonies in Alberta. Hobby farms account for most production in all provinces. At current levels of output, sheep manure is not concentrated and is unlikely to have any significant negative environmental effects, particularly in view of the environmental regulations, although local overgrazing or grazing too near streams remains a possibility.

Sheep (and lamb) production in the United States generally involves extensive grazing. Manure runoff into streams and waterways is a potential source of negative externalities, as is leaching into groundwater of nitrates from manure as a result of overgrazing. Overgrazing can also contribute to soil erosion problems. In both British Columbia and the U.S. Pacific Northwest region, sheep grazing is sometimes used in combination with silviculture (tree farming) to reduce the need for herbicides. In Oregon, sheep are also grazed on grass seed fields during the winter months, again reducing the need for chemical applications. These desirable production externalities may or may not be monetarily rewarded.

Mexican sheep production is extensive and small, and may result in improved soil conditions. Nonetheless, overgrazing in any one location may contribute to soil erosion and eutrophication of streams. Thus, in each of the three countries, the possibility exists for both positive and negative externalities.

approach is to utilize an existing model of international trade (e.g., Anderson 1992; Grossman and Kreuger 1993) in conjunction with separately estimated or available relationships between the economic activity represented by the trade flows and environmental outcomes. Our approach shares some features with these and other empirically linked studies. In common with Abler and Shortle's (1995) analysis of agricultural pollution control policies, optimizing producers in our model are assumed to substitute among inputs, and their choices alter the environmental consequences of production at any given level of output. The model shares with Anderson (1992) the approach of calculating market-based welfare gains from trade liberalization using the solution of a sectoral price equilibrium model and then considering the effect on the natural environment as a potential adjustment to the measured market welfare gain or loss.

A critical component of pre- and post-trade liberalization welfare comparisons is the measurement, including the valuation, of nonmarket effects of such liberalization. Our approach to the welfare question is to estimate the value of nonmarket effects required to exactly offset the market effects of liberalization under different environmental policy combinations. This approach is not too distant from Ballenger, Beattie and Krissoff's (1994) analysis of western hemisphere free trade in fruit juice. In their study, Ballenger, Beattie and Krissoff calculated the level of regulation the exporting countries would accept in order to obtain free trade for these products. We make welfare comparisons among scenarios without searching for optimal policy combinations in any absolute sense.

MODELING ISSUES

Empirical models of trade and environmental interactions have employed a variety of approaches, each with its strengths and weaknesses for the purposes of addressing a number of related questions. One common

EMPIRICAL MODEL

The key issues can be illustrated using a partial equilibrium model of international trade. As alluded to above, the model simulates trade (tariff removal) and other stylized (environmental) policy changes to the situation

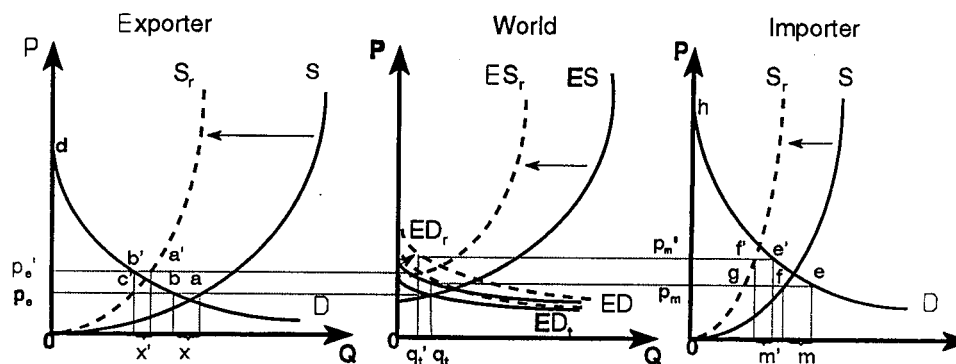


Figure 1. Trade effects of environmental restrictions

existing in 1990, facilitating evaluations of the questions posed rather than searching for optimal outcomes in the Krutilla sense. Our simulation model is developed and calibrated for 1990 North American trade in live sheep and lambs. The U.S. and Canada trade lambs, with Canada a net importer in 1990. Mexico imports cull ewes from the U.S. Canada and Mexico trade neither live sheep nor lambs with one another, and virtually all of North American trade in these two markets is intra-regional. The essence of North American live sheep and lamb trade therefore is captured by a pair of bilateral trade models. While the parameters differ, the sheep and lamb models are conceptually identical.

The trade segment of the model is illustrated by the three panel diagram in Figure 1, which shows the market level supply and demand curves for an importing and exporting country and their interaction through trade. Key features and underlying assumptions include:

- products geographically homogeneous
- border prices (in U.S. dollars) are used
- tariffs are assumed to be the only trade barrier in effect²
- both countries are large in the sense that price is determined through interaction of the excess supply and demand curves, which are the horizontal difference between each country's domestic supply and demand curve.

The quantity traded (center panel) corresponds to the equilibrium price(s). The quantities produced and consumed in the importing and exporting countries are determined by the intersection of the equilibrium price line(s) with the supply and demand curves.

The ambiguous effects of environmental policy in an open economy is illustrated for the imposition of environmental policy in both countries with tariffs in place. The two equilibrium solutions shown are for trade restricted by tariffs only, and with environmental restrictions on production as well. For the case with tariffs and no environmental regulation, the domestic supply and demand curves (S and D) are given by the solid lines.

In Figure 1, the exporting country's domestic supply and demand curves without regulation and the corresponding excess supply curve are given by S , D and ES . For the importing country, the unregulated supply, demand and excess demand curves are given by S , D and ED . The imposition of a tariff by the importing country causes the excess demand curve to shift down by the amount of the tariff and the tariff inclusive excess demand curve is shown as ED_t . The tariff inclusive equilibrium price for the exporting country is p_e and the price in the importing country equals p_e plus the tariff and is shown as p_m .

Regulation causes the supply curve in both countries to rotate leftward to S_r and the

regulated excess supply and demand curves are derived as ES_r and ED_r . The restriction on supply caused by the regulation causes the exporter to sell less on world markets at any price and leads to increased demand on world markets from importing countries. The regulation causes world prices to increase, but the effect on the volume of trade is ambiguous. Keeping the tariff in place, the prices in the exporting and importing countries increase to p_e' and p_m' , respectively. Figure 1 shows a decrease in the volume of trade from q_t to q_t' .

In both countries, consumer surplus declines following regulation due to higher prices and lower quantities: $p_e db > P_e' db'$ (exporter) and $p_m he > p_m' he'$ (importer). The effect of environmental regulation on producer surplus is given by $p_m' f' gpm - f' 0g$ for the importer and $p_e' a' c' p_e - a' 0c'$ for the exporting country. This cannot be signed *a priori*. The empirical model treats all possible combinations. Note that neither producer surplus nor total market welfare can be signed and that changes in tariff revenue and nonmarket welfare effects must also be considered to find the change in total welfare.

