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Free Trade and Pollution in the Manufacturing Industry in Mexico: A Verification of the Inverse Kuznets Curve at a State Level

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Abstract

There has been a long debate about the effects that free trade has on pollution. Most empirical analysis on this topic has focused at the national level. The objective of this study is to see if there is a relationship between the pollution generated by the manufacturing industry in each of Mexico's 32 states and the North American Free Trade Agreement (NAFTA). This was done via panel data regression models using information on pollution, income, and degree of trade from each of the states for the years 1993 and 2000. The pollution index level was constructed using the Industrial Pollution Projection System from the World Bank. In general we found a positive relationship between trade liberalization and pollution caused by manufacturing. Furthermore, we found that income and pollution follow the relationship expressed in the Environmental Kuznets Curve.

Keywords: Free Trade, Pollution in manufacturing industry, Environmental Kuznets Curve, State-level data.
***JEL classification*:** F18, Q56

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Resumen

Existe un largo debate acerca de los efectos que la apertura comercial ha traído sobre la contaminación ambiental. En general, la relación entre contaminación y apertura comercial en México, se ha estudiado en el nivel nacional. El objetivo de este estudio es determinar si existe una relación –para cada estado del país- entre la contaminación del sector manufacturero en México y la apertura commercial, después de la firma del Tratado de Libre Comercio de América del Norte. Para ello, se realizó una estimación de tipo panel con datos de las 32 entidades federativas de México para los años 1993 y 2000. Fueron analizadas variables, como apertura comercial, nivel de ingreso y niveles de contaminación, las cuales se construyeron usando el *Industrial Pollution Projection System* del Banco Mundial. Se encontró que, en lo general, la apertura tiene una relación positiva sobre la contaminación; además, se observó que la relación entre ingreso y contaminación está definida por la curva inversa de Kuznets para el medio ambiente.

Palabras clave: Libre comercio, contaminación en la industria manufacturera Pollution, curva ambiental de Kuznets, datos en el nivel estatal.
Clasificación JEL: F18, Q56

Introduction

As Mexico signed the North American Free Trade Agreement (NAFTA) there was much debate of the ecological outcome of such a contract. Two polar views of the possible outcomes were represented by Bhagwati (1994) and Daly (1994). On the one hand, Bhagwati believes that free trade helps improve the environment because it allows a country the possibility to import cleaner technology. In addition, the eventual rise in average income will increase the social demand for a cleaner environment, which is expressed in the Environmental Kuznets Curve, (EKC), see Bhagwati (1994). On the other hand, Daly believed Mexico would become a pollution haven, as dirty industries would migrate to Mexico trying to escape higher pollution abatement costs (Gallagher, 2004).

Mexico's economy went through several structural reforms after the crisis in the beginning of the eighties. The trade liberalizing strategy started with the integration to the General Agreement on Tariffs and Trade (GATT) in 1986, followed by regional integrating agreements, in which the North American Free Trade Agreement (NAFTA) was the first and most important. NAFTA began to operate the first of January of 1994. By November of 2006, Mexico had signed 12 other similar agreements that involved trade with 17 countries plus those of the European Union. NAFTA is the only trade agreement that contains an environmental protocol.

The debate about the environmental outcome of a free trade agreement began in the late 1970s, and still is a topic of great controversy. Some are afraid that there may be a generalized lowering of environmental standards in order to obtain foreign investment or to help local industries; this is known as a race to the bottom (Murandian and Martinez-Alier, 2000). Some of these concerns are based on the environmental damages that occurred along the border between the United States and Mexico as maquiladoras were established there. As Steininger (1994) states, this damage may have occurred because of Mexico's relatively lax environmental standards compared to the ones in the United States.

Trade liberalization in Mexico has had an evident effect in increasing its manufacturing exports. Mexico's main export since 1985 has been manufacturing, replacing petroleum. In September of 2006, manufacturing exports represented[1] 82.5% of total exports. Given the importance of the environment for a sustainable development and the large role manufacturing production has played on exports, this study's objective is to analyze the effect Mexico's trade liberalization had on the level of pollution produced by the manufacturing industry in each state. Analyzing state-level data has rarely been used in empirical studies in developing countries. It is important to consider the heterogeneity that exists between Mexico's states. For example, the environmental legislation[2] and its enforcement is different in each state of the country. In addition, Salazar and Varella (2004) pointed out that the effects on production from trade liberalization have been different among states. Therefore, taking into account theses differences can lead to a better measurement of the relation under consideration.

