A DYNAMIC INPUT-OUTPUT MODEL OF NAFTA'S EFFECTS ON POLLUTION

Andrés Blancas*

Abstract

This paper indicates the effects of NAFTA on pollution in Canada, Mexico and the United States that can be considered in a well-behaved multiregional input-output model. Since Mexico does not have enough data on sector-based pollution emission or pollution elimination costs to be used in an input-output model, nor does it have the technology to confront the increasing environmental deterioration that could result from NAFTA, active participation by Mexican authorities is necessary to achieve a win-win result. The Mexican government should, therefore, publish sector-based pollution data and promote the development of technology for improving the environment in order to be at the level required by the other NAFTA member countries.

Introduction

The objective of this paper is to show the impact of the North American Free Trade Agreement (NAFTA) on pollution emission and pollution elimination in the three countries involved. It focuses on the development of an input-output model for evaluating these effects, since input-output analysis is well-suited for this endeavor. In an input-output (I-O) model it is possible to clarify in a well-behaved way what Taylor (1994) calls intuitive perceptions of how aggregates interact. An input-output analysis considers both the direct and indirect effects of all economic sources of pollution generation, as well as the associated costs of pollution elimination and pollution emission. It is important here to highlight an advantage of an I-O analysis, as pointed out in Leontief's (1986) analysis of indirect effects: specifically, that it permits the disentanglement and accurate measurement of such effects.

In a more complicated multiregional and dynamic version, the input-output approach could make it possible to explain the spatial distribution of pollution and of its growth or decline over time. Furthermore, in an I-O table the environmental indicators could be represented in physical units[1] or in value terms, although in practice most I-O tables are developed using value terms. The point is whether it is possible to develop such a model at a regional level for Canada, Mexico and USA. If so, what is the nature of such a model? How can it work in a practical way? Before addressing these issues, it is worthwhile to answer the following questions: What does NAFTA mean in terms of pollution? What is the relationship, if any, between free trade and pollution which can be stated as a relationship between development and environment?

The relationship between NAFTA and the environment

NAFTA is the North American Free Trade Agreement between Canada, Mexico and the USA that has been in effect since January 1st, 1994. NAFTA is designed not only to gradually eliminate tariff barriers,[2] but also to promote fair competition, investment opportunities, and copyright protection, as well as to establish a forum for resolving trade disputes. NAFTA´s official text (SECOFI, 1994-b) states that all these endeavors must be congruent with the protection and conservation of the environment.[3]

With 370 million consumers and $6.5 trillion in output, the combination of Canada, Mexico and US under NAFTA has created a market larger than either the Asian or European Community markets.[4] However, if each of the regions involved in this agreement does not contribute to improving the environment, this huge market could also generate the largest source of pollution in what Wilson (1991, p. 3) has called the *century of the environment*. Wilson states that the global environment is currently being changed by the human element to a greater degree than it has changed at any previous time during the past sixty-five million years.

Thus, the feuding over the environmental effects of NAFTA is, as Merchand (1992) has pointed out, a conflict among interest groups that have different underlying ethics and political positions and which are engaged in struggles over the use of land and natural resources. For instance, a 1993 USA government report suggested that Mexico does not adequately enforce its own environmental laws with respect to new factories. Presidential candidate Ross Perot (1993) used this argument to assert that USA companies that had already moved to Mexico had violated Mexican environmental laws. Environmentalists and some economists such as Daly (1993) sustain this point of view. Daly states that economic growth is increasing environmental costs faster than benefits from production. A firm can save money by lowering its standards for pollution control, thus externalizing some of its costs. Free international trade encourages industries to shift their production activities to the countries with the lowest standards of cost internalization-hardly a move toward global efficiency. Public Citizen, Sierra Club, and Friends of the Earth initiated proceedings against the Clinton Administration in 1993, alleging that the defendant had failed to comply with the National Environmental Policy Act in the negotiation and signing of NAFTA, since it did not prepare an environmental impact statement on the effects of this agreement on the quality of the human environment.