Environmental and Trade Policy Scenarios

Trade liberalization is modeled as removal of the tariffs prevailing in 1990 as specified under the NAFTA provisions. The 1990 Canadian per-head tariff on live lambs was equal to \$0.60 or approximately 1% of the value, while Mexico had a 10% *ad valorem* tariff on live sheep imports.

Three different environmental policy scenarios are simulated to allow for both multilateral and unilateral imposition of environmental policies. Since most policies to regulate livestock waste have been imposed recently, the data used to calibrate the model are assumed to reflect no regulation (or a lower level of regulation than current standards). The first scenario assumes that the regulation implicit in the data remains the same (No Environmental Regulation or NOER). The second scenario assumes that both countries impose a stan-

dard (Both Environmental Regulation or BER). The final two scenarios represent unilateral environmental regulation by the exporting (Exporter Environmental Regulation or EER) and importing country (iMporter Environmental Regulation or MER), respectively.

The model is solved in two rounds, starting from the base case with the importing country levying a tariff with no environmental regulation. In the first round, environmental regulation is imposed. In the second round, tariffs are removed for each of the environmental policy scenarios. The two-step process shows both the effects of the environmental regulations and the way in which the impact of trade liberalization varies with different assumptions about environmental regulation. The full solution set includes market and nonmarket outcomes for both countries under each policy combination.

Figure 2 shows the effects on quantity traded and prices of trade liberalization (international market panel in Figure 1) for the environmental scenarios modeled. The first set of simulations corresponds to the equilibrium pairs as follows:

- $a, a' = \text{NOER}$
- $b, b' = \text{BER}$
- $c, c' = \text{EER}$
- $d, d' = \text{MER}$.

Tariff removal leads to a movement from each equilibrium pair to its corresponding starred value, e.g., from a, a' to a^* . The range of resulting price and quantity outcomes is shown on the axes. Pure trade liberalization has the expected market effects. The changes transfer back to domestic markets as illustrated previously in Figure 1. Comparison of selected equilibrium prices for the importing country serves to illustrate the potential for trade liberalization to ameliorate the price effects of environmental regulation. If the importer combines the two policy changes, it moves from a' to d^* (exporter does not regulate) or c' to b^* (exporter regulates). In each case, imports increase, but there is little price effect compared with standalone environ-

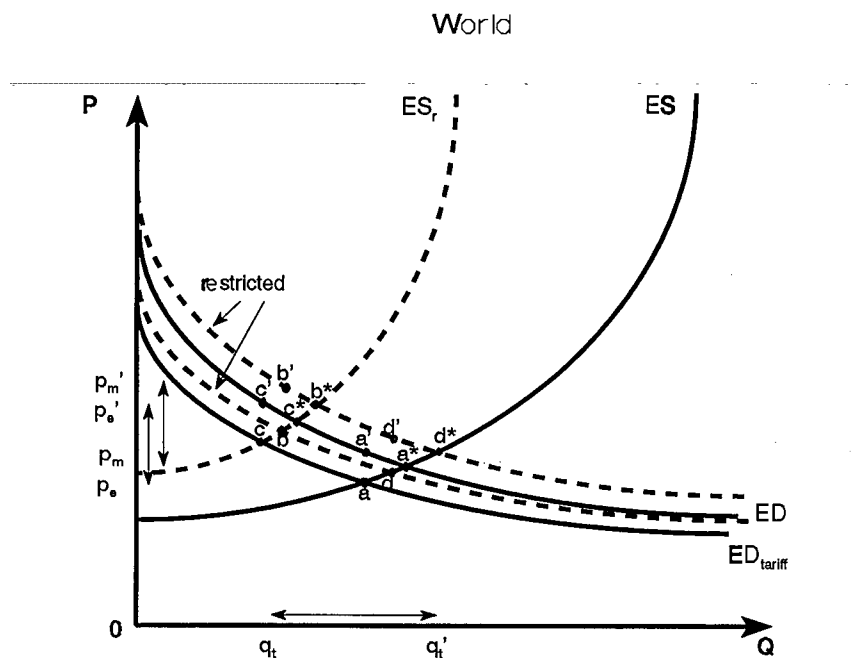


Figure 2. Trade liberalization and environmental restrictions

mental restrictions (points d' or b'). At the same time, the price drop normally associated with tariff removal ($a' \rightarrow a^*$ or $c' \rightarrow c^*$) does not materialize.³ Again, many of the welfare effects from these combinations are indeterminate, even on a market basis, and market effects can be outweighed by non-market effects.

Model Formulation

The model for an individual country is briefly described, followed by the world equilibrium conditions.

The supply curve is derived from a profit maximization problem at the farm level. Producers respond to relative prices within regulatory limits, if any, to choose the optimal combination of inputs and outputs. Producers are assumed to be price takers in all markets. The pollution externality is treated as an input in the production process.⁴ The Cobb-Douglas form is chosen as the simplest production function that allows for substitut-

ion between inputs. Two inputs are modeled, x_1 , a composite input of variable factors to produce output, q_s , and the pollution, x_2 .⁵

$$q_s = Ax_1^\alpha x_2^\beta \quad (1)$$

The assumptions made regarding production externalities are deserving of attention. Two relationships are used, one varying and one fixed. Producers are assumed to have some scope to adjust the mix of external and market inputs for any given level of production according to the production function. The amount of the external "input" is equal to the externality associated with the output. Starting at an arbitrary value for the base case, proportionate policy-induced changes in the externality are then calculated.

In this industry, sheep or lamb manure is considered the primary source of production externalities. In the model, x_2 represents pollution from components of manure such as nitrates and phosphates, not the quantity

of manure. The model allows other inputs (e.g., storage facilities, composting equipment) to abate the pollution from components of the manure.⁶

The aggregate supply curve, Q_s , is derived by assuming that farmers maximize profits subject to exogenous output, p , and input, w_1 , w_2 , prices. Market supply is assumed to be the sum of individual farmer supply curves:

$$Q_s = A^{1/(1-k)} (w_1/\alpha)^{-\alpha/(1-k)} (w_2/\beta)^{-\beta/(1-k)} p^{k/(1-k)} \quad (2)$$

where $k = \alpha + \beta$.

The supply curve has a constant elasticity form with the constant equal to $\{A^{1/(1-k)} (w_1/\alpha)^{-\alpha/(1-k)} (w_2/\beta)^{-\beta/(1-k)}\}$ and the elasticity equal to $\{k/(1-k)\}$ and can be used directly in the trade model. The Appendix on model calibration describes the specific linkages.