This paper comprises five sections. Section 1 discusses the theoretical framework, which includes some of the hypotheses of the relationship between economic productivity and trade, and the environment. Section 2 discusses the results of previous studies done in Mexico. The section 3 lays out the empirical framework, calculations of a pollution index for Mexico's manufacturing sector, the description of the data used and the empirical model. In the section 4 are presented the explanations of the procedure, and a

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[1] Calculations based on information obtained from the BIE-INEGI, consulted December 6, 2006.

[2] The federal government is responsible of establishing environmental norms, but each state has to legislate their own environmental laws. Even municipal governments have adopted their own set of laws in respect to the environment (M. J. Braqdley and Associates, 2004:16).

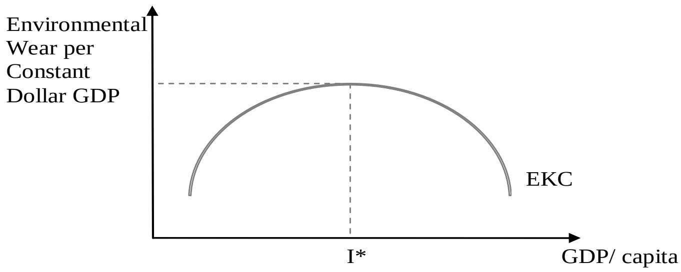
discussion of the results and conclusions are provided in the last section.

1. Theoretical Framework

In the neoclassical theory of international trade, Heckscher and Ohlin's theorem of comparative advantage states that free trade will help each country export goods which are produced intensely with the abundant factor, see Wong (1997, 91). Following the implicit idea in this theorem and considering the environment as a resource, a hypothesis could be established in relation to trade liberalization, in which countries that have relatively abundant environmental resources will tend to change their production towards goods that are intensive in these resources, increasing the risk of greater pollution levels. Lucas, Wheeler and Hettinge (1992) explain that an increase in pollution in developing countries may be a result of a shift in comparative advantage towards more capital intensive, and therefore pollution intensive economic activities. This is predicted by Daly (1994, 12): "the costs of environmental degradation grow at a faster rate than the benefits from economic growth, which in the end, makes us poorer, not richer."

The specialization in production brought about by trade liberalization allows each country to assign resources more efficiently, reaching greater production and income. Radetski (1994, 134) adds that the environment is a normal good. Parting from this idea, if international trade increases income, then it will also promote environmental quality. Radetski (1994, 131) proposed the relation shown in the following diagram.

Figure 1
Income and the environment: Environmental Kuznets Curve



The figure 1 illustrates that income *per capita* and environmental degradation have a positive relation up the average level of income *per capita*, I*, then the relation is inverted as income *per capita* increases. This relationship is known as the Environmental Kuznets Curve (EKC). This shape can result due to the development path of a country. More contamination is produced as industrialization takes off, but at higher levels of development there are structural changes, more efficient technologies and increased demand for environmental quality that lead to a reduction in environmental degradation, see Panayotou (2000, 2).

Selden, Forrest and Lockhart (1999) summarize the three mechanisms through which one can identify the effects of economic growth because of international trade has on the environment. These mechanisms are: scale, composition and technique effects. *Scale* effect is when free trade causes production to expand. If the production process is maintained the same, but output is increasing, then pollution must be increasing. The *composition* effect is when changes in trade policy cause a country to specialize in its comparative advantage. If a comparative advantage is created because of relatively laxer environmental standards, then this effect may cause an increase in pollution. The third effect, *technique*, is when technological changes improve production processes so they pollute less; idea originally stated by Grossman and Krueger (1993) based on the assumption that new technology would be more energy-efficient and use cleaner sources of energy. Cleaner technologies can result from international transfers due to free trade and foreign investors, as well as the increase demand of citizens for cleaner processes as free trade increases personal income.

2. Literature Review

Many authors have studied the relation between trade liberalization and its effect on economic growth. Rodríguez and Rodrik (1999) presented a critical analysis of important studies based on this relationship and concluded that there is not a consensus, but that most of the evidence confirms the theoretical hypothesis of a positive relation between international trade and income. Díaz-Bautista (2003) found this holds true for Mexico during the years 1970 to 2000. Furthermore, Salazar and Varella (2004) estimated positive effects of the growth in manufacturing production on the export specialization using state-level data.

Bhagwati (1994) agrees that free trade expands economic growth and production. He believes that this will help the environment because the greater tax revenues generated by the increased trade can be used for conservation. Bhagwati also explained that free trade could help improve the environment by transferring cleaner technologies to developing countries. He based his explanation on the EKC hypothesis.