Nevertheless, as Bhagwati (1993) states, the aversion to free trade displayed by many environmentalists is unfounded because growth enables governments to tax and to raise revenue for a variety of objectives including the abatement of pollution and the general protection of the environment. Generally speaking, efficient policies such as free trade should favor environmentalism, as opposed to representing harm. Nevertheless, Bhagwati does not consider NAFTA to imply unfair competition in environmental terms, even given that as a developing country, Mexico does not have the technological resources to confront environmental depletion, nor does it have the data to evaluate pollution generation as a result of economic activity and human population increases.

The relationship between free trade and the environment can be expressed in the concept of “sustainable development” which was brought into common usage by the World Commission on Environment and Development (the Brundtland Commission) in its seminal 1987 report entitled “Our Common Future”. This term was defined as meeting the needs of the present generation without compromising the needs of future generations. Actually, by the 1970s there was already a generalized interest in the relationship between development and environmental issues, but as pointed out by Leontief (1977), it was the International Development Strategy adopted in 1970 that not only expressed concern regarding the environment but also stated that national and international efforts should be intensified to put a stop to the deterioration of the human environment, to take measures toward improving the environment, and to promote activities designed to maintain the ecological balance on which human survival depends. Today, the primary goal and challenge for any society is to achieve sustained and equitable development —in other words, environmentally responsible development— in order to improve the welfare of the present and future generations.

There is a mutual or interdependent relationship between the environment and development. Environmental constraints can limit development, and development can cause serious environmental damage. However, environmental quality is itself part of the improved human welfare that development attempts to achieve. If the benefits from growing incomes are offset by the costs imposed on health and the quality of life by pollution, we cannot call this development.

Furthermore, environmental damage can undermine future productivity. Soils degraded, aquifers depleted, and ecosystems destroyed in the name of raising incomes today can jeopardize the prospects for earning income tomorrow. Taylor (1994) addresses this as a relationship between a set of macroeconomic variables, X, and a set of environmental variables, Y. If we assume that free trade promotes economic growth, then it could harm the environment. In a hypothesized response, in which X and Y are in dynamic equilibrium, it is possible to show (diagrammatically) how a policy that improves X, reduces Y. Such an outcome is a familiar and valid critique by environmentalists of many economic initiatives.

Thus, we can see that there are “genuine conflicts” between trade and the environment. Bhagwati (1993) identifies two kinds of environmental problems: “intrinsically domestic” and “intrinsically transnational”. The most important examples of transnational pollution are acid rain, created when sulfur dioxide emissions in one country precipitate into rain in another, and greenhouse gases, such as carbon dioxide, which contribute to global warming wherever they are emitted. It is necessary to identify the conditions under which policies for efficient income growth can complement those for environmental protection. Moreover, policies that are justified on economic grounds alone sometimes deliver substantial environmental benefits. Some examples of policies that improve both economic efficiency and the environment are: eliminating subsidies for the use of fossil fuels and water, giving poor farmers property rights on the land they farm, making heavily polluting state-owned companies more competitive, and eliminating regulations that reward those who clear forests with property rights. Similarly, investing in better sanitation and water and in improved research and extension services can both improve the environment and raise incomes.

But these policies are not enough to ensure environmental quality. Rather, strong public institutions and policies for environmental protection are also essential. Development relies more on markets and less on governments, but environmental protection is one area in which government must maintain a central role. So, although it may seem paradoxical, a satisfactory relationship between NAFTA and environmental protection is dependent on the government. Private markets provide little or no incentive for controlling pollution. Whether air pollution in urban centers, the dumping of unsanitary wastes in public waters, or the overuse of land whose ownership is unclear, there is a compelling case for public action. There may be tradeoffs between income growth and environmental protection, requiring a careful assessment of the benefits and costs of alternative policies as they affect both today's population and future generations.

Developing countries like Mexico frequently suffer most from the consequences of pollution and environmental degradation. Poverty implies a lack of technology to eliminate pollution emission and also means being unprotected from pollution exposure. Unlike inhabitants of developed countries such as Canada and theUSA, those living in Mexico cannot afford to protect themselves from contaminated water; city dwellers are more likely to spend much of their time on the streets, breathing polluted air; and their lands are most likely to suffer from soil erosion. The World Bank (1992) states that sound environmental policies are likely to be highly redistributive. However, this point of view does not contemplate the lack of technology faced by developing countries, making it difficult to reduce pollution emission. Thus, these sound environmental policies are not redistributive in a significant way. For instance, in order to reduce pollution emissions from cars in Mexico City, the government has required that models older than 1993 must not be driven one day a week. This policy is not a redistributive one.

