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International Trade, Transfrontier Pollution, and Environmental Cooperation: A Case Study of the Mexican-American Border Region

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ABSTRACT

Although some theoretical work has been conducted on the interdependence of international trade and the transfrontier diffusion of pollution, empirical analyses of the potential importance of such interdependence have not been conducted. This paper attempts to do so in the context of the Mexican-American Border Region. As will be demonstrated, the characteristics of production in the region and the specific geographical context make the interdependence of these two processes increasingly significant. As such, it must be taken into account in any binational cooperative attempt to address the problems of environmental degradation in the region.

INTRODUCTION

Although some theoretical work has been conducted on the interdependence of international trade and the transfrontier diffusion of pollution, empirical analyses of the potential importance of such interdependence have not been conducted.[1] This paper attempts to undertake such an analysis in the context of the Mexican-American Border Region. As will be demonstrated, both the characteristics of production in the region and the specific geographical context make the interdependence of these two processes increasingly significant. Moreover, this interdependence must be recognized and taken into account in any binational attempt to address the problems of environmental degradation in the region.[2] Section I is a brief discussion of the potential

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1. For discussions of the theoretical interdependence of the two phenomena, see John D. Merrifield, *The Impact of Selected Abatement Strategies on Transnational Pollution, the Terms of Trade, and Factor Rewards: A General Equilibrium Approach*, 15 J. ENVTL. ECON. & MGMT. 259 (1988); Michael Rauscher, *Foreign Trade and the Environment*, *in* ENVIRONMENTAL SCARCITY: THE INTERNATIONAL DIMENSION 17-31 (Horst Siebert ed., 1991).

2. It should be noted, however, that although the characteristics of the border region (i.e. the prevalence of international production-sharing arrangements and the close integration

importance of the role of the environment as a determinant of trade and investment patterns and the means by which such tendencies are affected by transfrontier pollution. Section II is concerned with the relative extent and cost effects of transfrontier pollution in the region. Section III outlines the theory of binational environmental cooperation. Finally, Section IV discusses the nature of binational agreements in the region and the means by which such agreements may contribute to continued environmental degradation.

I. INTERNATIONAL TRADE AND THE ENVIRONMENT

According to classical trade theory, a country will specialize in the production and export of a commodity which is relatively more intensive in the use of factors of production in which it possesses a relative abundance. The theory of environmentally-determined comparative advantage is merely an extension of this theory in the sense that the environment is introduced as a factor of production, analogous to the classical factors of production, labour and capital. In what sense might the environment be considered a factor of production? On the one hand, natural resources could be used directly either in processed form or as inputs in the production of other goods. For example, the exploitation of non-renewable natural resources (minerals, fossil fuels, etc...) has a direct effect on the available stock of such resources for future use. In addition, a harvest rate of renewable natural resources (forests, marine species, etc...) which exceeds the resource's natural growth rate will also reduce the stock of natural capital available for future use. Less obviously, but analogously, the environment can be considered a factor of production through the use of its capacity to absorb and assimilate the waste arising from production processes. To the extent that a body of water is able to render a limited concentration of industrial pollutants benign, for example, the production process that generates the wastewater flow uses the river's assimilative capacity. A similar point can be made with respect to climatic patterns which disperse air pollutants sufficiently to obviate adverse environmental effects. However, as is the case with the use of renewable resources as inputs in production, this capacity can be

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of transborder ecological systems) are likely to result in particularly acute relations of international economic and environmental interdependence, the findings of this study are by no means specific to this case study. As long as there are close relations of economic interdependence in pollution-intensive sectors and there are significant disjunctures between such production and its effects on the domestic environment the theoretical and empirical findings of this study have a relevance beyond the border region. And since production processes are increasingly international in nature and there is no reason to expect the geographic extent of political jurisdictions to be the same as the geographic extent of environmental systems, such relevance is likely to be widespread.

exceeded such that there is a permanent loss in the capacity of the environmental medium to process future streams of waste. In both cases there is a negative relationship between the use of the environment as a factor of production and the stock of natural capital. Irrespective whether a firm exploits natural resources or produces pollution-intensive goods, the firm's output embodies significant amounts of natural capital. In this sense, a factory that pollutes a body of water, destroying fish stocks, is no different from a fishery which over-exploits the species, rendering it extinct. The manufactures produced by the factory embody the river's natural capital no less than the fishery's output.

Although the environment can, in some sense, be considered a factor of production, analogous to physical capital and labour, it possesses special characteristics which discourage scarcity effects from being fully reflected in price changes. Why is this case? On the one hand, the reason why the environment is not priced appropriately is partly a result of the common property nature of rights to many environmental resources used in production processes. Since the environmental endowment from which natural capital is drawn is often held in common, there may not be a negative relationship between increased exploitation and the price of the resource since a property regime which can transmit the appropriate price signals does not exist. In addition, the environment possesses economic value as a source of environmental quality and not only as a factor of production. The subjective valuation that a society places on environmental quality might be the result of value attached to the environment for recreational purposes (consumptive use value), aesthetic reasons (non-consumptive use value), or even merely due to awareness of its very being (existence value).[3] However, in its capacity as a source of environmental quality the environment may be considered a pure public good in the sense that individual consumption does not result in increased scarcity. As such, the cost associated with the use of the environment as a source of environmental quality and natural capital is not expressed fully in the market since increased use may not increase prices. Instead, the economic cost to the firm usually manifests itself, at least in part, through regulation related to the preservation of natural capital and environmental quality.

The price associated with the use of the environment as a factor of production, therefore, is a reflection of environmental endowments, social preferences for the environment, and the extent to which the state reflects such endowments and preferences in appropriate regulations. As

3. For more on the valuation of the environment, see Maynard M. Hufschmidt et al., ENVIRONMENT, NATURAL SYSTEMS AND DEVELOPMENT: AN ECONOMIC VALUATION GUIDE (1983) and Per-Olov Johansson, THE ECONOMIC THEORY AND MEASUREMENT OF ENVIRONMENTAL BENEFITS (1987).

such, there may be significant differences across countries in the price attached to the use of environment as a factor of production. These differences should affect trade and investment patterns in the same way as differences in labour costs or capital costs. A number of empirical studies have been conducted in the past in order to determine the relative importance of such effects.[4] For the most part such studies have not uncovered significant evidence of environmentally-determined territorial restructuring of production. In addition, two studies of the Mexican-American trade relationship have been conducted. In an *ex ante* study Low (1992), analyzed the effects of a pollution abatement cost equalization tax on Mexican exports to the United States. Under special assumptions (infinitely elastic export supply elasticities and full abatement cost equalization), a two percent contraction in export earnings was estimated.[5] In an *ex post*, study Grossman and Krueger undertook a cross-section analysis of the determinants of manufactured imports from Mexico into the United States. Only two of the six specifications had statistically significant results for the "environment" variable (American abatement costs), but they were of the unexpected (negative) sign.[6]

The empirical evidence of environmentally-determined trade effects in the region, therefore, is quite limited. Part of the reason can certainly be attributed to the fact that the cross-sectional methodology used implicitly assumes that sectors with the heaviest pollution abatement and control expenditures will be those sectors which are most adversely affected by environmental regulations in terms of competitive displacement. However, since most such sectors (chemicals, basic metals, processed metals, pulp and paper) possess structural characteristics (i.e. demand and supply elasticities, input-output linkages, et cetera) which discourage territorial restructuring of production, cross-sectional studies and studies which concentrate on the most pollution-intensive sectors may not be an appropriate means of testing such hypotheses. Moreover, such studies tend to emphasize regulatory costs of production associated with the use of the environment at the expense of non-regulatory

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4. *See* James A. Tobey, *The Effects of Domestic Environmental Policies on Patterns of World Trade*, 43 KYKLOS 191 (1990); T. J. Bartik, *The Effects of Environmental Regulation on Business Location in the United States*, 19 GROWTH & CHANGE 22 (1988); Virginia D. McConnell & Robert M. Schwab, *The Impact of Environmental Regulation on Industry Location Decisions: The Motor Vehicle Industry*, 66 LAND ECON. 67 (1990); R. E. Lucas et al., Economic Development, Environmental Regulation, and the International Migration of Toxic Industrial Pollution: 1960-1988 (1992) (prepared as background paper for the *World Development Report 1992*).

5. P. Low, *Trade Measures and Environmental Quality: The Implications for Mexico's Exports*, *in* INTERNATIONAL TRADE AND THE ENVIRONMENT 105-20 (World Bank Discussion Paper No. 159).