Typical regulations for livestock waste management consist of limits on the amount that can be discharged on a given parcel of land. The regulations are a type of standard and are modeled as a constraint on the total amount of the externality that can be produced, $(\bar{x}_2)$, independent of the total amount of output. The restricted supply curve is given by Eq. 3:

$$Q_s^r = A^{-1/(\alpha-1)} (w_1/\alpha)^{\alpha/(\alpha-1)} \bar{x}_2^{-\beta/(\alpha-1)} p^{-\alpha/(\alpha-1)} \quad (3)$$

The elasticity for the restricted supply curve, ϵ_r , equals $[-\alpha/(\alpha-1)]$. It can easily be shown that the restriction reduces the supply elasticity (for α , $0 < \alpha < 1$) relative to the unrestricted elasticity. The restricted supply elasticity works through the trade model to alter the outcome of trade liberalization with environmental regulation in one or more countries.

If, instead, environmental regulation takes the form of an input (or effluent) tax, the price of x_2 , w_2 , becomes $(w_2 + t)$ where t is the per-unit tax rate. This expression is substituted into Eq. 2 and shifts the unrestricted supply curve without changing the elasticity.

Like the supply curves, the market demand curves are assumed to be an aggrega-

tion of individual utility maximizing consumers, and the market demand curve can also be thought of as the marginal social benefit curve. By exclusion, it is implicitly assumed that the income effects of the policy changes on demand for sheep and lambs are negligible.

A constant elasticity demand curve completes the domestic market. The difference between domestic supply and demand equals the countries' excess supply or demand relationships. Domestic supply, Q_s , demand, Q_d and net trade, T , for each country are given by constant elasticity functions stated in Eqs. 4 to 6. Eqs. 4a and 4b give the regulated and unregulated supply curves, respectively. The notation indicating a specific country has been suppressed:

$$Q_s = aP^\epsilon; a = A^{1/(1-k)} (w_1/\alpha)^{-\alpha/(1-k)} (w_2/\beta)^{-\beta/(1-k)} \text{ and } \epsilon = k/(1-k) \quad (4a)$$

$$Q_s^r = aP^\epsilon; a = A^{-1/(\alpha-1)} (w_1/\alpha)^{\alpha/(\alpha-1)} \bar{x}_2^{-\beta/(\alpha-1)} \text{ and } \epsilon = -\alpha/(\alpha-1) \quad (4b)$$

$$Q_d = cP^\eta \quad (5)$$

$$T = Q_s - Q_d \quad (6)$$

Equilibrium is found by solving for the price where world trade balances. The model described in this paper contains only two countries: an importer M and an exporter E . The equilibrium condition is given by Eq. 7

$$T^M + T^E = 0 \quad (7)$$

Trade is assumed to equalize prices except for tariffs. In the two trade models used in this paper, the importing country is assumed to have a tariff and the exporting country has neither a tariff nor an export subsidy. The price linkage equation is given in Eq. 8, where the tariff is given by t^M .⁷

$$p^M - t^M = p^E \quad (8)$$

The solution set for this model yields the equilibrium price(s), quantities supplied and demanded, net trade and production externality level for each country.

Measurement of Nonmarket Values

Critical to meaningful comparisons of the full social welfare implications of trade and environmental policy changes is the ability to measure the nonmarket effects of those changes. A frequent stumbling block for welfare assessments in the presence of nonmarket effects is the absence of market values for the nonmarket component, which leaves analysts at best comparing quantity changes with value changes — an “apples and oranges” comparison. In order to make the problem analytically tractable in the absence of values for marginal changes in lamb or sheep manure, we solve for threshold nonmarket values that leave welfare at the same level as before the policy change. The problem is formulated as follows, where Δw represents the change in social welfare:

$$\Delta w = \Delta w^M + \Delta w^{NM}$$

where

$$\Delta w^M = \Delta \text{producer surplus} + \Delta \text{consumer surplus} + \Delta \text{government revenues}$$

$$\Delta w^{NM} = \Delta \text{environmental effects.}$$

Setting $\Delta w = 0$ implies that $\Delta w^{NM}|_{\Delta w=0} = -(\Delta w^M)$. In the present context, there are known coefficients for the per-head production of manure for sheep and lambs. These coefficients are then combined with the projected changes in Q_s to convert the total $\Delta w^{NM}|_{\Delta w=0}$ into its per-ton equivalent. The calculation in terms of specific model variables is given by:

$$\$ \text{ per ton of manure}^{NM}|_{\Delta w=0} = \frac{1}{1/(Q_s^r - Q_s)(\text{ton/head})} [\Delta w^M] \quad (9)$$

In Figure 3, the relationship between the quantity of manure, m , and the quantity of output, q , is given by the line $m(q)$. This fixed relationship is used in Eq. 9 to calculate a value per ton of manure that offsets the market-based welfare gains. The actual environmental effect associated with any given quantity of output is given by $x(q)$ and $x(q)'$ for the unrestricted and restricted cases, and is measured along the right axis. The type of regulation imposed in the model is shown by

the move from $x(q)$ to $x(q)'$ to the right of output q , reflecting the restriction to no more than x_2^* . Note that it is possible for a policy-induced change in technology to change the shape of $x(q)$ to the left of point q as well.

The functions $x_2(q)$ and $x_2(q)'$ represent the input demand functions and can be derived from Eqs. 2 and 3, respectively. As previously explained, sufficient data do not exist to measure the initial amount of x_2 , and the model assumes a base level and calculates changes in the externality from this base. However, this does not produce a value of the externality that can be compared directly with the market-based welfare gains.

Model Specification and Calibration

The model is constructed utilizing 1986 SWOPSIM elasticities of supply and demand for mutton and lamb (meat) (Sullivan, Wainio and Roningen 1989). These are converted to (live) sheep and lamb elasticities through use of the derived demand and supply elasticity relationships; i.e., demand for live lambs is derived from the demand for lamb meat, and mutton supply is derived from live sheep supply (assuming constant marketing per-unit margins). The price ratios used in the conversions are border prices as reported by the United States (Fant 1992). Actual production, consumption and trade figures for 1990 are used in combination with the elasticities to calculate the constant of the supply and demand curves.⁸

As other researchers have found (Abler and Shortle 1995; Peronni and Wigle 1994), there is a severe shortage of data on the linkages between output and environmental pollution. Part of the solution is to use the theoretical linkages between the trade and production models to reduce the number of required parameters. Details on these calculations and data sources for production function parameters are contained in the Appendix.

