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The Globalization of Market Failure? International Trade and Sustainable Agriculture

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THE GLOBALIZATION OF MARKET FAILURE?
International Trade and Sustainable Agriculture

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Abstract: The economic case for trade liberalization rests on its capacity to extend the reach of the market's fabled invisible hand. With the globalization of the market, however, comes a globalization of market failures arising from the fact that prices do not to capture 'external' costs and benefits to third parties. Whether the social gains from trade liberalization will exceed the social losses from the attendant market failures is an empirical question, one which cannot be answered by theoretical fables. This essay considers the impact of two types of trade-driven market failures on sustainable agriculture. The first is the displacement of natural fibres by synthetic substitutes, illustrated by the competition between jute and polypropylene. The second is the erosion of crop genetic diversity, illustrated by the impact of NAFTA on campesino maize farming in Mexico. In both cases, 'free trade' pits pits environmentally 'clean' production in the global South against 'dirty' production in the North - the opposite of the what is often assumed in discussions of the environmental impacts of North-South trade.

1. Introduction

The economic case for trade liberalization rests on its capacity to extend the reach of the market's fabled invisible hand. As trade barriers are lowered and the world market grows more integrated, producers reallocate land, labor, and capital to those economic activities in which they enjoy a comparative advantage, and away from the production of goods and services which now can be more cheaply obtained from others. The result is a larger economic pie, which in principle - if seldom in practice - can benefit all concerned.

With the globalization of the market, however, comes a globalization of market failures, due to the fact that prices do not to capture 'external' costs and benefits to third parties. Say that country A produces corn more cheaply than country B, but in so doing generates more pollution. In the absence of countervailing policies, trade liberalization will cause production to shift from

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country B to country A, with a corresponding increase in pollution and its external costs. Similarly, if producers in country B generate higher positive externalities than those in country A - for example, via the conservation of crop genetic diversity - trade liberalization will erode the supply of these benefits. In both cases, the happy ending of a bigger pie - once the external costs and benefits are counted - can no longer be taken for granted. Whether the social gains from trade liberalization will exceed the social losses from the attendant market failures is an empirical question, one which cannot be answered by theoretical fables.

This essay considers the impact of trade-driven market failures on sustainable agriculture. By sustainable agriculture I do not refer solely to 'traditional' farming in developing countries but also to 'modern' farming: both are important to sustaining the supply of food and fibre for current and future generations. Moreover, the boundary between them is increasingly fuzzy as both traditional and modern agriculture evolve and interact through time.

I focus on two important types of market failures. The first is the displacement of natural fibres by synthetic substitutes, resulting from competition in which the higher pollution costs associated with the latter are not internalized in world prices. The second is the erosion of crop genetic diversity, arising from the fact that markets do not reward farmers for their provision of this public good. Section 2 discusses the displacement of natural fibres by synthetics, illustrated by the competition between jute and polypropylene. Section 3 discusses the erosion of crop genetic diversity, illustrated by the impact of the North American Free Trade Agreement (NAFTA) on Mexican maize farmers. Finally, Section 4 considers some policy implications of the globalization of market failure.

2. Natural Fibres versus Synthetic Substitutes: The Case of Bangladeshi Jute

Since World War Two, renewable natural raw materials including cotton, jute, wool, sisal, and rubber have lost international markets to synthetic substitutes. Between 1963 and 1986 substitution by synthetics is estimated to have reduced the consumption of natural raw materials in the industrialized countries by almost half.[1] While the production and consumption of natural raw materials are by no means free of negative environmental impacts, the environmental costs associated with the production and consumption of synthetics typically are considerably larger.

The production of many natural raw materials is concentrated in developing countries (the 'South'), while the production of synthetic substitutes is concentrated in the industrialized countries (the 'North'). Hence the competition between natural raw materials and synthetics pits relatively clean producers in the South against relatively dirty producers in the North - the opposite of what is commonly assumed in discussions of the environmental impacts of North-South trade. The competition between jute and polypropylene is a case in point.