The World Bank (1992) reports that environmental problems experienced by countries vary according to their stage of development, the structure of their economies, and their environmental policies. The most immediate environmental problems facing developing countries —unsafe water, inadequate sanitation, soil depletion, indoor smoke from cooking fires, and outdoor smoke from coal burning— are different from and are more immediately life-threatening that those problems associated with the affluence of rich countries, such as carbon dioxide emissions, depletion of stratospheric ozone, photochemical smog, acid rain, and hazardous wastes. It is common to find that cities in developing countries such as Rio de Janeiro, Santiago de Chile and Mexico City belong to the group of the most polluted cities in the world —with one additional characteristic: a high ecological vulnerability to global environmental problems or transnational pollution. Therefore, developing countries must confront both local pollution or more immediate environmental problems as well as transnational pollution.

While not every problem can be a priority for every country, as we can se on Table 1, global environmental problems are already very serious and include: the accumulation of toxic wastes; the greenhouse effect, caused mainly by a steady rise in atmospheric carbon dioxide and the depletion of the ozone layer; the excess of nitrogen and phosphorus in lakes and rivers which causes plants to increase rapidly and exhaust the oxygen supply; heated water which causes hard water, thermal pollution and smog when returned to rivers; and the chemical reaction between the sun and nitric oxides, sulfur dioxides, and hydrocarbons which produces smog (that is sulfurous, photochemical and dense). All of these problems require urgent attention and global solutions. Free trade can be a cooperative, multilateral solution. Satisfactory global solutions can be reached, if they are based on a multiregional and ecological input-output model, because this model identifies the direct and indirect effects of NAFTA on pollution.

===Insert Table 1 (file:table1.xls)=====

A multiregional and ecological input-output model

In the current literature (Miller and Blair, 1985) input-output models are referred to as regional-level or as economic-ecological models, but not as models that are integrated at both the regional and ecological levels. At the regional level there are three types of models: single region models, multiple region models (interregional and multiregional models), and balanced regional models. At the environmental level there are three kinds of models: generalized input-output models, economic-ecological models and commodity by industry models. If we assume that each country involved in NAFTA represents a region, then we have a three-region input-output model. Let C, M, and U represent the regions of Canada, Mexico and the USA, respectively. The main pollutants considered here are Sulfur Oxides (1), Carbon Dioxide (2), Nitrogen Oxides (3).[5]

Static Model

Pollution generation

If *p* denotes pollution generation, then X_p represents the total pollutants emitted into the air in all regions C, M, and U; z_{pC} indicates the amount of pollutants generated by region C; z_{pM} indicates the total pollutants generated by region M; and z_{pU} represents the amount of pollutants generated by region U. Thus, the pollution-generation coefficients are:

$$a_{pC} = z_{pC}/X_C, \quad a_{pM} = z_{pM}/X_M, \quad a_{pU}=z_{pU}/X_U$$

We can define the pollution coefficient as:

$$a_{pj} = z_{pj}/X_j, \qquad j = C, M, U,$$

representing the amount of regions' j pollution produced per unit of its output. If the technological relationship represented by these coefficients is assumed to be stable, then the total amount of pollutants emitted, X_p, for any given values of X_C, X_M, and X_U could be represented by

$$X_p = a_{pC}X_C + a_{pM}X_M + a_{pU}X_U$$

describing the regional distribution of pollution generation.