MODEL RESULTS

Recall that the purpose of the modeling exercise is to explore the market and nonmarket effects of environmental policies and trade

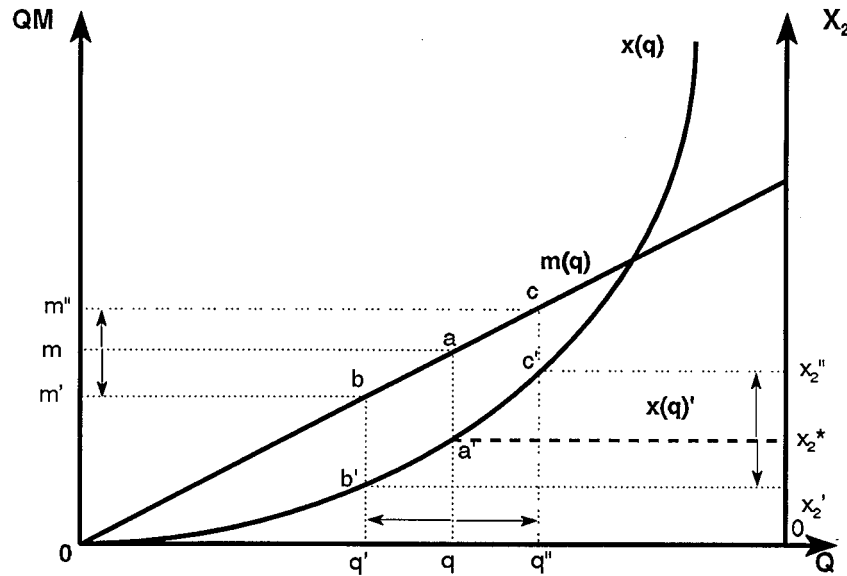


Figure 3. Nonmarket effects of regulation

liberalization, separately and in combination. First, we examine the effects of environmental regulation (restriction on amount of pollution)⁹ with tariff protection in place. What is its ability to shift production? How do the outcomes differ when both countries regulate versus unilateral regulation by the importing or the exporting country? The next set of results concerns the effects of trade liberalization. Having simulated trade liberalization under each of the environmental regulatory scenarios, we ask a set of related questions concerning the market and nonmarket effects of trade liberalization with environmental policies in place. Attention is then given to social welfare effects, allowing inferences to be drawn regarding the desirability of free trade, environmental regulation and “level playing fields” from several vantage points.

Environmental Regulation with Tariff Protection

The simulated market effects of imposing different combinations of environmental policy regimes with tariff protection are presented in Table 1. Environmental regulations

decrease the supply elasticity and rotate the supply curve to the left, reflecting in part a higher marginal cost for producing a given level of output (supply curve corresponding to Eq. 4b rather than Eq. 4a). The increase in marginal cost leads to a decrease in production, and the fall in output changes both the traded quantity and price.

The first two columns of Table 1 present the change in price in both the sheep and lamb markets under the various environmental policy regimes.¹⁰ In all scenarios, the reduction in output has the expected effect of increasing the world price, with the largest increase taking place when both countries impose regulations. The relative magnitude of the price increase between importing and exporting countries imposing regulations depends on the trade elasticities (equal to a weighted sum of domestic supply and demand elasticities with weights equal to the ratio of the domestic supply (demand) to the quantity traded). In the sheep market, the largest price increase occurs when the importing country, Mexico, regulates. This is because the U.S. excess supply is relatively

Table 1. Changes caused by environmental regulation with tariff protection

Scenario	Price		Net trade	Producer surplus		Consumer surplus		Net market welfare	
	(US\$/head)		(1000 head)	(US\$000)		(US\$000)		(US\$000)	
Sheep	Mexico	U.S.		Mexico	U.S.	Mexico	U.S.	Mexico	U.S.
Base	32.91	29.92	430.0	27,287	20,511	48,154	10,566	76,727	31,077
BER	13.86	12.60	1.7	10,639	8,776	-18,480	-4,152	-7,292	4,624
EER	3.62	3.29	-21.5	3,360	1,801	-4,877	-1,093	-1,447	709
MER	8.40	7.64	24.1	5,835	5,906	-11,260	-2,526	-5,005	3,380
Lambs	Canada	U.S.		Canada	U.S.	Canada	U.S.	Canada	U.S.
Base	63.39	62.79	11.0	21,211	251,537	43,484	401,087	64,701	652,625
BER	9.64	9.64	-8.9	2,845	34,970	-4,232	-50,680	-1,393	-15,710
EER ^a	8.87	8.27	24.7	3,702	30,964	-3,642	-46,665	53	-15,701
MER	0.64	0.64	27.1	-921	3,441	-289	-3,426	-1,194	16

Initial supply elasticities used: Canada lambs = 0.312; U.S. lambs = 0.331; Mexico sheep = 0.113; U.S. sheep = 0.112

Supply elasticities with regulation: Canada lambs = 0.295; U.S. lambs = 0.314; Mexico sheep = 0.091; U.S. sheep = 0.1007

Demand elasticities used: Canada lambs = -0.344; U.S. lambs = -0.167; Mexico sheep = -0.076; U.S. sheep = -0.057

Initial trade elasticities: Excess demand: Canada lambs = -26.5; Mexico sheep = -0.48

Excess supply: U.S. lambs = 241.2; U.S. sheep = 0.24

^a Environmental regulation causes a trade reversal.

inelastic and can meet the increase in demand only at relatively higher prices. Regulation by the exporting country causes the largest change in the lamb market because the import demand is relatively inelastic. Note that in this case the regulations are sufficiently restrictive to cause a trade reversal. On the other hand, when Canada regulates, the highly elastic excess supply for the U.S. leads to an increase in U.S. exports and only a small increase in the world price.

The changes in net trade depend on the pattern of regulation. When both countries regulate, the change in net trade cannot be predicted *a priori* because the reduction in supply causes an increase in excess demand and a decrease in excess supply. The results illustrate the two possibilities: in our simulations, regulations cause an increase in net trade in the sheep market and a decrease in the lamb market. When the exporting coun-

try regulates, the decrease in excess supply should result in less trade, as illustrated in the sheep market where trade falls by 21,500 head. The unexpected result in the lamb market occurs because of a trade reversal, which makes Canada a larger exporter than importer. Regulation by an importing country should increase excess demand and net trade, and the regulation turns the U.S. into an importer.