Jute is the second most important natural fiber in world trade after cotton. It has two main end-uses: burlap (also known as hessian) cloth, and carpet backing. In recent decades, jute consumption in the industrialized countries has contracted sharply in the face of competition from synthetics. Between 1970 and 1992 the annual jute imports of North America and western Europe plummeted from 1.0 million to 52,000 metric tons (Thigpen et al., 1987; IJO, 1993). Over the same period the real price of jute declined by roughly 70%.[2]

Bangladesh accounts for roughly 80% of world jute exports (FAO, 1994, p. 233). With a per capita income of \$220/year, Bangladesh ranks among the poorest countries in the world. Jute-related activities in agriculture, manufacturing, and trade affect the livelihoods of about 25 million Bangladeshis - roughly a quarter of the country's population (World Bank, 1992). Jute cultivation requires 50% more labor per hectare than rice, the principal alternative crop (Hye, 1993). The decline of the international jute market has therefore hit the incomes of some of the world's poorest people.

Polypropylene (PP), the main synthetic substitute for jute, is manufactured primarily in the North, although newly industrializing countries including Korea, China, and Brazil have now entered the industry. The United States is the world's largest producer, followed by Japan (United Nations, 1993 [update?]). PP producers include multinational firms such as Exxon, Hoechst, Hyundai Petrochemical, and Shell (Johnson, 1990).

The price advantage which permits PP to capture and retain the erstwhile markets for jute has been fairly modest. In 1990 the wholesale price ratio of jute to synthetic cloth in New York was 1.35; its average over the preceding decade was 1.42 (World Bank, 1992, p. 12). The incorporation of environmental costs into the prices of PP and jute could substantially alter this ratio.

The major environmental impacts of PP manufacture are from air pollution and energy consumption. Air pollutants generated in PP production include particulates, sulfur oxides, nitrogen oxides, carbon monoxide, and volatile organic compounds, total emissions of which are estimated at 127 kg per ton of PP (Tellus Institute, 1992, p. 9T-6). In addition, PP production emits smaller amounts of other toxic air pollutants, including ammonia, benzene, biphenyl, ethylbenzene, lead, methane, toluene, and xylene (ibid.).

Energy use in the production of PP cloth is estimated at 84 gigajoules/ton, at least six times the energy requirement for production of jute cloth (Braungart et al., 1992, p. 89). Carbon dioxide (CO_2) emissions in the PP production process are estimated at 3.7 tons per ton of fiber (ibid., p. 91). The long-term environmental effects of additions to atmospheric CO_2 derived from fossil carbon remain uncertain, but they include impacts on agriculture, forestry, biodiversity, and a rise in the sea level. By virtue of its low-lying deltaic terrain, Bangladesh is among the countries which stand to be most adversely affected by the latter (Pearce et al., 1995).

Polypropylene is not biodegradable. Its recycling potential is limited by the use of additives in the production process, and by mixture with other plastics in the collection process (leading to 'downcycling', re-use in products of inferior quality). At the end of the product life-cycle, PP disposal therefore incurs the costs of landfill storage, incineration, or litter. As much as six percent of PP cloth, by weight, is comprised of chemical additives, including stabilizers, coloring pigments, and flame retardants (Braungart et al., 1992, pp. 66-75). These contain heavy metals including chromium, copper, lead, nickel, and zinc, which also ultimately enter the waste stream (ibid., p. 66).

The environmental impacts of jute production are relatively modest by comparison. Jute growers use some chemical fertilizer, but not very intensively. Most apply no pesticides at all to the crop. The flooded fields in which jute ripens support diverse fish populations which play a critical role in the Bangladeshi diet (especially in the diets of the poor). Hence the fact that jute can be grown without reliance on pesticides is an important environmental plus.

Like all plants, jute absorbs CO_2 from the atmosphere when it grows and returns it when it decays. Atmospheric CO_2 is the most important of the greenhouse gases implicated in global warming. Jute thus provides a temporary environmental benefit: it sequesters carbon while in use. The transport and milling of the fibre, and the production and transport of inputs for the crop, generate some CO_2 emissions, but these amount to less than one-sixth of those generated in PP manufacture (Braungart et al., 1992, pp. 89-90).

The most serious negative environmental impacts of jute production probably arise in the process known as retting, when the jute stalks are submerged for 3-4 weeks in ponds where anaerobic microbial decomposition loosens the fibre in the inner bark. Retting causes transitory deterioration in water quality, including oxygen depletion, which can harm gill-breathing fish. The decomposition products are non-toxic, however, and these enhance soil fertility (Alam, 1993, p. 362). Retting releases methane, a potent greenhouse gas, in quantities which have yet to be measured; technologies to capture the methane for use as biogas fuel are still at an experimental stage.