The augmented input-output system can be written as:

$$\begin{aligned} X_C &= a_{CC}X_C + a_{CM}X_M + a_{CU}X_U + Y_C \\ X_M &= a_{MC}X_C + a_{MM}X_M + a_{MU}X_U + Y_M \\ X_U &= a_{UC}X_C + a_{UM}X_M + a_{UU}X_U + Y_U \\ X_p &= a_{pC}X_C + a_{pM}X_M + a_{pU}X_U \end{aligned}$$

rearranging:

$$(1 - a_{CC})X_C - a_{CM}X_M \quad - a_{CU}X_U \quad + 0X_p = Y_C$$

$$
\begin{array}{lllll}
-a_{MC}X_C & +(1-a_{MM})X_M & -a_{MU}X_U & +0X_p & = Y_M \\
-a_{UC}X_C & -a_{UM}X_M & +(1-a_{UU})X_U & +0X_p & = Y_U \\
-a_{pC}X_C & -a_{pM}X_M & -a_{pU}X_U & +X_p & = 0
\end{array}
$$

or, in more compact matrix terms:

The original (I-A) matrix is essentially bordered by a row of (the negatives of) pollution-generation coefficients and a column of zeros, and the X and Y vectors are appropriately expanded. $(I - A_p)$ is the expanded coefficient matrix. This simply enables the amount of pollution generated, X_p , to be calculated along with X_C, X_M, and X_U for any given Y_C, Y_M, and Y_U.

The solution to this system is given in the following compact matrix:

$$X^* = (I - A_p)^{-1} Y^* \text{ , where}$$
$$X^{*\prime} = [X_c \;\; X_m \;\; X_u \;\; X_p]$$
$$Y^{*\prime} = [Y_c \;\; Y_m \;\; Y_u \;\; X_p]$$

Pollution elimination

In a similar way, pollution abatement could be introduced into a Leontief structure (1986, pp. 241-260) in which the columns represent the three countries involved in NAFTA, whose function is to reduce or eliminate pollution. If $\hat{X}_p$ represents the total amount of pollution eliminated with NAFTA, and Y_p represents the total amount of pollution in the entire region that has not been eliminated, then Y_p would be equal to zero if all pollutants were eliminated,[6] giving us the following equation:

$$\hat{X}_p = X_p - Y_p \qquad \text{or}$$

$$\hat{X}_p = Z_{pc} + Z_{pm} + Z_{pu} - Y_p$$

Thus, the total amount of pollutants eliminated is equal to the total remaining pollutants produced. The pollution elimination coefficient can be defined as:

$$a_{ip} = X_{ip} / \hat{X}_p , \quad i = c, m, u$$

which represents the amounts of the countries output used per unit of pollution eliminated by the pollution abatement institutional sector. The input-output system can be reformulated as:

$$
\begin{array}{lllll}
(1-a_{CC})X_C & -a_{CM}X_M & -a_{CU}X_U & +a_{Cp}\hat{X}_p & = Y_C \\
-a_{MC}X_C & +(1-a_{MM})X_M & -a_{MU}X_U & +a_{Mp}\hat{X}_p & = Y_M \\
-a_{UC}X_C & -a_{UM}X_M & +(1-a_{UU})X_U & +a_{Up}\hat{X}_p & = Y_U \\
-a_{pC}X_C & -a_{pM}X_M & -a_{pU}X_U & +(1-a_{pp})\hat{X}_p & = -Y_p
\end{array}
$$

The solution to this system is given by the following compact matrix form:

$$X^{**} = (I - A_{pp})^{-1} Y^{**} \text{ , where}$$

$$X^{**\prime} = (X_c \quad X_m \quad X_u \quad \hat{X}_p)$$
$$Y^{**\prime} = (Y_c \quad Y_m \quad Y_u \quad -Y_p)$$

In this way, we can calculate the direct and indirect requirements of pollution elimination with a given level of tolerance for the remaining pollution (Y_p).