6. G. M. Grossman & A. B. Krueger, *Environmental Impacts of a North American Free Trade Agreement* (April 1992) (Centre for Economic Policy Research, Discussion Paper No. 644).

environment-related production costs. Among other costs, user charges associated with the use of environment-related public infrastructure, the potential magnitude of significant liability settlements arising from environmental damages, and restrictions related to urban planning regimes and land use controls may be of some significance. Such factors are particularly important for the Border Region since *ex post* liability regimes, public infrastructure finance mechanisms, and land use control institutions and objectives are so different on the two sides of the border.

There is, however, a more fundamental issue which must be raised. The preceding discussion implicitly assumes that goods which embody natural capital are mobile across countries through trade, but that the environment itself is not mobile across countries. Thus, it is assumed that the relationship between the use of domestic environmental factors of production, the domestic endowment of such resources, and the cost associated with their use is determined locally. However, in the presence of transfrontier pollution such an assumption is invalid. There is a disjuncture between domestic production of pollution-intensive goods and changes in the environmental endowment. Therefore, if rates of diffusion of transfrontier pollution and/or differences in cost sensitivity of environmental regimes to increased scarcity are significant, classic comparative advantage effects arising from changes in resources may be undermined or even reversed. Equilibrium may only be attained once significant environmental degradation has taken place. The importance of such effects are increased the greater the degree of economic and environmental interdependence. As such, the United States-Mexico Border Region, which is characterized by a preponderance of vertically-integrated production-sharing arrangements[7] and close ecological interdependence is particularly vulnerable.

II. THE TRANSFRONTIER DIFFUSION OF POLLUTION IN THE BORDER REGION

The discussion above implies that the diffusion of transfrontier pollution may have significant effects on the territorial pattern of production, particularly for sectors wherein comparative advantage is determined, at least in part, by environmental factors. The next question which must be addressed is whether or not there is significant evidence

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7. *See* Jorge Bustamente, *Maquiladoras: A New Face of International Capitalism on Mexico's Northern Frontier, in* WOMEN, MEN AND THE INTERNATIONAL DIVISION OF LABOUR 224-56 (June Nash & Maria Patricia Fernandez-Kelly eds., 1983); Leslie Sklair, ASSEMBLING FOR DEVELOPMENT: THE MAQUILADORA INDUSTRY IN MEXICO AND THE UNITED STATES (1989); LAS MAQUILADORAS: AJUSTE ESTRUCTURAL Y DESARROLLO REGIONAL (B. Gonzalez-Arechiga & R. Barajas Escamilla eds., 1989).

of such transfrontier diffusion pollution in the United States-Mexico Border Region. As such, a brief discussion of the region's topography, hydrography, and meteorology is required before proceeding to a more detailed discussion of the primary media of transfrontier pollution diffusion.[8]

The climate of the entire border region is very dry, with a gradual progression from semiarid steppe near the Gulf of Mexico in the East to the arid Sonora Desert in the West. For the most part prevailing winds tend to blow from west to east, however this depends upon specific regional characteristics. Topographically, the border itself is artificial, intersected by a series of parallel discontinuous mountain chains running north-south (the Sierra Madre Oriental and Occidental, the Sangre de Cristo, the San Juan Mountains, the San Gabriel Mountains, et cetera). Hydrologically, the frontier is also artificial, with drainage basins criss-crossing much of the border. The Rio Grande does, however, form the border for 1,244 miles of its length. The other major river, the Colorado, runs from north to south and empties into the Baja de California, while a number of smaller rivers—the San Pedro, the Tía Juana—run south to north. Finally, there are a number of aquifers crossing the international border, particularly in the central region.[9]

Transfrontier Diffusion of Air Pollution

Transfrontier diffusion of air pollution in the border region has been of significant concern for some time. In particular, area sources of emissions include agricultural production in the more arid regions which tend to generate particulates, the use of vehicles which generate carbon monoxide, nitrous oxides and hydrocarbons, the existence of unpaved roads which result in particulate emissions, and residential burning which generates carbon monoxide and particulate matter. Point sources are also numerous. For instance, sulphur emissions from copper smelters in sulphur dioxide the so-called binational "Grey Triangle" of Douglas (Arizona), Cananea (Sonora), and Nacozari (Sonora) were a source of much tension in the past. The American plant at Douglas is the oldest in the United States, while the two plants in Mexico are also significant sources of binational pollution. Indeed, Cochise County, where Douglas is located just over the border from the two Sonora plants, exceeded the

8. The discussion is necessarily cursory. A full discussion would, of course, require a comprehensive materials balance analysis of economy-environment interactions in the Border Region.

9. For a discussion of the geography of the Border Region, see Section II of BORDERLANDS SOURCEBOOK: A GUIDE TO THE LITERATURE ON NORTHERN MEXICO AND THE AMERICAN SOUTHWEST (Ellwyn R. Stoddard et al. eds., 1983).

PM-10 NAAQS, one of the few rural counties in the region to do so. Other incidences of point source transfrontier air pollution diffusion have been noted in the Lower Rio Grande Valley, Douglas-Agua Prieta, Nogales-Nogales, and Calexico-Mexicali. However, the two major transborder conurbations - Tijuana-San Diego and Ciudad Juarez-El Paso - have been of particular concern since in both cases two major industrialized cities share the same air basins.[10]

In the case of Ciudad Juarez-El Paso the two cities are entirely interdependent with respect to air quality, being located in a valley running along the Rio Grande with mountains to the north and south. Although air circulation within the basin is restricted, air moves back and forth across the border a number of times during the course of a given day. With respect to pollution, the effects of environmental interdependence are exacerbated by the frequency of atmospheric inversions in the air shed due to topographical and meteorological conditions. One commentator described the air shed as "one of the most polluted on the continent". Not surprisingly, pollutants emitted from either side of the border have tended to reflect the respective stages of development. In the past, emissions of particulate matter and carbon monoxide from residential burning of scraps, cardboard and even tires have been a source of transfrontier pollution emissions from Juarez. In addition, particulate matter from unpaved roads and cement plants have been problematic. In 1974 the mean of particulate concentrations in El Paso was. 139 $\mu g/m^3$, while the figure for Juarez was 342 $\mu g/m^3$. While American emissions have dropped drastically, PM-10 levels in downtown Juarez continue to exceed 300 $\mu g/m^3$, compared to a 24-hour EPA NAAQS of 150.[11]

More recently, many of the problems in Juarez related to vehicle emissions. It has been asserted that over the course of a ten-year period,

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10. *See* U.S. ENVIRONMENTAL PROTECTION AGENCY, SUMMARY: ENVIRONMENTAL PLAN FOR THE MEXICAN-UNITED STATES BORDER AREA, FIRST STAGE 1992-1994 (1992); C. Richard Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, 1 J. BORDERLANDS STUDIES 49 (1986); Stephen P. Mumme, *Complex Interdependence and Hazardous Waste Management along the U.S.-Mexico Border*, *in* DIMENSIONS OF HAZARDOUS WASTE POLITICS AND POLICY (Charles F. Davis & James P. Lester eds., 1988); U.S. OFFICE OF THE U.S. TRADE REPRESENTATIVE (USOTR), REVIEW OF UNITED STATES-MEXICO ENVIRONMENTAL ISSUES (1992); Howard G. Applegate, *Transnational Air Pollution*, *in* ECOLOGY AND DEVELOPMENT OF THE BORDER REGION 127-37 (Stanley R. Ross ed., 1983).

11. *See* C. Richard Bath & Victoria Rodriguez, *Comparative and Binational Air Pollution Policy in El Paso, Texas and Ciudad Juarez, Chihuahua*, 6 BORDERLANDS 171 (1983); Applegate, *supra* note 10; C. Richard Bath, *Health and Environmental Problems: The Role of the Border in El Paso-Ciudad Juarez Coordination*, 24 J. INTER-AM. STUD. 375 (1982); C. Richard Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, 1 J. BORDERLAND STUD. 49 (1986); USOTR, *supra* note 10.

although El Paso has been, and continues to be, an EPA non-attainment zone for carbon monoxide, El Paso emissions in themselves have never been sufficient to be solely responsible such a designation: Vehicle emissions from both cities have been required. With the introduction of a vehicle emissions inspection programme in 1991 significant tampering with air pollution devices on the vehicle fleet was revealed. Moreover, the average age of the vehicle fleet in Juarez is approximately double that of El Paso. Ironically, the border itself is a significant contributor to such emissions due to queues at border crossings. In addition, industrial sources have also been a subject of some binational concern. PM-10 levels are particularly high in regions where there are significant amounts of heavy industry in Juarez. More significantly, ozone levels in the region have also been a source of concern. As with TSP and carbon monoxide, El Paso is a non-attainment area for ozone with levels of .17 ppm in 1989 compared to an EPA standard of .12. The rapid growth in VOC-intensive production processes in Ciudad Juarez (electronics in particular, but also furniture and automotive sectors) has exacerbated the situation. Even though El Paso VOC emissions fell by 25 percent between 1980 and 1985, ozone levels continued to rise. Conversely, emissions from the American side of the border have also been a subject of concern. In particular, the Asarco copper smelter in northwest El Paso and the nearby Chevron oil refinery have been significant sources of binational pollution in the air shed, generating large amounts of sulphur, nitrogen, arsenic, lead, zinc and cadmium.[12]