Environmental impacts in the manufacturing stage of jute production arise primarily from energy consumption, the production of fibre wastes, and pollution from dyes. Energy use in jute production is estimated at up to 14 gigajoules/ton (Braungart et al., 1992, p. 89). Jute dust waste produced during processing amounts to roughly two percent of the fibre; some of this is burnt for energy (ibid., p. 35). Only a small fraction of jute fabrics -around 1-2 percent - is dyed, but effluent samples from jute dyeing processes show releases of heavy metals (ibid., pp. 34, 39).

Jute is biodegradable: at the end of the product life-cycle it decomposes in the soil. Residues from mineral oils used to soften the fibre may persist; conversion to the use of vegetable oils for this purpose would ensure rapid and complete biodegradation (Braungart et al., 1992, p. 38).

Several further positive side-effects of jute warrant mention. The edible leaves of the plant provide a cheap (often free) source of food for the poor, and the jute stalks, left after the fibre is stripped away, are a renewable source of cooking fuel and building material. The high labor intensity of jute cultivation can also be regarded a social benefit in a land where agricultural laborers are among the poorest of the world's poor.

To date there have been no comprehensive attempts to evaluate the full range of environmental impacts of jute and PP in economic terms. Elsewhere (Boyce, 1995), however, I have performed exploratory valuations for three major impacts: air pollution, carbon dioxide emissions, and solid waste disposal. Table 1 summarizes the results, showing how internalization of these costs would affect the relative price of jute and polypropylene.

[INSERT TABLE 1]

Air pollution has the greatest impact. The calculations in Table 1 include only the high-volume pollutants (particulates, sulfur oxides, nitrogen oxides, carbon monoxide, and volatile organics), and not the other toxic air pollutants released in smaller quantities in PP manufacture. The monetary values used to translate these emissions into costs are derived from the average values adopted by policy-making agencies in the United States as a whole; these are considerably below those used in densely populated and highly polluted regions such as southern California. Carbon dioxide emissions are here valued at $50 per ton of carbon.[3] No account is taken of the positive benefit provided by carbon sequestration in jute, on the grounds that in the long run this carbon returns to the atmosphere via biodegradation. Disposal costs at the end of the product life cycle are based on average tipping fees at landfills in the United States.[4]

A more complete analysis of the environmental costs of jute and PP would incorporate other impacts, including the effects of fertilizer runoff and retting on water quality in the case of jute; the impact of methane emissions during jute retting; the impacts of the heavy metals and other chemical additives used in the manufacturing processes of PP and jute; and the impact of other toxic air pollutants emitted in PP production. If, as seems likely, the most economically important of these are the costs associated with emissions of toxic pollutants - due to the use of chemical additives (the quantity of which is greater in PP), and due to the other air pollutants released in PP production - then internalization of these costs would further lower the jute/PP price ratio.

The price advantage which has enabled polypropylene to displace jute so dramatically in world markets therefore rests, in no small measure, on the failure of market prices to reflect environmental costs. Correction of this market failure would benefit not only the global environment, but also some of the world's poorest people, the jute growers and agricultural laborers of Bangladesh. The absence of corrective policies, on the other hand, benefits some of the world's largest corporations. The paucity of international attention to the environmental implications of the displacement of natural fibres by synthetics may reflect the power disparities between their producers.

3. Genetic Diversity: The Case of Mexican Maize

Some five millennia ago, the ancestors of the Mayan farmers in what are now Mexico and Guatemala achieved what must rank, in terms of its cumulative impact on human well-being, one of the great technological advances of history: the domestication of maize. Over time, the cultivation of maize spread among the indigenous peoples of the Americas, and with the arrival of the Europeans it would spread across the globe. Yet the crop's historic center of origin has remained its center of genetic diversity, in keeping with the association first postulated in the 1920s by the great Russian botanist N.I. Vavilov (1992).

No worldwide inventory of genetic diversity in maize (or other crops) exists. An indicator of its geographical distribution, however, can be derived from the holdings of the world's most comprehensive gene banks. The number of accessions from a given country, normalized for differences in acreage, provides a rough index of genetic diversity. Although not a perfect measure - gene-bank collections are uneven across countries, and some accessions are duplicates - this can provide a useful first approximation.