The welfare effects of environmental regulation are measured in part by changes in producer surplus, consumer surplus and net market welfare, which is the sum of changes in producer surplus, consumer surplus and tariff revenue. In all but one case (Canada, lambs) the increase in price caused by the regulation dominates any higher costs, and producer surplus increases. The exception in the lamb market for Canada when it imposes regulations shows the differences between small and large countries. Canada faces a highly elastic excess

Table 2. Changes in production, threshold nonmarket values, and externality

Scenario	Change in production				Threshold nonmarket value		Externality change	
	(1000 head)	(%)	(1000 head)	(%)	(\$/ton manure)		(%)	(%)
Environmental regulation with tariff protection:								
Sheep	Mexico		U.S.		Mexico	U.S.	Mexico	U.S.
Base	922		763		—	—	—	—
BER	−37.4	4	−4.9	1	−163	791	—	—
EER	10.8	1	−23.5	3	111	25	+12.3	—
MER	−47.3	5	19.9	3	−88	−142	—	+28.8
Lambs	Canada		U.S.		Canada	U.S.	Canada	U.S.
Base	439		5332		—	—	—	—
BER	−12.5	3	−134.4	3	−224	−234	—	—
EER ^a	17.1	4	−151.8	3	−6	−207	+18.6	—
MER	−28.7	7	18.0	0	−83	−2	—	+1.4
Pure trade liberalization:								
Sheep	Mexico		U.S.		Mexico	U.S.	Mexico	U.S.
NOER	−3.3	0.3	5.5	0.7	−209	−129	−3.5	+7.3
BER	−2.6	0.3	4.8	0.6	—	—	—	—
EER	−3.1	0.3	4.9	0.6	−246	—	−3.2	—
MER	−2.8	0.3	5.3	0.7	—	−166	—	+6.9
Lambs	Canada		U.S.		Canada	U.S.	Canada	U.S.
NOER	−1.2	0.3	1.7	0.03	0	−1	−1.1	+0.1
BER	−0.9	0.2	1.3	0.02	—	—	—	—
EER ^a	—	—	—	—	—	—	—	—
MER	−1.0	0.2	1.6	0.03	—	−3	—	+0.1

^a Environmental regulation causes a trade reversal. Consequently, trade liberalization is not relevant, given the absence of U.S. tariffs.

supply and is nearly a small country in this market. In this case, the reduction in Canadian output causes only a slight increase in price (64 cents), and producers must absorb the higher costs. One might expect greater resistance to regulation from producers in industries that face strong competition on world markets. Consumer surplus decreases in every case because of higher prices.

Changes in net market welfare illustrate the linkages between optimal trade and environmental policy that have been discussed in the literature (Krutilla 1991). In the sheep market, the net market welfare of the U.S. increases when it imposes environmental regulation because the decrease in supply

causes an increase in the terms of trade. The U.S. had not previously imposed an export tax to take advantage of its market power, and the environmental policy partially substitutes for the optimal trade policy.¹¹

The simulated impact of divergent environmental policies on the location of production, changes in nonmarket values, and externality changes are given in the top half of Table 2. Changes in production are shown in the first two columns and are all small when expressed in percentage terms. The largest change, 7%, occurs for Canada in the lamb market when it unilaterally imposes regulation and corresponds to conditions that approximate a small exporting country.

Given that environmental policy is implemented in response to nonmarket concerns, a complete analysis includes some measure of nonmarket benefits. Presumably, a country would not impose environmental restrictions in the absence of negative externalities. Thus we assume that the environmental regulation, where imposed, is justified, and any reductions in the amount of the environmental input serve to increase social welfare. Table 2 gives the calculated threshold nonmarket values for each regulation scenario. The case where both countries impose regulations is discussed to interpret the results. Recall that the threshold nonmarket value is calculated as the per-ton nonmarket value for manure required to restore welfare to the pre-regulation level given by Eq. 9. In the sheep market, Mexico experiences a fall in both net market welfare and production. If production causes pollution, then the threshold value represents the cost (negative value) of pollution required to offset the regulation-induced fall in market welfare. Environmental regulations lead to a decrease in sheep production but an increase in net market welfare for the U.S. The positive threshold nonmarket value is consistent with a positive externality associated with sheep manure. A per-ton value of \$791 would be required to eliminate the positive welfare gains. Obviously, if manure causes pollution, then the nonmarket gains increase the total benefit from regulation. In this case, the terms of trade benefits provide some compensation to producers, facilitating the implementation of environmental regulation, as suggested by Krutilla.

The last piece of the puzzle is the simulated changes in the production externality. These are presented in the last two columns of Table 2 as percentage changes from the base amount for the country that does not impose regulation. As expected, unilateral regulation by the trading partner leads to an increase in the level of externalities for the other country *ceteris paribus*. The increases range from a low of 1.4% for the U.S. when Canada regulates, to a high of 28.8% for the U.S. when Mexico regulates. The changes

for the importers when the U.S. regulates are less diverse: 17.4% for Canada and 12.3% for Mexico. These values are driven both by the relative size of production and the elasticities of demand and supply.

Three conclusions emerge from the simulation results where environmental policy is imposed with tariffs. First, environmental policy can be effective even with trade barriers. Second, domestic producers gain from environmental regulation because of the increase in price. This result presumes a large country in world markets. Producers in small countries would have to bear the full costs of regulations without any benefit of higher prices. The MER scenario for lambs shows results for a case where the importing country imposing the environmental policy has almost no ability to affect prices, and is the only case where producer surplus falls. Third, the failure to match the regulations imposed by one's trading partner has the potential to increase a country's own level of production externalities. In the lamb market, social welfare may well decline for the non-regulating partner, given the small size of the net market welfare gains. In the sheep market, the increased externality would add to Mexico's simulated loss in net market welfare and provide a full or partial offset to U.S. market welfare gains. In all cases, the heightened externality levels serve to exacerbate the consumers' losses.¹²

Trade Liberalization

The model results from trade liberalization under different environmental regulation scenarios are given in Table 3. The calculations assume that the same environmental policy exists before and after trade liberalization. With regulations in place, trade liberalization has the expected effects. Tariff removal causes prices to fall for the importing country and increase for the exporting country, and net trade increases.

Trade liberalization induces small changes in prices, quantities and welfare across scenarios. The small tariffs and inelastic supply and demand curves drive the size of the changes. The results obtained by our

Table 3. Changes caused by pure trade liberalization

Scenario	Price		Net trade	Producer surplus		Consumer surplus		Net market welfare	
	(US\$/head)		(1000 head)	(US\$000)		(US\$000)		(US\$000)	
Sheep	Mexico	U.S.		Mexico	U.S.	Mexico	U.S.	Mexico	U.S.
NOER	-1.05	+1.95	6.6	-961	1490	1414	-647	-833	843
BER	-1.51	+2.74	5.9	-1337	2083	1995	-892	-1178	1191
EER	-1.07	+2.25	6.1	-997	1670	1437	-744	-916	926
MER	-1.44	+2.31	6.4	-1260	1817	1920	-759	-1046	1058
Lambs	Canada	U.S.		Canada	U.S.	Canada	U.S.	Canada	U.S.
NOER	-0.54	0.06	2.5	-237	316	244	-315	0	1
BER	-0.54	0.06	2.0	-231	306	232	-306	0	0
EER ^a	—	—	—	—	—	—	—	—	—
MER	-0.54	0.06	2.3	-223	300	244	-298	-2	2

^aEnvironmental regulation causes a trade reversal. Consequently trade liberalization is not relevant since the U.S. has no tariffs.

model are representative of most commodities where pre-NAFTA tariffs were small. As expected, trade liberalization without environmental regulation leads to a decrease in production externalities for the importer and an increase for the exporter (Table 2).