Like Ciudad Juarez-El Paso, Tijuana-San Diego share a common airshed bisected by the international border and bounded by the ocean to the west, the Santa Ana mountains to the north, the Laguna mountains to the east and the Sierra Juarez to the south. There is a daily exchange of air as winds blow from the west to east in the afternoon and evening when air pressure is higher over the ocean and southeast to northwest overnight when the land surface begins to cool. The circular flow covers an area of 120 kilometres from north to south and 70 kilometres from west to east, but is more pronounced in the summer months. In addition, like Ciudad Juarez-El Paso the basin also tends to suffer from atmospheric inversions in the winter months, exacerbating air pollution problems. Therefore, there is considerable diffusion of air pollution between the two cities. In the case of Tijuana-San Diego, however, the air pollution

12. Bath & Rodriguez, *supra* note 11; Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, *supra* note 11; Bath, *Health and Environmental Problems*, *supra* note 11; USOTR, *supra* note 10; Howard G. Applegate & Conrado Díaz Q., *Vehicles and Air Pollution in El Paso-Ciudad Juarez*, *in* ECOLOGÍA Y FRONTERA 132-36 (Juan Alvaréz & Victor Castillo eds., 1986); James W. Yarborough et al., The El Paso-Ciudad Juarez Air Quality Study (paper presented at the Air and Waste Management Association National Meeting, June, 1990).

problems are of a somewhat different nature since topographical and meteorological conditions tend to favour San Diego relative to Tijuana. Finally, as is the case with Ciudad Juarez-El Paso, the emissions from either side have tended to reflect levels of development in the past but are becoming increasingly similar.[13]

Comprehensive monitoring of Tijuana emissions is only just beginning. However, monitoring of Tijuana particulate concentrations conducted by the SDAPCD and the SMA in 1980-81 revealed that particulate levels in the city exceeded the EPA 24-hour standard (260 $\mu g/m^3$) in 79 percent of the samples taken. Due to meteorological conditions these levels are only likely to affect the southwest part of San Diego County. In addition to particulate matter emissions from unpaved roads and residential waste incineration, other sources of concern include carbon monoxide, nitrous oxide and hydrocarbon emissions from vehicles,[14] sulfur dioxide, nitrous oxide and particulate matter emissions from the *Termoeléctrica* electricity generating station on the coast at Rosario, and toxic and sulfur dioxide emissions from brick plants in the Mesa de Otay. More recently, however, an increasing amount of concern has revolved around the more general pattern of industrialization and the lack of appropriate controls.[15]

San Diego is a non-attainment zone for both carbon monoxide (10 ppm relative to the NAAQS of 9 ppm) and ozone (.19 ppm relative to .12). In 1990 the city exceeded the state ozone standard (.09 ppm) on 139 separate occasions, and the less stringent federal standard on 39 occasions. Air pollutant transport from San Diego to Tijuana is probably significant, particularly in the summer months when there is a stronger north-south component in the local air circulation patterns. Diffusion, however, is somewhat difficult to monitor since photochemical smog formation may take as long as six hours.[16] In addition, both cities tend

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13. Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, *supra* note 11; Enrique Jauregui, Air Pollutant Transport in the Tijuana-San Diego Air Basin, (Jan. 1980) (paper presented at the Second Conference on Coastal Meteorology of the American Meteorological Society; Hal W. Brown et al., An Example of Border Cooperation: The Tijuana-San Diego Air Quality Project, (April 1982) (paper presented at the Annual Meeting of the United States-Mexico Border Health Association).

14. 85% of vehicles in Tijuana do not have emissions controls. *See* Juan Alvarez Lopez, *Contaminacion Atmosferica: Cuenca Tijuana-San Diego*, *in* ECOLOGÍA Y FRONTERA 137-56 (Juan Alvarez Lopez & Victor M. Castilla eds., 1986).

15. Memorandum from Hal W. Brown & Virginia Bigler-Engler, An Example of International Cooperation: The Tijuana-San Diego Air Quality Project (1984); Joseph Nalven, *Social and Cultural Aspects of Transborder Environmental Cooperation*, 2 MEXICAN STUD. 107 (19-86); Joseph Nalven, *Transboundary Environmental Problem Solving: Social Processes, Cultural Perception*, 26 NAT. RESOURCES J. 793 (1986); Alvarez Lopez, *supra* note 14; USOTR, *supra* note 10; EPA, *supra* note 10.

16. The chief meteorologist at the SDAPCD believes that much of the ozone arising from

to suffer from Los Angeles emissions—in particular hydrocarbons, carbon monoxide and nitrous oxides—when the so-called Santa Ana conditions are weak and there is significant pollutant transport out over the ocean and south into the air basin. Ozone levels in San Diego-Tijuana remained more or less constant throughout the 1980's despite the considerable drop in local VOC emissions. Overall, Los Angeles VOC emissions were responsible for well over two-thirds of San Diego violations of EPA ozone standards in 1991.[17]

Transfrontier Diffusion of Water Pollution

Although many of the binational problems associated with surface water questions in the border region have been related to water quantity, water quality issues have also been a source of some concern. Responsibility, however, is somewhat easier to determine in the case of surface water pollution relative to air pollution since it is easier to trace the diffusion of pollutants. Perhaps, the single issue to which the most attention has been paid in the past is related to the salinity of the Colorado River when it crosses the international border and enters Mexico. At its headwaters, the Colorado has a salinity concentration of approximately 50 ppm, but dissolved solids from irrigation projects and natural sources results in a level of 870 ppm by the time it reaches the border. This is exacerbated by diversion projects which reduce the flow of water, increasing concentrations of inorganic salts. Other sources of tension have included copper tailings in the San Pedro River from the smelter in Cananea, Sonora. These wastes affected agriculture and wildlife downstream in Arizona until the late 1970s, when a diversionary canal was created to reduce degradation. In addition, the 1979 *Ixtoc* oil-rig spill in the Gulf of Mexico which caused damage to Texas beaches created considerable binational concern. Without question, however, the most significant binational water quality problems in the border region are related to effluent in the major twin-cities. Although there is significant diffusion from north to south - only 1 percent of the *colonias* which border the Rio Grande in Texas have sewer connections and until the late 1980s Las Cruces, New Mexico dumped untreated sewage

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San Diego hydrocarbon and VOC emission manifests itself in the desert southeast of Tecate. (Personal communication from Hal Brown, SDAPCD.)

17. San Diego Air Pollution Control District, Air Quality Scorecard (1991) (SDAPDC memo); USOTR, *supra* note 10; Jauregui, *supra* note 13; C. Richard Bath, *United States-Mexico Experience in Managing Transboundary Air Resources: Problems, Prospects, and Recommendations for the Future*, 22 NAT. RESOURCES J. 1147 (1982).

directly into the Rio Grande most of the diffusion is from south to north.[18] Four particularly acute cases will be discussed.

The New River, which passes through Mexicali before crossing the border at Calexico, California and flowing north through the Imperial Valley and emptying into the Salton Sea, has been described as the most polluted river in North America. Most of the waste originates in Mexicali, with large volumes of untreated municipal sewage and industrial waste discharged directly into the New River and indirectly into collector system, being the prime culprits. The sewage treatment system in Mexicali consists of three anaerobic ponds and 10 aereated ponds. Designed to treat 750 litres per second, it was receiving 1,200 to 1,300 in 1989. Indeed, over 100 toxics have been detected in the river at the border. Significantly, 13 of the 16 VOCs most commonly used in the electronics sector were detected in the river in 1982. Water samples taken by the Regional Water Quality Board in 1990 continued to show high levels of many industrial chemicals. In addition, Nuevo Laredo, Tamaulipas across the river from Laredo, Texas disgorges 24 mgd of untreated sewage into the Rio Grande, resulting in significant degradation. While samples taken upstream have revealed concentrations in the order of 200 fecal bacteria per 100 mls of water, downstream sample concentrations have been as high as 22,000. Conversely, Laredo has two sewage treatment plants, both in compliance with state and federal standards. Given the industrial base of Nuevo Laredo's economy, industrial pollutant concentrations arising from direct and indirect discharges are probably also high. Such emissions affect both the quality of water used in Laredo and other cities downstream as well as the estuaries and coastal zones in the Lower Rio Grande as it empties into the Gulf of Mexico.[19]

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18. Allen V. Kneese, *Environmental Stress and Political Conflicts: Salinity in the Colorado River*, 4 TRANSBOUNDARY RESOURCES REP. 1 (1990); Niles Hansen, *Transboundary Environmental Issues in the U.S-Mexico Borderland*, *in* INTEGRATED PHYSICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL PLANNING 167-89 (Yusuf J. Ahmad & Frank G. Mueller eds., 1982); Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, *supra* note 11; Mumme, *supra* note 10; USOTR, *supra* note 10.