Table 2 presents data on accessions held at the world's premier maize research institute, the International Center for Maize and Wheat Improvement (CIMMYT) near Mexico City. Mexico accounts for about one-third of the gene bank's 13,000 holdings, and the country ranks highest on the diversity index. Guatemala, with only 2.5% the maize acreage of the United States, accounts for almost 14 times as many varieties.

[INSERT TABLE 2]

Scientists call the hilly, rainfed maize plots of south-central Mexico and Guatemala 'evolutionary gardens,' or 'gardens of chaos' (Wilkes, 1992). Here the maize plant continues to evolve under the full pressure of natural selection. As the climate changes, and as new strains of insect pests and plant diseases evolve, the interaction between nature and human purpose in these plots yields a stream of new varieties adapted to the new conditions. The campesino (peasant) farmers of the region thus not only maintain a vast stock of maize varieties, but also manage an ongoing flow of new varieties.

Maize is the number one crop in Mexico and the United States. In the U.S. it covers one-seventh of the arable land; in Mexico nearly one-third. With average yields of 7.4 metric tons per hectare (mt/ha), the U.S. produces roughly 200 million mt of maize annually on roughly 300,000 farms. Mexico, with average yields of 2.0 mt/ha, produces roughly 14 million mt on 2.7 million farms (see Table 3). Most U.S. maize is used as animal feed; most Mexican maize is consumed directly by humans.

[INSERT TABLE 3]

U.S. production techniques differ dramatically from those of the Mexican campesinos. Half a dozen varieties account for almost half of the U.S. maize acreage, and only a few hundred, many of them closely related, are available commercially. With so much area under so few varieties, the U.S. maize crop is highly vulnerable to insect and disease epidemics, as was dramatically illustrated when a leaf blight destroyed one-fifth of the nation's harvest in 1970 (Walsh, 1981). To keep ahead of rapidly evolving pests, plant breeders must release a constant stream of new varieties; for this reason, the average commercial lifespan of a maize varieties in the U.S. is only seven years (Duvick, 1984, p. 164). The ultimate raw material for this varietal relay race the maize germplasm originating from the evolutionary gardens of traditional agriculture.[5]

Ninety-six per cent of U.S. maize acreage is treated with herbicides, and about one-third with insecticides. Comparable data are not available for Mexico, but pesticide usage in maize farming there is considerably lower, particularly among small farmers.[6] The herbicides and insecticides applied to U.S. maize have resulted in widespread contamination of groundwater. A survey conducted by the U.S. Environmental Protection Agency (1990) found that atrazine, the most widely used herbicide in corn fields, was present in the water of one in every 60 community water systems and in one in 140 private wells nationwide.[7]

By the price standard of the market, the U.S. produces maize more 'efficiently' than Mexico. When NAFTA was being negotiated, U.S. maize cost about $110 per ton at the border, while in Mexico maize farmers received $240 per ton (Scott, 1992). The Mexican government has long restricted maize imports to protect domestic farmers. This protection is now being phased out over a 15-year period under the terms of NAFTA. The controversial nature of this move within Mexico is reflected by the fact that this is the slowest phase-out of protection for any commodity under the agreement.[8]

The price advantage of U.S. maize has four sources: (1) natural factors, notably better soils, more regular rainfall, and a killing frost which limits pest populations in the U.S. corn belt; (2) farm subsidies which reduce the U.S. market price; (3) the exclusion of environmental costs such as groundwater contamination from market prices, which is of greater importance in the U.S., where agrochemical use is more intensive, than in Mexico; and (4) the failure of market prices to value the maintenance of genetic diversity by Mexican maize farmers.