Prices

The pollution elimination process is costly, thus the price per unit of pollution elimination must cover the cost of inputs used, including labor costs and any other component of value added.
Mathematically:

$$P_C = a_{CC}P_C + a_{MC}P_M + a_{UC}P_U + 0 + v_C$$
$$P_M = a_{CM}P_C + a_{MM}P_M + a_{UM}P_U + 0 + v_M$$
$$P_U = a_{CU}P_C + a_{MU}P_M + a_{UU}P_U + 0 + v_U$$
$$P_p = a_{Cp}P_C + a_{MP}P_M + a_{Up}P_U + 0 + v_p$$

The final solution to this system in a compact matrix form is:

$$P^{*\prime} = (P_c \quad P_m \quad P_u \quad P_p)$$
$$V^{*\prime} = (V_c \quad V_m \quad V_u \quad V_p) \quad \text{, where:}$$
$$P^* = (I - A'_{pp})^{-1}\, v^*$$

We can arrive at the solution to this system such that given the computed unit price of pollution elimination, we can calculate the total $ amount that consumers and industries in the three NAFTA regions must pay in order to eliminate a certain amount of pollution. If they desire to eliminate $\hat{X}_p$ amount of pollution, they will have to pay P_p. $\hat{X}_p$ either directly to the region with a "common law of nuisance" [7] or through the so-called "green taxes," "Pigovian taxes" or "environmental federalism" [8] paid to the government which, in turn, will bear the costs of eliminating that amount of pollution.

Dynamic model

We can expand the static model to a dynamic version but the static solution to the system is the basis for more developed input-output techniques.[9]

In the static model of pollution elimination we have:

$$(I - A_P)X = Y \quad \text{where} \quad X = \begin{pmatrix} X_C \\ X_M \\ X_U \\ \hat{X}_P \end{pmatrix}, \quad Y = \begin{pmatrix} Y_C \\ Y_M \\ Y_U \\ -Y_P \end{pmatrix}$$

and $$\mathrm{A}_P = \begin{pmatrix} a_{CC} & a_{CM} & a_{CU} & a_{CP} \\ a_{MC} & a_{MM} & a_{MU} & a_{MP} \\ a_{UC} & a_{UM} & a_{UU} & a_{UP} \\ a_{PC} & a_{PM} & a_{PU} & a_{PP} \end{pmatrix}$$

is the enlarged matrix of pollution elimination coefficients.

In the dynamic model, the equation system in matrix form that includes the **pollution generation** is given by:

$$\mathrm{X}^t = \mathrm{A}^t_P \mathrm{X}^t + \mathrm{B}^t_P \left(\mathrm{X}^{t+1} - \mathrm{X}^t\right) + \mathrm{Y}^t$$

where $$\mathrm{X}^t = \begin{pmatrix} \mathrm{X}^t_C \\ \mathrm{X}^t_M \\ \mathrm{X}^t_U \\ \mathrm{X}^t_P \end{pmatrix}, \quad \mathrm{A}^t_P = \begin{pmatrix} a^t_{CC} & a^t_{CM} & a^t_{CU} & 0 \\ a^t_{MC} & a^t_{MM} & a^t_{MU} & 0 \\ a^t_{UC} & a^t_{UM} & a^t_{UU} & 0 \\ a^t_{PC} & a^t_{PM} & a^t_{PU} & 0 \end{pmatrix},$$

$$\mathrm{B}^t_P = \begin{pmatrix} b^t_{CC} & b^t_{CM} & b^t_{CU} & 0 \\ b^t_{MC} & b^t_{MM} & b^t_{MU} & 0 \\ b^t_{UC} & b^t_{UM} & b^t_{UU} & 0 \\ b^t_{PC} & b^t_{PM} & b^t_{PU} & 0 \end{pmatrix}$$ and

$$\mathrm{Y}^t = \begin{pmatrix} \mathrm{Y}^t_C \\ \mathrm{Y}^t_M \\ \mathrm{Y}^t_U \\ 0 \end{pmatrix}$$

The $b^t_{ji}\left(\mathrm{X}^{t+1}_i - \mathrm{X}^t_i\right)$ terms represent the capital goods produced by country j at time t required for the production of country i in time period $t + 1$; b^t_{Pj} shows the pollution generated by capital goods exports from country j to NAFTA region at time t for to be used in time period t+1 divided by total exports of j to the region.