19. Hansen, *supra* note 18; USOTR, *supra* note 10; NATIONAL TOXICS CAMPAIGN FUND (NTCF), BORDER TROUBLE: RIVERS IN PERIL (1992); International Boundary Waters Commission (IBWC), Tijuana Sanitation (1989) (IBWC Memo); Richard Alm & Bruce Tomaso, *Dirty Water: U.S. Must Live with Border Pollution or Aid Mexico's Cleanup*, 4 TRANSBOUNDARY RESOURCES REP. 3 (1990); Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, *supra* note 11; Charles Metzner, *Water Quality Issues of the San Diego-Tijuana Border Region*, 5 SAN DIEGO ST. U. BORDER ISSUES SERIES (1989); Diane M. Perry et al., *Binational Management of Hazardous Waste: The Maquiladora Industry at the United States-Mexico Border*, 14 ENVTL. MGMT. 441 (1990).

The situation in Ciudad Juarez-El Paso is equally dire. Juarez, a city of over 1.5 million, does not have any treatment facilities whatsoever. Unfortunately, little data is available on the quality of the Rio Grande downstream, however, bacterial and chemical pollution is thought to be high and Juarez officials have reported traces of various heavy metals in the collector system. In addition, a National Toxics Campaign Fund study of effluent concentrations at various industrial sites in Juarez found significant evidence of industrial pollution. And finally, the situation in Tijuana-San Diego is, perhaps, the worst of any of the twin cities. In terms of transborder effects it is important to remember that approximately 13 mgd of Tijuana's sewage is redirected to the treatment plant in San Diego via an emergency connection. In addition, an estimated 12 mgd of raw domestic and industrial waste (direct discharges from plants, runoff from residential neighborhoods, and leakages from collector systems) is carried by the Tijuana River across the border and into the estuary at the coast. And finally, effluent from the treatment plants themselves affect the coastline. Indeed, many of San Diego's beaches have been under quarantine since 1980.[20]

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20. *See* NTCF, *supra* note 19; USOTR, *supra* note 10; EPA, *supra* note 10. The relative contributions of sources on the two sides of the border to coastal degradation can be documented with samples of effluent waste at the respective treatment plants:

Comparison of Tijuana and San Diego Treatment Plant Effluent Waste Concentrations

Waste	*San Diego*	*Tijuana-Ensenada*
BOD	161	325
TSS	114	384
Oil and Grease	116	29.3
Silver	0.013	0.031
Cadmium	0.008	0.003
Chromium	0.043	0.291
Mercury	0.133	0.353
Selenium	-	0.040
Lead	0.136	0.275
Nickel	0.007	0.073
Copper	0.133	0.353

These would not, however, reflect percentage contributions to coastal degradation since San Diego volumes are larger than Tijuana volumes. Conversely, since the Punta Bundera outfall pipe is just off the beach while Point Loma's extends out into the ocean, a given volume and concentration of effluent from Tijuana will have more significant coastal effects. *See* Jose A. Segovia Zaval & Francisco Delgadillo Hinojosa, *Diagnostico y Alternativias de Reduccion y Control de la Disposicion de Aguas Residuales Sobre la Zona Costera Fronteriza, in* ECOLOGÍA Y FRONTERA 236-44 (Juan Alvarez Lopez & Victor M. Castilla eds., 1986).

Transfrontier Diffusion of Soil Pollution

The transfrontier diffusion of land-based pollution may appear to be anachronistic in that the environmental medium, soil, is not subject to diffusion in and of itself. However, there are two potential forms of land-based transfrontier diffusion of wastes, particularly hazardous wastes, in the border region. One form of diffusion of land-based pollution arises from the illegal export and import of hazardous wastes across the border. Most such diffusion is from north to south. For instance, in 1981, 160 drums of toxic waste, including 42 drums of polychlorinated biphenyls, were illegally dumped in Zacatecas. In another case in 1986 SEDUE officials discovered 10,000 gallons of heavy hydrocarbons and other toxic wastes at an illegal dump near Tecate. The wastes were traced to a hazardous waste management firm based in Long Beach, California. In addition, a large number of drums containing toxic wastes of unknown origin were found near Mexicali in 1992.[21]

There is also the potential for significant natural diffusion of land-based transfrontier pollution. The diffusion arises from the seepage of pollutants from landfill sites located in the recharge areas of cross-border aquifers and is particularly problematic in the border region since a number of aquifers (Hueco Bolson, Mesilla Bolson, and others) cross the border and can thus be contaminated from seepage on either side. These water quality issues are exacerbated by withdrawal rates which exceed the aquifer's recharge capacities, reducing water volumes and thus increasing pollutant concentrations. In such cases transfrontier diffusion would be in both directions. As testament to its potential significance, it has been estimated that there are 9,000 hazardous waste sites in the border region with 1,400 of these being uncontrolled. Discussions of hazardous waste treatment and disposal practices in Mexico indicate that there is significant potential for diffusion from south to north. Perhaps, more ominous is the potential for the two diffusion processes to work in concert. Thus, illegal exports of hazardous waste from the United States to Mexico which are then dumped in inappropriate sites may, paradoxically, result in greater environmental degradation of American natural resources than domestic treatment due to the potential for the contamination of transborder groundwater aquifers.[22]

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21. See Mumme, *supra* note 10; Roberto Sanchez, *Manejo transfronterizo de residuos tóxicos y peligrosos: Una amenaza para los países del tercer mundo*, FRONTERA NORTE 91-114 (1990).

22. Ludwik A. Teclaff, *Principles for Transboundary Groundwater Pollution Control*, 22 NAT. RESOURCES J. 1065 (1982); Albert E. Utton, *Transborder Water Quality: Institutional Alternatives*, *in* ENVIRONMENTAL HAZARDS AND BIORESOURCE MANAGEMENT IN THE UNITED STATES--MEXICO BORDERLANDS 49-61 (Paul Ganster & Hartmut Walter eds., 1990). *See* Mumme, *supra*

III. THE EFFECT OF TRANSFRONTIER POLLUTION ON PRODUCTION COSTS IN THE BORDER REGION

Therefore, there is significant evidence of transfrontier diffusion of pollution (in both directions) in the Border Region. Clearly this has significant *environmental* repercussions. In order for such diffusion to have significant *economic* effects, however, there must be a relationship between the diffusion of pollution across the border and the relative production costs on the two sides of the border. For instance, if both sides of the border possessed regulatory regimes whereby pollution permits were issued on the basis of ambient pollutant concentrations the diffusion of pollution would push down permit costs in the upstream country and increase their costs in the downstream country. However, such a regime is an ideal to which neither side of the border subscribes. Therefore, a more detailed empirical analysis of the cost effects of transfrontier pollution in the border region is required. In general, it would appear that whereas the transfrontier diffusion of pollution from north to south certainly affects the Mexican environment, it does not affect production costs for plants located in Mexico to the same extent that diffusion from the United States to Mexico affects production costs for plants located in the United States. Three cases will be analyzed: the financing of binational sewage facilities, expenses for water treatment facilities, and air pollution abatement costs.