In addition to producing small market effects, a striking similarity in the results is observed across scenarios. Once environmental regulation is in place, trade liberalization involving the elimination of small tariffs produces similar results, even if only one country imposes regulations. In North America, pre-liberalization tariffs are most commonly either small or absent. Therefore, for most commodities, the removal of tariffs can be expected to have a small direct environmental effect.

The results from the trade liberalization scenarios reinforce the conclusion that trade liberalization does not render environmental policy impotent. With some types of policies, such as standards that place absolute restrictions on the amount of pollution, there may be no damage to the environment from trade liberalization, even for the exporting country, as illustrated in Figure 3. The bottom half of Table 2 reports the changes in output and threshold nonmarket value in the absence of

regulation. The environmental standard imposed in our model allows a country to have complete control over externalities irrespective of changes in output.¹³

Sensitivity Analysis

The sensitivity of our model to elasticity values is examined for both sets of scenarios. The analysis focuses on the supply elasticity because:

- the low values in the available data raise questions about their accuracy
- increasing the demand elasticity would have a similar effect on world markets
- supply is directly related to concerns about pollution.

In each set of experiments, the supply elasticity in both countries is increased by an equal percentage from the base (in fixed increments). The related regulated elasticity is calculated for each elasticity value following Eq. 3. The unit increases are 50% and 10% for the sheep and lamb markets, respectively. A larger increment is used to generate a wide range of possible outcomes in the sheep market because of the low value of the base lamb/mutton elasticity. The constant unit increases from the base result in increasingly smaller percentage changes from the

previous value, and this causes the graphs of the sensitivity analysis calculations to display a concave function.

Figure 4 presents the changes in threshold values per ton of manure for the sheep model for the trade liberalization scenario with no environmental regulation, and for the divergent regulation scenario when the exporting country (U.S.) imposes regulation. Under the trade liberalization scenarios, U.S. output and net market welfare increase. Therefore, a negative externality effect is required to offset the welfare increase. The per-tonne value falls as supply becomes more elastic for two reasons. First, the increased supply response translates into more manure and the damage per ton required to offset the welfare gain falls. Second, the change in market welfare is inversely related to the supply elasticity because quantity traded adjusts more and the change in terms of trade required to bring the market back into equilibrium is smaller. Mexican output decreases and there is a fall in net market welfare. Therefore, if manure harms the environment, the lower output will improve welfare from nonmarket effects. The threshold per-ton value decreases as supply becomes more elastic for the same reasons given for the U.S. In neither scenario is the sign of the change in net market welfare or the threshold value reversed.

The sensitivity experiments for the EER scenario illustrate the possibility of changes in the sign of the welfare effect and related threshold nonmarket value. Using the baseline data, Mexico has an inelastic excess demand curve, and unilateral regulation by the U.S. increases market welfare by taking advantage of a previously unexploited opportunity for an export tax. The change in welfare becomes negative exactly at the point where the increase in the supply elasticity makes excess demand elastic. The threshold value for Mexico decreases because of the increase in supply response, similar to the U.S. results.

Figure 5 shows the effect in the lamb market of trade liberalization with no environmental regulation and the MER scenario

as the supply elasticity for the importing country, Canada, increases. In the MER scenario, the negligible change in U.S. welfare results from the fact that Canada has almost no impact on the North American market price. The fall in Canadian welfare reflects the loss in producer surplus (consumers pay the North American market price) as larger changes in output occur in response to regulation. In the trade liberalization scenarios, similar to the sheep market, the per-tonne nonmarket values fall because of an increased quantity over which to spread welfare effects and a smaller change in the terms of trade.

Other Modeling Issues

As is always the case, our results are determined in important ways by the general methodological approach employed and the specific assumptions invoked. The model considers only aggregate production and may not capture large regional changes in environmentally sensitive regions. This weakness is to some extent ameliorated for evaluation of nonmarket effects, since our approach has the potential to support disparate regional comparisons of costs and benefits relative to the threshold per-ton levels calculated. The threshold values also have the advantage of pertaining only to the marginal environmental effects due to the changes in production levels, rather than representing some average over all production. One of the well-known drawbacks to using partial equilibrium models for this type of analysis is the absence of consideration of alternative uses for the resources. This can be particularly troubling when external effects are one of the focal points of the analysis. In the present case, arbitrary values are assigned to the initial environmental input, and they can be considered to incorporate the *net* environmental input, taking into account alternative uses at different output levels. The use of a static framework allows for only limited changes in technology, and thus long-run implications cannot be addressed. Through the border price equalization assumption, it is implicitly assumed in the

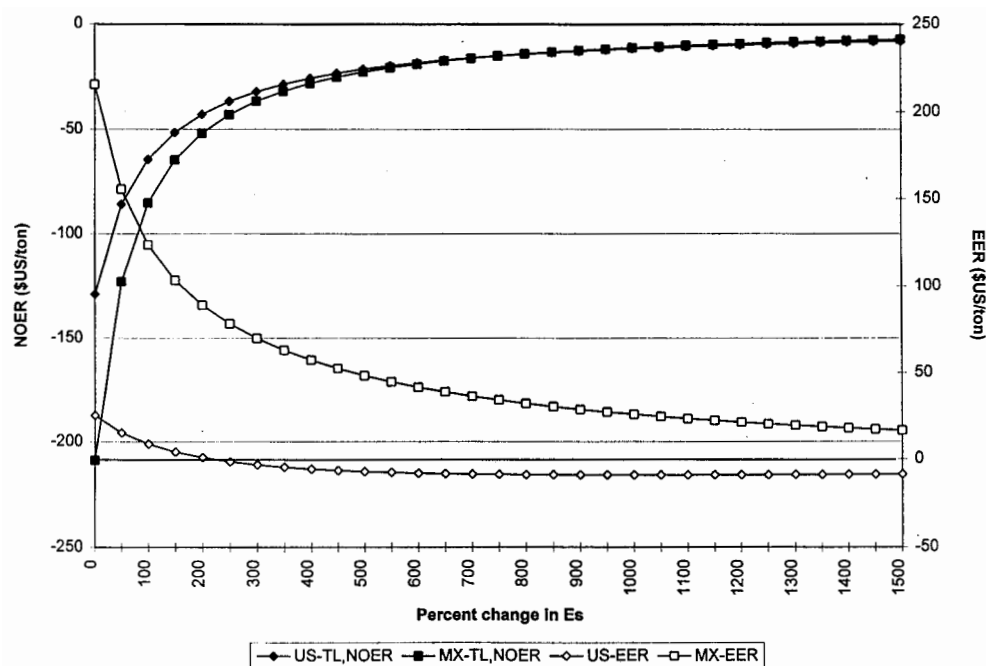


Figure 4. Sensitivity analysis for sheep model: Threshold values as a function of supply elasticities