Grossman and Krueger (1993) were the first to test and find empirical evidence of the EKC hypothesis. They found that the common turning point for sulfur and smoke on this curve is around US$ 5,000 (PPP terms prices of 1985) average *per capita* gross domestic product. Even though Mexico reached an average of US$ 8,000 GDP *per capita* in 1999, it has not yet reached the turning point on the EKC (Gallagher, 2002). There has been a large range of estimated turning points, if any, depending on the pollution taken into consideration. List and Gallet (1999) did a state-level analysis of air pollution in the United States for the years 1929 to 1994. They found estimated turning points for nitrogen oxide (NO_x) at US$ 10,778 (prices of 1987) *per capita* income and US$ 20,138 (prices of 1987) *per capita* income for sulfur dioxide (SO_2). Taylor (2003) in a multi-country study estimated that a 1% increase in income per capita decreases pollution concentration in 1%.

Gallagher (2005) asserts there is limited evidence of an EKC for a single country. The majority of early EKC studies utilize cross-section data of largely developed countries, for more details see Gallagher (2005, 6). Therefore this study contributes to the understanding of the EKC by analyzing a single developing country, Mexico, and by analyzing an aggregate pollution index that is risk weighted according to its toxicity to human health.

There has been a wide range of research trying to answer the effects that free trade has on the environment in Mexico. Even though there is a wide variety of methods used, there is not a consensus of the effects. Grossman and Krueger (1993) did a cross-sectional study for 1987, where they analyzed whether the high air pollutants abatement costs in the United States affected its imports from Mexico. They found a positive relationship between higher costs and greater imports from Mexico, but it was small and statically insignificant. Furthermore, Kahn (2001) compared pollution of the Toxic Release Inventory (TRI) in the United States and other countries, among them Mexico, for 1972, 1982 and 1992. He found that the level of pollution in goods that United States imported from Mexico had been decreasing.

Other studies have concentrated on finding out whether Mexico is a pollution haven through analyzing Foreign Direct Investment (FDI). Eskeland and Harrison (1997) found a positive relationship between pollution abatement costs and FDI, in a cross-section study for the year 1990. Furthermore, Waldkirch and Gopinath (2004) found that for industries where FDI and air pollution levels are positively related, these industries receive almost 40% of the FDI. These industries also account for 30% of all output.

A different method used to evaluate the effects of free trade on pollution is through analyzing changes in each sector. Gallagher (2004) compared five of the dirtiest air polluting industries in the United States to the same ones in Mexico for the years 1988, 1994 and 1998. He found out that the manufacturing production of these industries decreased in the United States, but surprisingly decreased even faster in Mexico; rejecting the hypothesis that polluting industries in the United States moved to Mexico. In a further study, for the period 1988-2000, Gallagher (2002) found that emissions in Mexico decreased 10% from 1988 to 1994, but after NAFTA, from 1994 to 2000, emissions doubled.

Islas-Camargo (2002) calculated the Revealed Comparative Advantage (RCA) of five dirty industries for 34 countries, Mexico among them, for the years 1970-1972, 1980-1982 and 1990-1992. The five dirty industries considered are: ferrous metals, non-ferrous metals, chemical substances, petroleum derivatives, and paper, prints and editorials. In general the author found that developing countries have a tendency to form a RCA in these dirty industries, while developed countries have the opposite tendency. Mexico, in particular, was demonstrated to have a revealed comparative advantage in ferrous metals and petroleum derivatives, which was not the case in the initial years of 1970-1972.

The methods used, as well as the results obtained in examining the effects of free trade on pollution levels are widely varied. One of the greatest problems is the lack of information about pollution in Mexico. Many studies on the environment and production processes are done with data adapted from the United States. Ten Kate (1993) was the first to use data from the Industrial Pollution Projection System (IPPS) from the United States and adapted them to Mexico, later Mercado and Fernández (2005) use the IPPS for Mexico again. This system provides estimated data for pollution intensities, per unit of production or number of employees, in each sector. Ten Kate (1993) found that from 1950 to 1970 the number of polluting industries in the manufacturing sector en Mexico increased 50%, increasing only 25% from 1970 to 1989. He explains this change is due to the composition effect. He also ascertained that manufacturing industries were polluting 20 times more in 1989 than in 1950, which is explained by the scale effect.

Using IPPS data for other countries has three implications. First, equal technology and environmental standards to those in the U.S. are assumed by using U.S. emissions. It is also assumed that the production of each manufacturing industry is similar to those in the United States, leading to the postulation that emissions are related to output and not on added value, see Lucas *et al*. (1992, 71).

3. Research Method

Given the fact that there is not sufficient pollution data at the state level in Mexico, these had to be constructed using the IPPS. As Hettige *et al.* (1994, 1) state:

> "IPPS has been developed to exploit the fact that industrial pollution is heavily affected by the scale of industrial activity, its sectoral composition, and the process technologies which are employed in production. Although most developing countries have little or no industrial pollution data, many of them have relatively detailed industry survey information on employment, value added or output. IPPS is designed to convert this information to the best feasible profile of the associated pollutant output for countries, regions, urban areas, or proposed new projects. It operates through sector estimates of pollution intensity, or pollution per unit of activity."