Financing Binational Sewage Facilities

As noted above, much of the wastewater collected in Tijuana is conveyed via an emergency connection for treatment on the American side of the border at the San Diego treatment plant. In addition, in an attempt to reduce transfrontier flows of wastewater Inter-American Development Bank funds have been made available for the improvement of collection systems. Although there are financial arrangements whereby Mexico pays compensation to San Diego for the use of such facilities the extent to which it does so has not historically been in line with the actual costs incurred. It should be emphasized, however, that a partial subsidy must be considered legitimate since there is little basis upon which to expect Mexican authorities to treat waste bound for the United States to a higher degree than waste which remains in the country. According to the Office of the United States Trade Representative the quantity of such waste treated in the United States reached 13 million gpd by the

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note 10; Alm & Tomaso, *supra* note 19; L. KOCHAN, THE MAQUILADORAS AND TOXICS: THE HIDDEN COSTS OF PRODUCTION SOUTH OF THE BORDER (1990).

mid-1980s. Thus, cumulative payments of less than $2 million over the course of three decades have not covered the real cost for the use of the facility. For purposes of comparison it is interesting to note that a number of "participating agencies" within San Diego County also use the Point Loma treatment facilities but are not themselves directly responsible for financing the metropolitan sewage system. In the late 1980's such participating agencies paid approximately $15 million per year to the City of San Diego (City of San Diego Water Utilities Department 1988), while average wastewater flows from participating agencies was 50 million gpd (City of San Diego Water Utilities Department 1992). Thus, at equivalent rates Tijuana would have to pay approximately $4 million dollars per year. Therefore, it is safe to assume that the subsidy received by Tijuana users of the Point Loma Treatment plant is quite significant.[23]

The city threatened to increase treatment fees for transfrontier wastewater from $520/day to $5,000/day in 1985 and later threatened to discontinue treatment of such waste unless it received reimbursement from the federal government for expenses incurred.[24] To some extent, the same is true of the payments for the use of the emergency connection and Point Loma treatment plant. For instance, the $90 million IADB loan for investment in Tijuana's sewage collection system only covers the operating costs of the collection system, with the capital costs being paid by the IBWC. Although the IBWC is financed by the federal governments in both countries, it remains true that the Mexican collection system is financed, in large part, by American taxpayers. This transnational subsidy is likely to continue to be the case for the foreseeable future, as is documented by the proposed budget for the new $400 million binational IBWC treatment plant:

Table 1:

Proposed Allocation of Capital Costs for IBWC Plant[25]

U.S. Government	$208.0 million
California	$ 31.6 million
San Diego	$ 75.2 million
Mexico Government	$ 85.2 million

23. Comite de Planeacion Para el Desarrollo Urbano (COPLADU), PLAN MUNICIPAL DE DESARROLLO DE TIJUANA (1990); USOTR, *supra* note 10; SAN DIEGO WATER UTILITIES DEPARTMENT, FISCAL YEAR OVERVIEW—1992 (1992); SAN DIEGO WATER UTILITIES DEPARTMENT, ANNUAL FINANCIAL REPORT—1988 (1989).

24. Stephen P. Mumme & Joseph Nalven, *National Perspectives on Managing Transboundary Environmental Hazards: The U.S.-Mexico Border Region*, 3 J. BORDERLANDS STUD. 39 (1988).

25. The total cost ($400 million) was obtained from the EPA (*supra* note 10), while the proportion of such expenditures attributable to different jurisdictions was obtained from the IBWC (*supra* note 9).

Considering that the plant is designed in large part to deal with Tijuana wastewater it is evident that industrial users located in Tijuana will be receiving an effective subsidy. To the extent that users on the American side of the border generate the revenue from which the responsible agencies are financed, such costs will be borne by firms located in the United States.

Binational arrangements for sewer financing elsewhere in the border region have also followed this pattern. For instance, financing for the new $44 million Nuevo Laredo wastewater collection and treatment facility is to be borne by the United States Government, the State of Texas and the city of Laredo on the United States side of the border, while on the Mexican side of the border only the federal government is responsible for financing. Capital costs for the original Nogales, Sonora—Nogales, Arizona binational treatment facility were borne on the American side with part of the operation and maintenance costs paid, according to volumes discharged, by Mexico. In addition, the $13 million expansion of the binational facility is to be funded at all three levels of government in the United States but only at the federal level in Mexico. In the face of such arrangements it is clear that industrial users located in Mexico receive a subsidy from users on the American side of the border with respect to binational treatment facilities. There are, of course, numerous other environmental subsidies which users on both sides of the border obtain, the distinction in this case is that the subsidy pertains directly to a transnational environmental externality. Paradoxically, this would indicate that American firms manufacturing (or subcontracting from Mexican firms) in Mexican border areas receive a subsidy from the federal tax base in the United States which is not available to firms manufacturing in the United States since the EPA, and not the municipality or the state, is supposed to pay for those costs associated with wastewater flows originating from outside national territory.[26]

Water Treatment Costs

There are also significant costs borne by industrial firms in regions which receive their process water from treatment facilities which draw their water from transnational surface waters. In effect, whereas the case of sewage collection and treatment discussed above represents a form of transnational financial externalization, incremental water treatment costs represent an instance of transnational technological

26. See EPA, *supra* note 10; Jose L. Calderón Barthemeuf, *Policies and Strategies for the Control of Contamination of Water on the Northern Mexican Border, in* ENVIRONMENTAL HAZARDS AND BIORESOURCE MANAGEMENT IN THE UNITED STATES-MEXICO BORDERLANDS 31-47 (Paul Ganster & Hartmut Walter eds., 1990).

externalization. To understand how this affects production costs it is necessary to realize that under the regulatory framework of the Safe Drinking Water Act (1974), the EPA must set Maximum Contaminant Levels (MCLs) which represent binding standards—including a margin of safety against adverse health effects - for concentrations of a variety of contaminants in drinking water. The Act was amended in 1986, and 83 new drinking standards were passed within three years. Since the regulations are pollutant-based instead of technology-based, water treatment costs (for all users) rise with source water pollution levels as more comprehensive treatment levels are required. Thus, industrial users will have to pay more for water charges unless they source their water directly from surface or groundwaters. Moreover, even if they do not source their water from the public system, they will be forced to undertake more comprehensive treatment as water quality deteriorates.

Instances of increased treatment costs due to transfrontier pollution are more common in the section of the border on the Rio Grande since communities on the western section of the border (principally Tijuana-San Diego and Mexicali-Calexico) draw most of their water from higher up on the Colorado River in the United States, while 98 percent of residents of the Lower Rio Grande draw their water from the binational river. Although samples taken as recently as 1981 indicated that water quality in the Rio Grande was deemed to be satisfactory, the quality appears to have deteriorated significantly in recent years. Laredo/Nuevo Laredo is such a case. In the face of increased emissions of untreated wastewater from Nuevo Laredo, the quality of the Rio Grande declined, resulting in higher water treatment costs. To the extent that industrial users pay higher water rates as a result they are paying for the transfrontier diffusion of pollution.[27] The same would be true of other cities lower down the river which are adversely affected by untreated effluent discharges. For instance, the community of Rio Bravo, Texas has been forced to upgrade its water treatment facilities in the face of an increasingly polluted Rio Grande. The International Falcon Reservoir which provides drinking water for 1.5 million people has also been adversely affected. Ciudad Juarez-El Paso does not draw its water from the Rio Grande, but from the Hueco Bolson aquifer. Consequently, water treatment costs are not affected by emissions into the river. However, extra costs for treatment of water drawn from the aquifer may

27. As the chief of environmental health for the Laredo-Webb County Health Department stated: "The more polluted the river, the more it costs us to put out safe water. If we have a very polluted river, we will have an expensive water treatment plant to run." *See* Alm and Tomaso, *supra* note 19.

prove to be costly in the near future. Moreover, Juarez wastewater emissions already affect the costs of water treatment downstream.[28]

Air Pollution Abatement Costs

The last case to be discussed involves the extra production costs associated with the transnational nature of air pollutants in the border region. The particular case of ozone levels in Ciudad Juarez-El Paso will be discussed since it is particularly acute. However, the insights are true of the diffusion of other pollutants in other cities along the border as well. As noted, El Paso is a non-attainment zone for ozone, with 1989 levels of .17 ppm in comparison to the federal and state standard of .12 ppm. Indeed the city has been a non-attainment zone with respect to ozone since the 1970's. However, in recent years total emission levels have fallen. Between 1980 and 1985 there was a 25 percent fall in El Paso emissions. This is due in part to the installation of the most effective air pollution control devices legislated by the EPA for industrial point sources.[29]

Nonetheless, due to emissions from Juarez, ozone levels remain above EPA standards. Effectively El Paso is faced with a dilemma in terms of the appropriate treatment of Juarez emissions in abatement plans. For instance, the 1979 and 1985 State Implementation Plans for El Paso air pollution did not include Juarez emissions in the plan. The result was that the state required unrealistically low control levels and as a consequence the EPA rejected the Texas SIP's for the city. However, if Juarez emissions are taken into account, unduly stringent control levels would be required for industrial sources in El Paso. Indeed it is possible that El Paso would not meet EPA ozone standards even if emissions were reduced to zero. Therefore, to the extent that Juarez emissions are responsible for El Paso's non-attainment status, industrial sources of VOC's in El Paso must undertake significant expenditures on pollution control technology as a consequence of the transfrontier diffusion of air pollution. Moreover, under the 1990 Clean Air Act Amendments non-attainment zones for ozone must undertake the following measures:[30]

1) VOC emissions must be reduced by 3 percent/year after the first six years of the programme until the NAAQS is attained.

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28. See NTCF, *supra* note 19; Alm and Tomaso, *supra* note 19; Utton, *supra* note 22.
29. *See* USOTR, *supra* note 10; Yarborough et al., *supra* note 11.
30. See USOTR, *supra* note 10.