In the **dynamic model of pollution elimination**, the equation system in matrix form is given by

$$\mathrm{X}^t = \mathrm{A}^t_{PP} \mathrm{X}^t + \mathrm{B}^t_{PP} \left(\mathrm{X}^{t+1} - \mathrm{X}^t\right) + \mathrm{Y}^t$$

$$\text{where} \quad X^t = \begin{pmatrix} X^t_C \\ X^t_M \\ X^t_U \\ \hat{X}^t_P \end{pmatrix} ,$$

$$A^t_{PP} = \begin{pmatrix} a^t_{CC} & a^t_{CM} & a^t_{CU} & a^t_{CP} \\ a^t_{MC} & a^t_{MM} & a^t_{MU} & a^t_{MP} \\ a^t_{UC} & a^t_{UM} & a^t_{UU} & a^t_{UP} \\ a^t_{PC} & a^t_{PM} & a^t_{PU} & 0 \end{pmatrix} , \; a^t_{jP} = \frac{X^t_{jP}}{\hat{X}^t_P} \qquad j = C, M, U$$

this coefficient matrix represents the inputs required by the institutional sector of pollution elimination in the NAFTA region divided by the total pollution eliminated at time *t*.

$$B^t_{PP} = \begin{pmatrix} b^t_{cc} & b^t_{CM} & b^t_{CU} & 0 \\ b^t_{MC} & b^t_{MM} & b^t_{MU} & 0 \\ b^t_{UC} & b^t_{UM} & b^t_{UU} & 0 \\ b^t_{PC} & b^t_{PM} & b^t_{PU} & 0 \end{pmatrix} \qquad \text{and}$$

Note that B^t_{PP} is equal to B^t_P considering that the institutional sector of pollution elimination does not require neither produces capital goods.

$$Y^t = \begin{pmatrix} Y^t_C \\ Y^t_M \\ Y^t_U \\ -Y^t_P \end{pmatrix}$$

Let $A^t_P = A_P(t)$ be the augmented matrix of technical coefficients that change with the time, and let $B^t_P = \left(b^t_{ij}\right)$ be the augmented matrix of capital coefficients at time *t*, where *i, j = C, M, U and P*. This use of the capital coefficients assumes that production is at or near effective capacity of country *j*. Thus, the exports to NAFTA region at time *t* from country *j* satisfies:

$$\begin{aligned} X^t_j = \; & a^t_{jC} X^t_C + a^t_{jM} X^t_M + a^t_{jU} X^t_U + a^t_{jP} \hat{X}^t_P \\ & + b^t_{jC} \left(X^{t+1}_C - X^t_C\right) + b^t_{jM} \left(X^{t+1}_M - X^t_M\right) \\ & + b^t_{jU} \left(X^{t+1}_U - X^t_U\right) + Y^t_j \end{aligned}$$

for $j \; \varepsilon \; \{C,M,U\} = E$ and for $j = P$

$$\hat{X}^t_P = \sum_{i \varepsilon E} a^t \; X^t_i + \sum_{i \varepsilon E} b^t \left(X^{t+1}_i - X^t_i \right) - Y^t_P$$

The coefficients $b^t_{ij} \;\; i, j \, \varepsilon \, E$ represent the imports of capital goods of country *j* from country *i* divided by total exports of *j* to NAFTA region at time *t*, from equations in matrix form we have that for both dynamic models.

$$X^t = A^t X^t + B^t \left(X^{t+1} - X^t \right) + X^t \qquad -(1)$$

$$\left(I - A^t + B^t \right) X^t - B^t X^{t+1} = Y^t \qquad -(2)$$

Let $G^t = \left(I - A^t + B^t \right)$, thus from equatin (2) we have:

$$G^t X^t - B^t X^{t+1} = Y^t ,$$

If Y^t *for* $t = 0, \ldots, T$ is estimated, then one can solve recursively the system

$$\begin{bmatrix} G^0 & -B^0 & & 0 & 0 & 0 \\ 0 & G^1 & \cdots & 0 & 0 & 0 \\ \vdots & & & & & \vdots \\ 0 & 0 & \cdots & G^{T-2} & B^{T-2} & 0 \\ 0 & 0 & & 0 & G^{T-1} & -B^{T-1} \\ 0 & 0 & & 0 & 0 & G^T \end{bmatrix} \begin{bmatrix} X^0 \\ \\ \vdots \\ \\ X^{T-1} \\ X^T \end{bmatrix} = \begin{bmatrix} Y^0 \\ \\ \vdots \\ \\ \\ Y^T \end{bmatrix}$$

we solve for $X^T, X^{T-1}, \ldots,$ etc., in that order until X^0. Thus, we get the solution $X^0, X^1, \ldots, X^T$.