NAFTA will not completely eliminate maize production in Mexico. Large-scale Mexican growers on the best soils, many of whom use U.S.-style production techniques - including commercial hybrid varieties, irrigation, and intensive agrochemical applications - probably will be able to compete successfully. And very small-scale growers producing solely for their own household consumption might be less sensitive to the market price.[9]

NAFTA is likely to result in a substantial contraction of Mexico's maize acreage in the years ahead, however, as imported U.S. maize displaces domestic production. Much of the abandoned maize land will be converted into cattle pastures, requiring far less labor. Estimates of the number of Mexican maize farmers who will be displaced by U.S. imports vary widely. Relatively conservative estimates predict that hundreds of thousands of campesinos will migrate to Mexican cities (and perhaps to the U.S.) as a result. Upper-end predictions run as high as 15 million people, including family members - one-sixth of the Mexican population.[10]

The extent of campesino displacement could be mitigated by government measures to support 'modernization' of maize production and diversification to other crops (de Janvry, Sadoulet, and Gordillo de Anda, 1995). In a similar vein, Levy and van Wijnbergen (1995) advocate a program of public investment in land improvements, notably irrigation, to offset losses to Mexican maize farmers. Such support would represent a marked departure from the policy trends of recent years, which have seen cutbacks in marketing, credit, and technical assistance services for small farmers. Even if such policies were forthcoming, however, they would not necessarily arrest the erosion of genetic diversity in maize; indeed, they could accelerate it.

In the face of this prospect, only limited comfort can be drawn from the fact that seed samples of many Mexican maize varieties are stored at CIMMYT and several gene banks around the world. It would be difficult to overstate the value of these ex situ (off-site) collections. But they do not provide a satisfactory substitute for on-the-ground, in situ genetic diversity for three reasons.

First, the gene banks are not completely secure. Accidents happen. So do wars. The seeds must be stored under controlled temperature and humidity conditions, and periodically regenerated by planting to harvest new seed. The world's largest maize germplasm collection is at the Vavilov Institute in St. Petersburg; the second largest is in Belgrade (Plucknett et al., 1987, p. 120). Today the viability of the seeds in both collections is an open question. Even in relatively wealthy and stable countries such as the United States, plant breeders routinely lament the inadequate funding for seed collection maintenance from financially strapped governments. Irreplaceable material in gene banks has already been lost as a result of human error and mechanical failures. At CIMMYT, for example, maize collections from the 1940s were lost (Wade, 1974, p. 1187); 'back-up copies' of Mexican maize at the U.S. National Seed Storage Laboratory in Fort Collins, Colorado, were destroyed, too (Raeburn, 1995, pp. 62-63).

Second, many genetic attributes of crop varieties can be identified only by growing them in micro-habitats similar to those from which they originated. For example, the fact that a particular Mexican maize variety has a gene which enables it to withstand droughts at four-week intervals will not be apparent unless the plant is grown under those specific conditions. The alternative of expressing such genetic attributes in laboratory growth chambers is extremely costly.

Finally, even if it were possible to establish perfectly secure gene banks (which it is not), these could at best store only the existing stock of genetic diversity at any point in time. The ongoing process of evolution, which gave us this diversity and which continues to yield a flow of new varieties, cannot be stored in the bank; it can happen only in the field. Plant breeders can develop new crosses from the existing genetic stock, but they cannot replace the flow of new raw material from the evolutionary gardens.[11]

None of this implies that ex situ gene banks are unnecessary. On the contrary, the world needs more gene banks, better funding for them, and more investment in professional training for plant breeders whose knowledge is an essential complement to the gene banks (Wilkes, 1992). Modern plant breeding has played a central role in the rapid growth in world food output in the past 50 years. Moreover, as recent experiences in Nicaragua and Cambodia have shown, in situ biodiversity is also vulnerable to losses - due to wars, among other causes - and in these cases ex situ collections provide crucial back-up copies (Plucknett et al., 1987, p. 94). But while necessary, ex situ collections are not sufficient to sustain the genetic diversity on which long-term world food security ultimately rests. The gene banks are vital complements to in situ biodiversity, but not substitutes for it.

The competition between Mexican and U.S. maize thus entails both positive and negative externalities. The positive externality - the conservation and evolution of crop genetic diversity - is generated south of the border. The negative externalities arising from intensive agrochemical use are concentrated north of the border, though they also characterize 'modern' Mexican maize farming. Under free trade, the Mexican campesinos who generate positive externalities sell at prices which fail to internalize the full social benefit of their production, while U.S. producers sell at prices which fail to internalize the full social cost. The resulting double market failure not only undermines sustainable rural livelihoods in Mexico, but also jeopardizes the long-term sustainability of this key food crop worldwide.