2) Existing stationary sources with emissions in excess of 50 tons/year must install Reasonably Available Control Technology (RACT).
3) The city must introduce a construction permit programme for new stationary sources which requires the Lowest Achievable Emissions Rate (LAER) and offsetting reductions in emissions from other sources of 1.2:1.

In addition, since many significant industrial VOC sources also emit some of the 189 toxic air pollutants listed in the CAAA, they will also have to install the Maximum Achievable Control Technology (MACT) for such pollutants. Considering the capital costs of abatement equipment for VOCs and toxic air pollutants (carbon absorbers, thermal incinerators and acid/alkali scrubbers), such regulations are likely to be quite burdensome. In 1990 the 357 firms in the SIC 36 sector in the state with more than 20 employees spent $3.9 million on capital costs related to VOC abatement.[31] This comes to approximately $10,900 per firm.

IV. THE THEORY OF BINATIONAL ENVIRONMENTAL COOPERATION

The discussion thus far assumes that there is no international cooperation to resolve the sorts of binational environmental problems which exist in the border region. That is to say, it assumes that the only way in which a country can improve its environmental quality is to restrict emissions within its own borders and that it continues to do so even if doing so proves to be ineffective. Is this a realistic assumption for the border region? Although there has, in fact, been significant progress on binational environmental problems in terms of institutional agreements (i.e. the IBWC, the La Paz Agreement, the North American Agreement on Environmental Cooperation, etc...), this has not been fully translated into practical solutions to some of the more intractable problems associated with hazardous waste. In order to understand why this has been the case it is necessary to look at the theoretical literature on transfrontier pollution and cooperative solutions.

In effect, negotiations of controls for transfrontier pollution are more similar to private bargaining situations than to the national setting of environmental controls. In the international case, however, the bargaining agents are states instead of individuals. In both cases, the agreement struck must be satisfactory to all participants without compulsion since there is no authority in a position to compel compli-

31. U.S. DEPT. OF COMMERCE (USDOC), COUNTY BUSINESS PATTERNS-TEXAS tbl. 1b (1991); U.S. DEPT. OF LABOR, POLLUTION ABATEMENT AND CONTROL EXPENDITURES tbl. 3b (1992).

ance. Consequently, in many senses the case of a transfrontier pollution problem possesses characteristics similar to an ordinary problem of externalities amongst individuals, and thus one would expect that a Coasean solution could be achieved, wherein Pareto optimality emerges regardless of property right allocation. There is, however, one important distinction between the two cases which must be noted. In international questions one cannot assume a given legal regime. Indeed the regime itself is subject to negotiation. The essential point is that a Coasean solution assumes a given system of property rights and merely asserts that what precisely this system constitutes is irrelevant in terms of allocative efficiency. In the international case, however, since one can not assume a definite system of property rights of any sort there is no reason to expect an efficient solution to arise spontaneously through bargaining.

Although in theory the principle of non-discrimination would seem to imply that the polluter-pays-principle applies to international questions and consequently that the affected party possesses a "right" to a clean environment, in practice this is by no means self-evident. For instance, in the ruling it was asserted that it is unlawful for a state to cause transfrontier pollution which entails serious damage in another state. However, precisely what is perceived to constitute "serious damage" may differ between states. If a downstream country is unwilling to tolerate levels of pollution which are deemed acceptable by the upstream country within its own borders does this constitute serious damage? Moreover, in recent years the principle of non-discrimination has been extended to include the notion of "risk creation of serious damage." However, there is much scope for ambiguity in this notion in terms of both uncertainty about the degree of probability of the damage and the seriousness of the damage itself.[32] Risk is a fundamentally contextual term. Consequently, there are no general principles which can be universally applied in order to determine the "rights" of states to a clean environment on the one hand or to pollute the environment on the other. In this light, the use of international financial transfers (IFT's) has been advocated as a means to resolve such problems.[33] IFT's enable a downstream country to obtain what it perceives to be an efficient solution to a transfrontier problem in a manner that is perceived to be equitable by the upstream country. These transfers are, however, merely the outcome

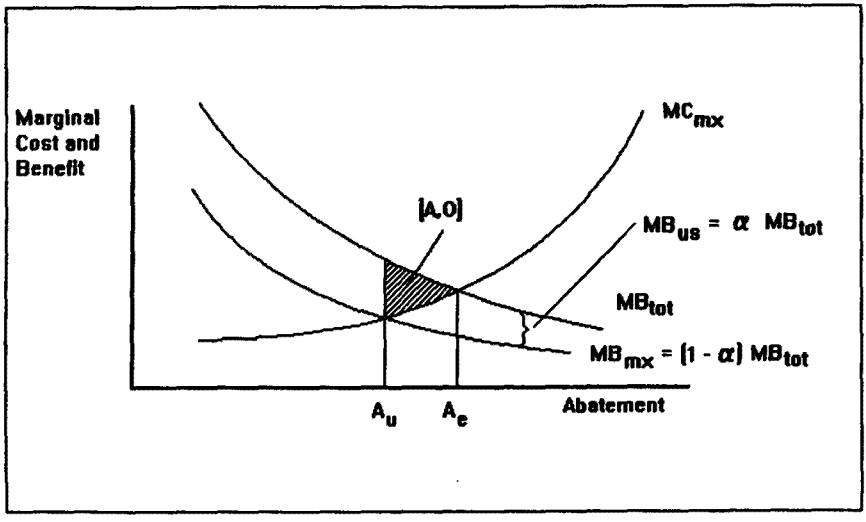
32. For discussions of the economic and legal implications of transfrontier pollution, see OECD, Transfrontier Pollution and the Role of States (1981).

33. In a sense, other forms of compensation—debt-for-nature swaps, environmental project lending, and loans tied to environmental improvement—are all specific forms of the more general notion of IFTs. For a discussion, see Peter Nunnenkamp, International Financing of Environmental Protection, Kiel Working Paper No. 512 (1992).

of negotiations and as such must be analyzed in a game-theoretical framework.

Let it be assumed that there is a unidirectional transfrontier externality from Mexico to the United States. Let it also be assumed that the total cost function C(A) of abatement in the emitting country (Mexico) is upward-sloping (i.e. $C'(A) > 0$) and that the marginal cost of abatement is also increasing (i.e. $C''(A) > 0$). The binational benefit function of abatement B(A) is also increasing ($B'(A) > 0$), but it will be assumed that the marginal benefit is decreasing (i.e. $(B''(A) < 0)$.[34] Given the existence of TFP, the benefit function can be split into two parts, with one part referring to the pollution which remains in Mexico, and the other part referring to the pollution which is diffused across the border into the United States.

Figure 1:
Transfrontier Pollution and Environmental Cooperation



In the figure $MB_{TOT} = MB_{MX} + MB_{US}$. Let α be the proportion of benefits of abatement (cost of damages arising from emissions) for the United States. As such,

$$MB_{MX} = (1 - \alpha)\, MB_{TOT}$$

$$MB_{US} = \alpha\, MB_{TOT}$$

34. These are standard assumptions in the literature. They are not, however, necessary assumptions. All that is required for the analysis to be valid is that the marginal cost of abatement at the unilateral equilibrium is less than the binational marginal benefit.

α will be a function of the rate of diffusion and the relative valuation of damages.[35] MC_{MX} is simply the marginal cost of abatement. Unilaterally, Mexico will choose a level of abatement A_U since at this point it will equate its own marginal benefit and marginal cost curves. This is not, however, the efficient binational optimum, which would be achieved at A_E, where the total marginal benefit of abatement to the two countries is equated with the emitting country's marginal cost of abatement. In order to determine where the two countries will end up as a result of a negotiated solution to the transfrontier externality, the negotiations can be presented as a non-cooperative game.[36]

Let it be assumed that both abatement and damage functions are known and that there are no transaction costs. The downstream country offers the upstream country a payment (O_{US}) if it agrees to abate pollution by a given amount (A_{US}). Similarly, the upstream country offers to abate pollution by a given amount (A_{MX}) if it receives a payment (O_{MX}) from the downstream country. The net benefit for Mexico for a given offer (A^*, O^*) is:

$$NB_{MX} = (1 - \alpha)\, B\, (A^* - A_U) + O^* - C(A^* - A_U).$$

And the net benefit for the United States is:

$$NB_{US} = \alpha B\, (A^* - A_U) - O^*.$$

As long as the two offers are compatible there will be an agreement. That is to say, as long as the offer from the downstream country is as good for the upstream country as its own offer, or as long as the offer from the upstream country is as good from downstream country as its own offer, an agreement will be reached. Consequently the feasible set of all agreements will be:

$$\{(O^*, S^*);\ \alpha\, B\, (A^* - A_U) > O^* > C\, (A^* - A_U) - (1 - \alpha)\, B\, (A^* - A_U)\}.$$

In this set, the benefits of additional abatement to the United Sates are greater than the bid, which in turn, is greater than the costs of additional abatement to Mexico minus its own benefits of additional abatement.