We can derive **the dynamic model of prices of pollution elimination**. To derive the total elimination cost of $\hat{X}^t_P$ pollution in NAFTA region at time *t*, we have to get P^t_P as a function of time *t.* Let

$$A^t_{PP} = \begin{pmatrix} a^t_{CC} & a^t_{MC} & a^t_{UC} & 0 \\ a^t_{CM} & a^t_{MM} & a^t_{UM} & 0 \\ a^t_{CU} & a^t_{MU} & a^t_{UU} & 0 \\ a^t_{CP} & a^t_{MP} & a^t_{UP} & 0 \end{pmatrix}, \qquad P^{*t} = \begin{pmatrix} P^t_C \\ P^t_M \\ P^t_U \\ P^t_P \end{pmatrix}, \qquad V^{*t} = \begin{pmatrix} V^t_C \\ V^t_M \\ V^t_U \\ V^t_P \end{pmatrix}$$

and ℓ_4 = (0 0 0 1), thus the prices at time *t* are: $P^t_P = \ell_4 \left(I - A^T_{pp} \right)^{-1} V^{*t}$; and the total pollution elimination cost C^t in NAFTA region by year is given by:

$$C^t = \hat{X}^t_P \cdot P^{*t}_P = \ell_4 \left(I - A^t_{PP} \right)^{-1} V^{*t} \, \ell_4 \, X^t \quad \text{for } t = 0, \ldots, T.$$

Note that $\hat{X}_P^t$ corresponds to the total amount of pollution elimination for *t = 0, 1,...,T*. X^t is the concatenated vector of exports and pollution elimination. Given the total cost of pollution ellimination C^t one can get the pollution elimination cost for each country C_j^t, that it is a function of the pollution generation and the pollution elimination coeficients

$$C_j^t = F_j\left(a_{Pj}^t, a_{jP}^t\right) \quad , j = C, M, U .$$

Finally, an input-output model for NAFTA's effects on pollution could be a practical step toward "sustainability" as defined by Solow. If we would speak about the economy in a more sensible and precise way, we might actually be better able to conduct a rational policy in practice with respect to natural and environmental resources. Furthermore, if the environment is a global issue, then NAFTA is a good way to develop the so-called "industrial ecology" (Duchin and Lange, 1994) in overall regions, in order to achieve a "win-win" situation in which a policy aimed at improving the set of economic variables X will lead to improving the set of ecological variables Y.

Concluding Remarks

Since pollution emission and pollution reduction are global issues, the most satisfactory way to achieve sustainable development in the context of NAFTA is through active government participation aimed at a satisfactory multiregional solution, which should be based on a well-behaved multiregional ecological input-output model. We are addressing one of the present-day paradoxes: economic globalization and free market philosophy on the one hand, and active government participation and policies on the other hand in order to achieve sustainable development. The main problem in applying a multiregional, ecological input-output model is the lack of available data on sector-based pollution generation and pollution elimination costs in the case of Mexico. Therefore, Mexican authorities should publish this kind of data as part of the System of National Accounts in order to improve the policy-making process in the area of the environment.

References

- Bhagwati, J. (1993), "The Case of Free Trade", in *Scientific America,* November.
- *Business Week,* November 22, 1993.
- Cropper, L.M., and Oates, E.W. (1992), "Environmental Economics: A Survey", in *Journal of Economic Literature,* Vol. XXX, June.
- Daly, H.E. (1993), "The Perils of Free Trade", in *Scientific American,* November.
- Duchin, F. and Lange G.M. (1994), "Strategies for environmentally sound economic development", in Jansson, A., Hammer, *et al*. (editors), *Investing in Natural Capital: The Ecological Economic Perspective,* Island Press.
- Eatwell, J., Milgate, M. and Newman, P. (editors,1987), *The New Palgrave: A Dictionary of Economics,* W.W. Norton & Company, 1987.
- Lange, G.M. (1994) *Strategic Planning for Sustainable Development Using Natural Resource Accounts: The case of Indonesia*, New York University Press.
- Leontief, W., *et al.,* (1977), *The Future of the world economy: A United Nations Study,* Oxford University Press.
- Leontief, W. (1986) *Input-Output Economics*, Second Ed., Oxford University Press.
- Merchand, C. (1992), *Radical Ecology,* New York, Routledge.
- Miller E.R. and Blair, P.D. (1985), *Input-Output Analysis Foundations and Extensions*, Prentice Hall, Inc,. NJ.