model that live sheep and lambs are geographically homogeneous. This may or may not be an adequate simplification if, for example, one country exports feeder lambs while importing fed lambs. One desirable feature of the approach used is the fact that the environmental consequences are not held constant across borders or across policy scenarios, and the level of environmental input is not fixed with respect to output.

While only one type of environmental regulation is simulated in this model, it has been established in other research (Bohman and Lindsey forthcoming) that results are not qualitatively different when pollution taxes are included as an alternative to direct restrictions.

CONCLUSION

Returning to the questions motivating this research, several conclusions are suggested by the models' results. These are presented with full cognizance of their dependence

upon the parameterizations employed. The first set of questions concerns the extent to which environmental restrictions affect production and trade outcomes, and whether or not environmental regulations remain effective following trade liberalization. One inference that may be drawn from the simulated market outcomes is that, beyond importer versus exporter status, relative size matters to the effect on production and trade outcomes. In the lamb market, Canadian production is so small relative to U.S. production that Canadian regulations have no significant effect on U.S. market outcomes, although trade volumes are affected by the drop in Canadian production. As expected, it makes a difference whether the exporter, the importer or both regulate, with production declining where regulations are imposed and increasing when they are imposed by the trading partner. If price changes are unfettered, price increases of varying sizes can be expected for both trading partners associated

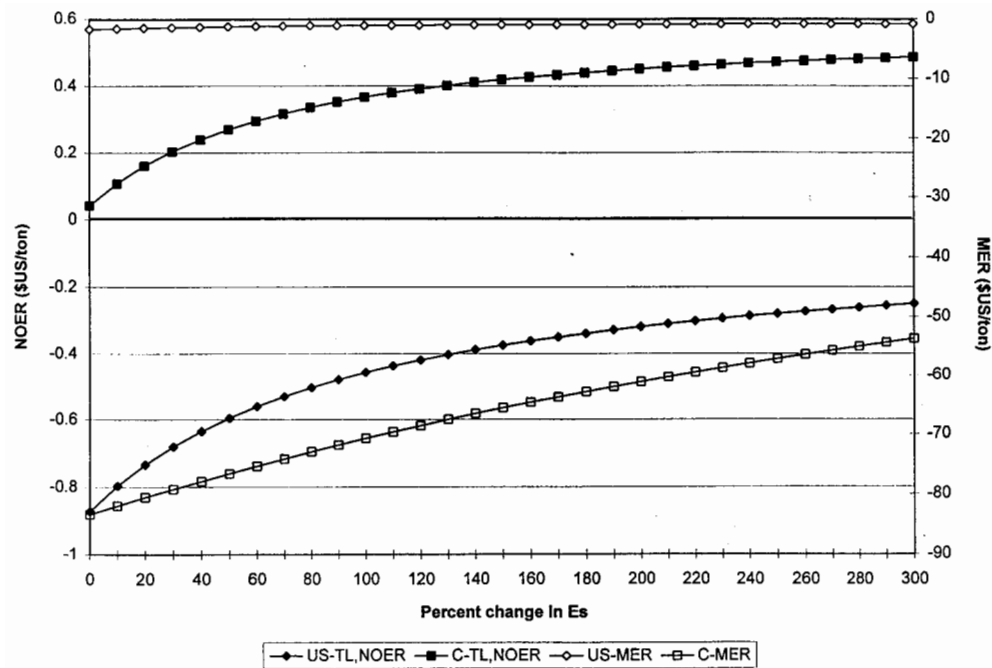


Figure 5. Sensitivity analysis for lamb model: Threshold values as a function of supply elasticities

with the imposition of environmental regulations. Net trade increases if the importer unilaterally imposes regulations, but may increase or decrease when the exporter regulates, depending on other factors. Some support is found for the concern that unilateral environmental regulations may lead to a change from exporter to importer status, as demonstrated in the lamb market. Finally, our results provide no evidence to support concerns that environmental policies will be rendered ineffective following trade liberalization. In neither of these North American markets is trade liberalization in the form of tariff removal shown to make any appreciable difference in the outcomes across regulation scenarios. In fact, trade liberalization appears to be remarkably neutral in this regard.

The more significant changes are found in the various welfare results. Environmental regulations in this open market framework for these markets lead to sometimes substantial shifts in market welfare from consumers

to producers, as producers are able to pass along the costs of environmental regulations to consumers even in an open economy. Shifts in market welfare among countries are also found to occur. The importing country experiences a market welfare loss when it regulates, and may or may not lose when the exporting country unilaterally regulates. The exporting country gains when the importer unilaterally regulates, and may gain or lose welfare otherwise. Trade liberalization has little effect on overall welfare, but may exacerbate the shift among countries.

Turning our attention to the desirability of a "level playing field" in the sense of equal restrictions (harmonization), our results support the conclusion that combined net market welfare, not taking into account externalities, is highest without additional environmental regulations in both the sheep and lamb markets and lowest when both countries regulate. Thus the two "level playing field" scenarios form the endpoints, with

the divergent regulation (mutual recognition) scenarios in between. Nonmarket and distributional consequences come into play. When nonmarket welfare is considered, it would require implausibly high per-ton nonmarket costs to turn the welfare loss into a gain in the lamb market under bilateral regulation, with or without trade liberalization. In the sheep market, the threshold nonmarket values suggest that the U.S. is apt to gain and Mexico apt to lose from bilateral “level playing field” regulations. Our results also suggest that producers are likely to benefit from bilateral regulation, with producers in large countries gaining more from bilateral regulation than from regulations imposed only on their trading partner. Consumers of these products foot the bill while society as a whole is presumed to gain from environmental protection.

There is little evidence in these results to support the view that environmental policy divergence meaningfully affects the desirability of free trade or that free trade conditions make a significant difference to the desirability of harmonized environmental regulations. To be sure, the threshold nonmarket values differ across trade liberalization scenarios, but in one market they are trivial, while in the other the range is bounded by the values from the two level playing field scenarios.