The feasible set of equilibria, however, is infinite. Where, precisely, this solution will lie depends upon the respective bargaining

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35. For instance, if 50% of emissions are diffused across the border, assimilative capacity is the same on both sides of the border, but the United States values damages twice as highly as Mexico, α will equal .667.

36. Karl-Goran Mäler, *International Environmental Problems*, 6 OXFORD REV. ECON. POL'Y 80 (1990).

powers of the two countries. Therefore, in a one-shot game the agreement could lie anywhere in the shaded area bounded by the MB_{TOT} curve and the MC_{MX} curve, to the right of A_U and to the left of A_E. In every equilibria the negotiated solution will involve a level of abatement that is lower than had been the case in the optimal solution. The Coase Theorem does not hold since property rights can not be explicitly determined in international situations. However, there will be a tendency toward the efficient equilibrium in a model involving repeated games. The solution of each consecutive game will represent a movement toward the optimal solution.[37]

V. BINATIONAL ENVIRONMENTAL COOPERATION IN THE BORDER REGION AND CONTINUED ENVIRONMENTAL DEGRADATION

Game theory enables us to present the nature of the problem of binational cooperation in the presence of a transfrontier externality, but it does not enable us to analyze the reality of a given incidence of such an externality. In this section, the reasons why, despite the magnitude of the benefits available, the two countries have thus far been unable to address the problem of environmental degradation are discussed. In a general sense, three elements have been cited as impeding transboundary environmental cooperation in the border region: The ambivalence of both sides toward concessionary aid from the United States; Mexico's inability to participate in cooperative agreements to the same extent as the United States; and, Mexico's desire to engage in independent action. Although, it is possible that the latter point can be understood as primarily the consequence of cultural and social factors, it is asserted that most aspects of the relationship are influenced by national differences in the level of economic development and relationships of dependency.[38] Nonetheless, as will be shown there has been significant cooperation with respect to

37. Henry Thulkens, Theoretical Foundations of Negotiations and Cost Sharing in Transfrontier Pollution Problems (Sept. 1991) (paper presented at the Sixth Annual Congress of the European Economic Association).

38. See Mumme, *supra* note 10; Nalven, *Social and Cultural Aspects of Transborder Environmental Cooperation*, *supra* note 15; Bath, *Environmental Issues in the U.S.-Mexico Borderlands*, *supra* note 11; Mumme & Nalven, *supra* note 25; Bath & Rodriguez, *supra* note 11; Nalven, *Transboundary Environmental Problem Solving*, *supra* note 15. A good case study of the relative importance of such factors is the case of SDAPCD-SMA cooperation on Tijuana air pollution from 1979-1984. In one instance, the SMA refused the loan of gaseous pollution monitoring equipment from the SDAPCD for related reasons. However, officials involved put much of the blame for the cooperative agreement's demise on differences in degrees of political centralization in the two countries. *See* Alvarez Lopez, *supra* note 14; Brown & Bigler-Engler, *supra* note 15; Brown et al., *supra* note 13.

the environment. Therefore, it will be argued that continued environmental degradation arises not so much from a lack of cooperation but from the very nature of cooperation, which, in turn, is a consequence of the nature of production in the border region. To see why this is so it is necessary to analyze the nature of cooperation which presently exists (i.e.. the IBWC, the Joint Marine Contingency Plan, the La Paz Agreement, the Integrated Border Environment Plan etc...) in the border region.

Binational Environmental Cooperation in the Border Region

Originally signed in 1944 the binational IBWC was designed to deal with sanitation and sewage issues in the border region. However, with the passage of time more general water pollution problems were included in its mandate, particularly following the passage of Minute 261 in 1979. Amongst the other more important agreements, Minute 242 (1973) addressed the problem of salinity in the Colorado while Minute 264 (1980) addressed the problem of domestic sewage and industrial waste in the New River. Despite the aspirations of some observers, the IBWC has never become involved in environmental matters related to media other than water, or indeed, even groundwater.[39]

Under Minute 242, the United States agreed to the construction of a desalination plant at Yuma, Arizona before the river crosses the border. Although, presented as necessary due to international IBWC obligations, the plant was also built to serve the Wellton-Mohawk irrigation project which serves Imperial Valley, California. Moreover, salinity in the river remains excessive, partly due to reduced flow as the cities of the South-West draw an increasing volume of water from the river. Similarly, although Mexico has made significant progress with respect to pollution in the New River under Minute 264, it remains one of the most polluted rivers in North America. And finally, binational sewage-related work carried out elsewhere in the Border Region—particularly Nogales/Nogales and Laredo/Nuevo Laredo—under Minute 261 has met with qualified success.[40]

Signed in 1983, the Border Environment Cooperation Agreement (the La Paz Agreement) has constituted one of the most comprehensive

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39. Stephen P. Mumme, *La Paz Agreement: Progress and Problems in Managing the Border Environment*, 2 TRANSBOUNDARY RESOURCES REP. 1 (1988). *See* Mumme & Nalven, *supra* note 24; Utton, *supra* note 22; Albert E. Utton, *Shared Water Resources in the United States-Mexico Border Region*, *in* ECOLOGY AND DEVELOPMENT OF THE BORDER REGION 167-81 (Stanley R. Ross ed., 1983).

40. See Utton, *supra* note 22; Stephen P. Mumme, *International Boundary Water Commission*, 1 TRANSBOUNDARY RESOURCES REP. 1 (1987); Metzner, *supra* note 19; Kneese, *supra* note 18; Mäler, *supra* note 35.

efforts to resolve transnational pollution questions. Broken up into separate working groups and with the heads of the EPA and SEDUE/SEDESOL as national coordinators, it has passed a number of Annexes dealing with specific border region environmental problems. Annex I (1985) is concerned with the problem of raw sewage being dumped into the Tijuana River. Although the problem has not been resolved, loans for improved collection systems and the binational plant to be constructed at South Bay represent an important contribution. Annex II (1986) authorized the creation of an Inland Joint Response Team to respond to accidental oil spills and hazardous waste incidents in the border region. The JRT has conducted several training and response exercises and responded effectively to a potentially dangerous spill in El Paso 1990. Annex III (1986), which became the model for the international Basel Convention, established manifest and notification procedures for the transport of hazardous waste across the border. Although there is some debate about its effectiveness, there is little question that Annex III has improved coordination between customs officials on the two sides of the border. Annex IV (1987) addressed the problem of SO2 emissions from copper smelters in the "Grey Triangle." Under the Annex the EPA revoked Phelps Dodge's request for a Clean Air Act waiver and SEDUE required that the Nacozari plant install pollution control devices. And finally, Annex V (1989), provides for an assessment of air quality problems in the twin-city areas of the border region. Under the agreement expanded binational monitoring programmes are in place in Ciudad Juarez, Mexicali and Tijuana and emissions inventories are being undertaken in Tijuana and Juarez.[41]

Many of the initiatives of the IBWC and the La Paz Agreement have now been incorporated into the Integrated Border Environment Plan. The Plan's first stage (1992-94) involves the following four main objectives: Strengthening enforcement of existing laws; Reducing pollution through new initiatives; Increasing cooperative planning, training, and education, and; Improving understanding of the border environment. Cooperative efforts will be further strengthened in the second stage (1995-2000). The combined EPA-SEDUE budget for 1992 was $326 million. Overall SEDUE has agreed to spend $460 million during the first stage, $220 million of which is for sewer systems. EPA has not released proposals for all three years, however for 1993, the total was $179 million, with an additional $60 million from other agencies.[42]

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41. *See* Mumme, *supra* note 38; EPA, *supra* note 10; Mumme & Nalven, *supra* note 24; USOTR, *supra* note 10.

42. See EPA, *supra* note 10.

Perhaps most significantly, the plan makes provisions for an additional 100 SEDUE/SEDESOL inspectors on the Mexican side of the border, doubling the total. In addition, improved enforcement cooperation and information exchange across the border has been established. New and improved wastewater collection system and treatment plants have been proposed for the Nogales Wash, Tijuana-San Diego, Nuevo Laredo-Laredo, Matamoros, Reynosa, Piedras Negras, Ciudad Juarez, Mexicali and the *colonias* of Texas. Most significantly, there will be cooperation in the establishment of industrial wastewater pretreatment programmes in cities which use the binationally-funded plants. With respect to solid waste, $25 million will be invested in new landfills, and there will be improved cooperation to detect illegal hazardous waste shipments and monitor treatment. Some of the problems associated with air pollution will be addressed through increased paving of roads and better transportation facilities. It is hoped that comprehensive binational air pollution control strategies for TJ-SD, Mexicali-Calexico and Juarez-El Paso will be in place by 1994.[43]

Finally, the North American Agreement on Environmental Cooperation signed between the governments of Canada, the United State and Mexico represents a more general form of environmental cooperation. A Commission for Environmental Cooperation was set up, comprising a cabinet-level Council, a permanent Secretariat, and a Joint Public Advisory Committee. The commission is to address questions such as environmental protection and trade distortions, the economic efficiency of environmental measures, administrative transparency and public participation, and international cooperation in developing measures and enforcing them. Although scope of the Agreement extends far beyond the Border Region, as part of the North American Free Trade Agreement the agreement will certainly possess significant influence.