- Phillsbury, Madison and Sutro (1993), *Mexico Report*, Winter.
- SECOFI (1994a), *Fracciones Arancelarias y Plazos de Desgravación, Tratado de Libre Comercio de América del Norte*, Porrúa Ed., México.
- SECOFI (1994b), *Tratado de Libre Comercio de América del Norte, Texto Oficial*, Porrúa Ed., México.
- Solow, R., "An Almost Practical Step toward Sustainability", in *Resources for the Future.*
- Taylor, L. (1994), "Environmental and Gender Feedbacks in Macroeconomics", Mimeo.
- *The New York Times*, November 8, 1993.
- The World Bank (1992), *World Development Report,* Oxford University Press.
- The Organisation for Economic Co-operation and Development(1996, 1998), *Environmental Performance Reviews.*
- United States District Court for the District of Columbia (1993), *Civil Action #92-2102 (CRR)*, June 30.
- Wilson, E.O. (1991), "Biodiversity, Prosperity and Value", in Bormann, R.H. and Keller, S., *Ecology, Economics, Ethics The Broken Circle*, NH, Yale University Press.

Notes

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1 For example, in a environmental and gender analysis L.Taylor (1994, p. 5) recommends to work with flow environmental variables such as volume of logging per year and stocks such as the percent of national forest cover. In the same way, G.M. Lange (1994, p. 1) considers that the United Nations Statistical Office has added Natural Resource Accounts (NRA) to the System of National Accounts (SNA). NRA are constructed initially in physical units as stock and flow accounts. The flow accounts are similar in structure to the input-output table of the SNA: for each sector and for households, the flow accounts record the extraction of resources, the use of resources in production, and the discharge of waste materials or other impact on the environment.

2 The velocity to reduce the overall levy chargers is classified in: immediate, fifth annual equal stages, tenth annual equal stages, and fifteenth annual equal stages, all of which started in January 1st, 1994 (SECOFI, 1994a, pp. 12-13).

3 This text also refers to the specific relationship with another environmental and conservational treaties: International Trade of Threaten Species Convention (Washington, March 3, 1973), Montreal Protocol about depleting substances of the ozone layer (Montreal, September 16, 1987), The Basilea Treaty about control of border movements of hazardous waste (Basilea, March 22, 1989), The agreement between the governments of Canada, and USA about the border movements of hazardous waste (Ottawa, October 28, 1986), and the Treaty between Mexico and USA about the Protection and Improvement of the environment in the border zone (La Paz, Baja California Sur, August 14, 1984).

4 *Business Week* (1993, p. 40).

5 There are many other pollutants, however, Duchin , and Lange (1994, pp. 259-262) estimate that the emission of these three pollutants still increase substantially between 1990 and 2020, since people in developing regions can be expected to aspire to the material standards of those in developed regions.

6 This value of Yp could be the optimal but it is so far of reality because Duchin & Lange (1994, pp. 260-261) have showed that the pollution emission will increase between 1990 and 2020, in particular carbon emissions nearly double in all the world from 5 632 metric tons to 9 044 mt.

7 This is a Coase's contribution which emphasizes the reciprocal nature of externalities and suggests remedies based on common law doctrines (Eatwell J. *et al.*, editors, 1987).

8 Cropper and Oates (1992).

9 Leontief (1986, 294-320) states that the dynamic inverse could play a role analogous to the role played in static input-output analysis by the inverse of the flow coefficient matrix. While in a static inverse such effects can be described by a single number, within the framework of dynamic analysis they have to be presented in a time series. Every element of this inverse is itself a square matrix.