4. Policy Implications

With the increasing integration of world markets - a phenomenon lately dubbed 'globalization', but one which has been gathering momentum for centuries - comes a corresponding need for international policy responses to market failures. Unilateral measures by individual governments can have only limited impacts on trade-driven market failures. To confront such problems as the erosion of crop genetic diversity, and the displacement of renewable natural raw materials by pollution-intensive synthetic substitutes, multilateral initiatives are necessary.

Such initiatives could advance the goal of sustainable agriculture, with 'sustainability' understood to mean maintaining the production of food and fibre sufficient to meet the needs of current and future generations worldwide. By this definition, sustainable agriculture implies neither the worldwide hegemony of 'modern' agriculture nor a romantic return to 'traditional' agriculture. Instead the world needs both high-productivity, low-diversity 'modern' farming and low-productivity, high-diversity 'traditional' farming (and intermediate technologies which combine the two). Productivity is vital for world food security in the short run, and diversity for world food security in the long run.

In the absence of corrective policies, the market rewards only short-run productivity as measured by price. One limitation of this myopic objective was noted by Schumpeter (1976, p. 83):

> A system - any system, economic or otherwise - that at every point in time fully utilizes its possibilities to the best advantage may yet in the long run be inferior to a system that does so at no point in time, because the latter's failure to do so may be a condition for the level of speed of long-run performance.

The role of crop genetic diversity in long-run agricultural performance illustrates Schumpeter's point.

In the discussions of trade and the environment at such multilateral fora as the United Nations Conference on Trade and Development and the World Trade Organisation, it is often assumed that negative externalities are more prevalent in the South, while in the North tougher regulations have led to a greater internalization of environmental costs.[12] The threat of 'environmental dumping' - exports at prices below the full cost of production, including the social costs of pollution - is therefore viewed primarily as a route by which Southern producers may win markets at the expense of their Northern competitors.

The examples discussed in this essay illustrate the opposite possibility: international trade can result in the displacement of relatively clean and sustainable Southern production by environmentally more costly and less sustainable Northern production. Indeed, if one reflects on the history of international commerce since the Industrial Revolution, it is arguable that this has been the main direction of environmental dumping.

Southern governments have been slow to call for policies which would help them to translate the comparative environmental advantages of their farmers into comparative economic advantages. In the case of jute, for example, the main response to the challenge from synthetics has been an effort to diversify into new end-uses for the natural fibre. Little serious attempt has been made to defend jute's position in its traditional end-use markets on the basis of its lower environmental costs. In the case of maize, the Mexican government is actually dismantling the quotas, tariffs, and price supports which provided some protection to Mexican farmers, reflecting both the government's embrace of neoliberal ideology and the declining political clout of the country's campesinos.

Yet the governments of the developing countries have an opportunity to move beyond a defensive posture in trade negotiations - in which they are cast as the international laggards in environmental protection - to a more positive stance as proponents of sustainable agriculture. They can draw support for this stance from the international environmental movement and, in particular, from citizens in the North who bear the environmental costs of pollution-intensive production. A genuine 'greening of world trade' could help to secure the livelihoods of some of the poorest people in the world today - the small farmers and agricultural laborers of developing countries - as well as the well-being of future generations worldwide.

Notes

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1.. Based on calculations by Maizels (1992, p. 189; 1995, p. 108), who reports that substitution reduced the developed market-economy countries' consumption of natural raw materials by 2.9%/yr from 1963-65 to 1971-73, 0.9%/yr from 1971-73 to 1978-80, and 1.2%/yr from 1978-80 to 1984-86.

2.. The nominal price of raw jute was $299/ton in 1972 (World Bank, 1992, p. 12) and $277/ton in 1992/93 (IJO, 1993, p. 4). The real price trend is here calculated using the US producer price index as a deflator.

3.. Dixon and Mason (1994) summarize various damage cost estimates, ranging from $5.3-$50/ton of carbon in the decade 1991-2000 and rising to $6.8-$120/ton in the following decade. Pearce et al. (1995, p. 68) report similar estimates.

4.. This can be regarded as a lower-bound estimate insofar as (i) landfill costs are higher in more densely populated countries; (ii) landfills are publicly subsidized; (iii) landfills generate negative externalities; and/or (iv) the improper disposal of PP is common and this generates higher environmental costs than disposal in landfills.