Cooperative Agreements as Contributors to Continued Environmental Degradation

From the preceding discussion it is apparent that the United States and Mexico have undertaken significant cooperative efforts to resolve binational environmental problems in the border region. However, the region remains exceptionally polluted. In order to understand why this is so it is necessary to analyze the nature of the cooperative agreements and place them in the context of a region wherein there is significant interdependence of environmentally-determined comparative advantage and transfrontier diffusion of pollution.

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43. *See* EPA, *supra* note 10; USOTR, *supra* note 10.

Game theoretical analyses assume, as noted, that states are sovereign agents, representing the interests of their citizens. Thus, the analysis of negotiated solutions to international problems assumes, implicitly, that the interests of citizens within a given political jurisdiction are complementary. For instance, in the case of water-based transfrontier diffusion of pollution, citizens in the recipient country are affected as residents (the degradation of water quality), taxpayers (sewer and water costs), and producers (reduced natural capital). All agents possess an interest in ensuring that the government negotiates for a solution wherein the transfrontier diffusion of pollution is reduced. This may, however, be circumscribed to the extent that negotiations involve instances wherein one example of transfrontier pollution is linked with another, seemingly unrelated, case.[44] Agents who are adversely affected by negotiated solutions to transfrontier pollution arising from their own emissions will have rather more complex interests, and binational solutions will be correspondingly more involved. However, such cases are merely instances of political linkage related to negotiating strategies. In the United State-Mexico Border Region, more fundamental economic linkages are of greater interest.

As noted, the economy of the Border Region is characterized by relations of close economic interdependence. Much of this involves vertically-integrated production-sharing arrangements within individual firms, particularly for those firms involved in the Border Industrialization Program.[45] In the instance where firms have production locations on both sides of the border—or, are in a position to exploit sub-contractual or shelter arrangements from suppliers on the opposite side of the border—the interests of producers are not strictly complementary with those of other agents in the economy. Assuming that ß represents the proportion of production in the Mexican Border Region which is associated with American capital the "national" marginal costs of abatement of production located in the United States and Mexico can be represented as,

44. See Mäler, *supra* note 35. Such cases arise frequently in the Border Region. For instance, Mexico linked negotiations over compensation for the Ixtoc spill with the question of Colorado River salinity. *See* Hansen, *supra* note 18.

45. *See supra* note 6.

$$MC_{US} = ß\ MC_{TOT}^{46}$$

$$MC_{MX} = (1 - ß)\ MC_{TOT}$$

In this case the net benefit for the United States for a given offer (A*, O*) is:

$$NB_{US} = \alpha B\ (A^* - A_U) - O^* - ß\ C\ (A^* - A_U)$$

And the net benefit for Mexico for a given offer is:

$$NB_{MX} = (1 - \alpha)\ B\ (A^* - A_U) + O^* - (1 - ß)\ C\ (A^* - A_U).$$

The feasible set of all agreements will be:

$$\{(O^*, S^*);\ \alpha\ B\ (A^* - A_U) - ß\ C\ (A^* - A_U) > O^* > (1 - ß)\ C\ (A^* - A_U) - (1 - \alpha)\ B\ (A^* - A_U)\}.$$

The optimal level of abatement remains the same. However, in this case the United States would be more willing to accept relatively lower levels of abatement since American capital will (directly or indirectly) pay for part of such abatement. Conversely, Mexico would be more willing to undertake higher levels of abatement for the same reason. Thus, the outcome of negotiations over conditions of production in Mexico with respect to the environment depends upon the relative power of American capital with links to production sites in Mexico and the Mexican state. If production costs in Mexico are a significant factor in the viability of many American firms and/or the Mexican state values the viability of the BIP relatively more than environmental quality a negotiated solution which involves relatively lower levels of abatement is more likely than would otherwise be the case.

46. Given the rather convoluted nature of production-sharing arrangements in the region (subsidiaries, sub-contractors, shelter programmes, et cetera) and the multiplicity of objectives pursued by the respective governments with respect to the BIP (employment creation, firm profitability, et cetera) such a crude distinction is, in some sense, invalid. However, if the magnitude of ß is understood as an index of the inverse of the relative benefits derived from the existence of low production costs on the Mexican side of the border rather than the incidence of abatement costs *per se*, the use of such a coefficient is not entirely without justification.

Cooperative Agreements as Contributors to Continued Environmental Degradation

In a closely related sense, even if the agreement reached involves an efficient level of environmental degradation in a static sense, it may not be tenable if it does not institute appropriate incentives. Thus, it is important to distinguish between cooperative agreements which constitute *ex post* attempts to "clean up" the environment and *ex ante* attempts to attach an appropriate price to its use. In other words, the means by which degradation is reduced in the emitting country is of paramount importance. For instance, if the reduction in TFP is achieved through the establishment of a comprehensive industrial wastewater pretreatment programme the responsible agent will bear significant costs. Conversely, if such flows are reduced through state investment in POTWs and collection systems financed by Mexico City and Washington D.C., then the responsible agent will bear little of the cost of reduced flows. In certain instances the latter case may actually increase use of environmental resources since firms are not adversely affected by environmental degradation and nor do they pay for its use as a factor of production. Thus, productivity in pollution-intensive sectors will increase. For instance, sectors which have significant levels of water intake and wastewater discharge will be relatively more viable than if no cooperative agreement had been reached.

Which of the two poles do existing solutions more closely resemble? Clearly some cooperative solutions adhere to the polluter-pays--principle more closely (Annex IV of the La Paz Agreement) than others (Minute 242 of the IBWC). However, in general, the cost of cooperative solutions tends to have been borne at the national level, not affecting costs of production significantly. Agreements related to sanitation and sewer issues constitute the most striking example. This is, to some extent, inevitable. Most such resolutions are concerned primarily with efforts to resolve public health related problems. Given the magnitude of health problems associated with uncollected and untreated sewage in the region, such aid is both necessary and desirable. However, such aid should not simultaneously generate environment-related production subsidies, particularly since much of the subsidy is obtained, directly or indirectly, by American producers. Not only will this prove to be inequitable (American firms in Mexico will receive a subsidy which is not available to firms in the United States) but also inefficient (Mexico will continue to possess a comparative advantage in waste-intensive production and the region's environment will continue to suffer degradation). Ideally, the perfect solution for regions which share a single ecosystem rests with cooperative agreements which make the border irrelevant in terms of environment-related costs of production. Transnational bubbles have been

recommended as such a solution for binational pollution in common air sheds in the region.[47] However, such solutions are only efficient for pollutants with predictable and localized effects. For instance, with respect to ozone, Tijuana-San Diego share an air shed with Los Angeles, but only occasionally and irregularly. Moreover, given the very different legal status of the environment in the two countries (state ownership versus common ownership), such solutions may prove to be politically infeasible. Nonetheless, there are components of the IBEP which are encouraging in that they recognize more fully the necessity for adherence to the polluter-pays-principle (PPP) with respect to industrial transfrontier pollution effluent and emissions.

Most significantly, the implementation (with the EPA's financial and technical support) of an industrial wastewater pretreatment programme is encouraging. In terms of POTW costs, the agreement by Ciudad Juarez maquiladoras to cover 30 percent of capital costs for the new sewer system stands in marked contrast to the response to proposals for a 5 percent infrastructure tax in the 1980s. In addition, the development of a proper air pollutant emissions' inventory and the establishment of a comprehensive air pollution control programme by the end of 1994 should represent a movement toward greater internalization of environment-related production costs. Moreover, better hazardous waste manifest and tracking procedures should reduce the possibility of illegal disposal and thus increase the costs of treatment for firms which are presently taking advantage of lax enforcement. And finally, private sector participation in the creation of the proposed $20 billion North American Development Bank for the financing of infrastructure projects should also result in greater internalization of transboundary pollution externalities.

47. Howard G. Applegate, *A Discussion of United States-Mexican Experience in Managing Transboundary Air Resources: Problems, prospects, and Recommendations for the Future*, 22 NAT. RESOURCES J. 1169 (1982); Applegate, *supra* note 10; Mumme & Nalven, *supra* note 24.