The contribution of this research to the body of evidence concerning the interplay of environmental and trade policies and outcomes is enhanced by our relaxation of the assumption that environmental externalities are rigidly linked to output levels and through calculation of the threshold external per-unit values necessary to maintain a given level of social welfare. The fruitfulness in terms of its contribution to the policy dialogue is thus linked to the methodological contribution herein, particularly in view of the scarcity of data and measurement difficulties surrounding nonmarket valuation. Additional explorations of these questions for other markets will take our profession further down the path of empirically sorting out which are the key parameters.

APPENDIX: CALIBRATION METHOD

The direct linkage of the producer profit maximization problem to the trade model facilitates imposing environmental regulations in a theoretically consistent model. The calibration method for the base case is described first, followed by the method to implement the regulated scenario.

The elasticity of the supply curve and the production function coefficients, α and β are linked by the relationship $\varepsilon = k/1 - k$ (recall that $k = \alpha + \beta$). Therefore, if data exist for the supply elasticity, then only one free production function exponent remains. We assume a common value for the environmental input coefficient, β , and derive the composite input exponent, α , such that $\alpha = \varepsilon - \varepsilon\beta - \beta / (1 + \varepsilon)$. The calibration strategy allows for the productivity of the composite input to vary across countries as a function of the output elasticity. A positive relationship exists between ε and α . With this model, different values of β across countries could be used to analyze differences in levels of externalities. For example, the proximity to urban areas or ground or surface water changes the externality per unit of manure for livestock. However, given the data limitations, we have assumed a common externality effect across countries.

The relationship between the constant in the production function and the constant in the supply function is exploited to calibrate the production function. Note that the constant for the aggregate supply function is derived following the well-known calculation using data on the supply elasticity and data on price and quantity. From Eq 4., $a = A^{1/(1-k)} (w_1/\alpha)^{-\alpha/(1-k)} (w_2/\beta)^{-\beta/(1-k)}$. The value of a can be derived with existing data and information about the input price ratios. Data for relative cost of environmental inputs relative to total costs are available from several sources. For the livestock industry, the BEA's Pollution Abatement and Control Expenditures Statistics, estimate the costs for agricultural businesses (= feedlot operations) for 1990 totaled \$12 million (\$3 million for capital expenditures and \$9 million for

operating costs). Capital expenditures have fallen since a peak in the mid-1970s. Using USDA data for livestock on feed (cattle, sheep and lambs and hogs/pigs), this works out to 0.2% of the value of the animals. This may overestimate costs, since most of the regulations only apply to operations with at least 100 head.

Ingo Walter's I-O-based calculations of direct and overall environmental control "loadings" for livestock and products entering international trade flows is 1.28% direct and 1.98% overall (percentage of final sales). The data are for 1968–70. Jaffe et al (1993) estimated that the 1991 gross annual pollution abatement and control costs as a percentage of value of shipments for all industries was 0.62%, those with "high" abatement costs include paper and allied products with 1.27%, chemical and allied products with 1.38%, petroleum and coal with 1.8% and primary metal with 1.51%.

We estimate the relative price of environmental inputs to other inputs equal to 2% in the base period. The composite input price, w_1 , is set equal to 1. As discussed in the text, environmental regulations for the livestock industry have been tightened since the base period in the model. The new regulations impose limits on the amount of pollution that can be discharged and have been modeled as a restriction on the amount of the pollution input. The new elasticity value is calculated based on Eq. 3 and is used in place of the observed elasticity value in the regulated scenarios. At the margin, we would expect the restricted elasticity (and the price of the externality) to alter both the mix of inputs and the quantity supplied to the market at any given output price.

NOTES

¹The regulations in British Columbia illustrate one approach to regulation. The British Columbia Code of Agricultural Practices legislates that manure disposal must not exceed an amount such that the soil can absorb the nutrients. The amount that can be spread depends on both the weather and the soil. The long rainy season provides the largest constraint to spreading, and most farmers

had approximately three months' manure storage, which is less than that implied by the regulations. In British Columbia, construction of four months of additional storage for a 100 cow dairy herd costs between C\$12,000 for a clay pit in favorable soil conditions to C\$120,000 for a concrete-lined, covered pit. Thus the costs differ according to environmental conditions, even with the same regulations in place. Note that these same variables affect the amount of externality associated with production of a unit of manure.

²While this study singles out environmental regulations, it should be kept in mind that the livestock industries of North America and their related markets operate under a complex set of rules and regulations. Hillman (1991) lists an array of nontariff measures for Canada and the U.S. These are likely to have complex market effects, even without the inclusion of water quality or other environmental regulations. Should true harmonization of nontariff measures be completed, the assumption represents an understatement of the extent of trade liberalization.

³The extent of the offset is determined by the size of the tariff relative to the magnitude of the environmental policy-induced shift in the excess demand curve and the slopes of the excess supply and demand curves.

⁴The same result would be obtained were it treated as an output (Copeland and Taylor 1994), but the model would be more complicated.

⁵The same formulation has been used as the basis for modeling technology as a pollution control policy by Abler and Shortle (1995).

⁶In the model, manure is assumed to be produced in fixed proportions to output, but does not enter the production function directly. When the level of production changes, the manure output changes by this proportion, although the associated externality can vary. To illustrate, assume that manure is equal to γq_s and the nitrogen content is equal to Γ manure (i.e., nitrogen is equal to $\gamma \Gamma q_s$). The pollution, x_2 , is related to output by the production function and is less than the fixed proportions relationship because the composite good is a substitute input for pollution ($x_2 = (q_s A x_1^\alpha)^{1/\beta}$).

⁷The model could easily be extended to accommodate additional countries and domestic policies.

⁸The data for 1990 are representative of prices and quantities in a typical year for live sheep and lambs in North America.

⁹We also simulate imposition of a 100% environmental tax. The main qualitative difference in the results from those presented here are to be found in the government revenue figures, which reflect

changes in production as well as import levels. Tables of results for this set of simulations are available upon request from the authors.

¹⁰The changes in price for the sheep market differ between the U.S. and Mexico because Mexico has an *ad valorem* tariff. Canada imposes a per-unit tariff that, by definition, remains constant when price increases.

¹¹Note that U.S. law prohibits export taxes. Related to this point, while an optimal export tax may increase welfare for a individual exporting country (assuming no retaliation) it lowers world welfare. Keep in mind that environmental policy is a second-best solution to achieve trade policy objectives.

¹²These statements are made presuming negative externalities. If, instead, the production externalities are desirable, the welfare effects would be in the opposite direction.

¹³Copeland and Taylor (1995) discuss this case.

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