5.. Plant breeders rely heavily on selected 'elite' breeding lines for the production of new hybrids. The traditional 'landraces' from the farmers' fields provided the original genetic material in these lines, and landraces continue to be used as the main source for introducing greater diversity into them. For discussion, see Duvick (1984).

6.. A 1994 survey of ejido maize producers in Mexico found that only 35% used herbicides, insecticides, or fungicides. For small farmers (cultivating less than 2 hectares), medium farmers (2-10 hectares), and large farmers (more than 10 hectares), the shares using any of these pesticides were 15%, 34%, and 51%, respectively (calculated from data reported by Secretaría de Reforma Agraria, 1995, pp. 5.17 and 5.19).

7.. In 1994, citing concerns about human cancer risks and effects on aquatic organisms, the U.S. Environmental Protection Agency (1994) launched a Special Review of atrazine and two closely related herbicides.

8.. Mexican resistance to U.S. corn imports was one of the most difficult issues in the negotiation of NAFTA's agriculture chapter. In return for the 15-year phase-out, Mexico agreed to allow the immediate duty-free import of up to 2 million mt of U.S. corn per year (Thurston and Negrete, 1992).

9.. De Janvry, Sadoulet and Gordillo de Anda (1995) cite survey data which indicate that roughly half of ejido maize growers do not produce market surpluses, and conclude that neglect of this fact has caused other studies to overstate the labor displacement likely to result from NAFTA. Even among these growers, however, some households may shift to cheap imported corn to meet consumption needs, resulting in further contraction of maize acreage.

10.. Estimates prepared for the World Bank indicated that in the first five years of NAFTA, between 145,000 and 300,000 farmers could abandon their land (DePalma, 1993). José Luis Calva (1992, p. 35) of the National Autonomous University of Mexico predicted that total rural out-migration, including family members, could reach 15 million people. For other estimates, see Levy and Wijnbergen (1991), Robinson et al. (1991), and Harvey and Marblestone (1993).

11.. For further discussion of the need and potential for in situ conservation of crop genetic resources, see Prescott-Allen and Prescott-Allen (1982), Altieri and Merrick (1987), and Brush (1992, 1995).

12.. Some authors (for example, Grossman and Krueger, 1995) find evidence of an 'environmental Kuznets curve', whereby total pollution at first rises and then declines as per capita income grows. Torras and Boyce (1998) offer evidence that changes in the distribution of power, rather than income alone, explain declines in pollution.

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Table 1:

Effect of Internalization of Environmental Costs on Relative Price of Jute and Polypropylene

	Prices (\$/000 yd^2)		Price ratio
	Jute	PP	(jute/PP)
Market price (1990)	240	178	1.35
Prices internalizing PP air pollution costs only:			
	240	224	1.07
Prices internalizing CO_2 costs only:			
	242	182	1.33
Prices internalizing non-biodegradable disposal costs only:			
	240	180	1.33
Prices internalizing all of the above:			
	242	230	1.05

Source: Boyce (1995).

Table 2: Maize Diversity in Selected Countries

Country	Number of accessions at CIMMYT	Maize acreage (1992-94 average, 000 ha)	Genetic diversity index*
Mexico	4,220	7,536	289.8
Brazil	2,508	12,992	146.3
Guatemala	590	709	82.4
Argentina	152	2,430	14.7
United States	43	28,047	2.0
China	25	20,821	1.3
India	4	6,052	0.3
Philippines	3	3,240	0.3
Nigeria	1	1,567	0.1

Source: Boyce (1996).

* Genetic diversity index = $V/A^{0.3}$, where V = number of accessions and A = acreage.

Table 3: Corn Agriculture in Mexico and the United States.

	Mexico	United States
Production:		
Area (million hectares)	7.3	27.1
Share in total cropland (%)	31.7	14.4
Yield (metric tons/ha)	2.0	7.4
Output (million mt)	14.6	201.5
Number of farms (million)	2.7	0.3
Input use:		
Area fertilized (%)	70	97
Area under hybrids (%)	33	100
Area irrigated (%)	15	80
Area treated with herbicides (%)	NA	96
Area treated with insecticides (%)	NA	29
Tractors/farm worker	0.02	1.5
Varietal diversity:		
Number of varieties available	5000	454
Share of top six varieties (% of area)	NA	43

NA = not available.

Source: Boyce (1996).