Calculations were done by adapting the linear acute human toxic intensity[3], estimated by Hettige *et al.* (1994) for 74 industries in the United States in 1987, to Mexico's manufacturing production. The 74 U.S. industries were grouped by adding the linear acute human toxic index into one of the nine corresponding manufacture divisions of the Mexico's National Computing System "Sistema de Cuentas Nacionales." The nine divisions of the manufacturing divisions were used due to the accessibility of the data. The risk-adjusted pollution weights, in pounds per $1,000,000 U.S. dollars of production, for each of the nine manufacturing divisions are presented in Table 1.

The risk-weighted amounts that appear in Table 1 coincide with the six most polluting industries, which are: iron and steel, non-ferrous metals, chemical substances, pulp and paper, non-metallic minerals, and petroleum refineries, see Murandian and Martinez-Alier (2000). It can be seen that the fifth division, chemical substances, is highly contaminating.

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[3] Hettige *et al.* (1994) calculated a Toxic Release Inventory (TRI) index for 74 industries in the U.S. for 1987 in pounds per $1,000,000 dollars of production. They used information from the Toxic Chemical Release Inventory, elaborated by the Environmental Protection Agency (EPA), referent to the annual emissions of 328 toxic chemicals substances produced by approximately 20,000 industrial firms in the U.S. during 1987. The annual quantities of polluting substances were aggregated and then weighted from 0 to 4 according to their level of toxicity, taking into account the toxicity index and carcinogenic reported in the Human Health and Ecotoxicity Database, elaborated by the EPA.

Table 1
Mexico's risk-weighted pollution weights

Manufacturing division	Risk-weighted pounds/ million of dollar output value
I. Food, beverages and tobacco	16.3
II. Textiles, clothing and leather	74.7
III. Wood industry and products	74.7
IV. Paper, paper products, prints and editorials	63.25
V. Chemical substances, petroleum derivatives and plastics	257.36
VI. Non metallic mineral products, except petroleum derivatives and coal	18.63
VII. Basic metallic industries	26.16
VIII. Metallic products, machinery and equipment	59
IX. Other manufacturing industries	32.79

After estimating the nine weights, they are multiplied by the corresponding dollar value of each manufacturing division of each state.[4] An index of volume of pollution adjusted to human health risks for each state is obtained by converting the result into tons. These pollution indexes are shown for each state in Table 2 for the years: 1993, 2000, 2003 and 2004.

In the majority of the states the largest pollution estimations were emitted in the year 2000. After a substantial increase from 1993 to 2000, there was a very slight decrease from 2000 to 2004. There are only eight states that did not decrease their pollution levels during that time: Coahuila, Colima, Guanajuato, Hidalgo, Nuevo Leon, San Luis Potosi, Sinaloa and Tamaulipas. The three states with the largest amount of pollution are: Distrito Federal, Mexico and Nuevo Leon. The states holding the fourth and fifth most polluted status have changed over time. In 1993, Veracruz and Jalisco were ranked as the fourth and fifth most polluted states, respectively, whereas in 2004 Coahuila took Veracruz´s position and Jalisco remained constant.

The three most polluting states are also the states that have the larges manufacturing production. It is worth analyzing Guanajuato as it moved from forth place of manufacturing production in 1993 to fifth place in the year 2000. Guanajuato has less manufacture activity than Coahuila or Jalisco, but the industries located in Guanajuato are more toxic according to the IPPS. This is due in part to the large participation in the plastic and petroleum derivative industry, but mostly to the increasing participation in

[4] The *"Sistema de Cuentas Nacionales de México"* shows the participation of each manufacturing division in percentages. Multiplying this times the value of the production in thousands of pesos at 1993 constant prices, the GDP of each division for each State was obtained. Then it was converted into millions of dollars with a peso-dollar exchange rate of 3.11 from Banxico.

the metallic production and machinery production. This division was responsible for 11% of Guanajuato's total manufacture GDP in 1993, expanding up to 40% in 2000.

Table 2
Mexico: Distribution of Manufacturing Pollution Volume by State

Name of State	**1993**	**2000**	**2003**	**2004**
Aguascalientes	21.41	46.12	42.32	46.15
Baja California	49	106.68	85.35	97.22
Baja California Sur	0.84	1.68	1.32	1.29
Campeche	0.94	1.23	1.57	1.43
Coahuila	87.94	160.06	178.57	189.7
Colima	2.76	3.87	3.63	4.09
Chiapas	9.5	7.45	6.5	6.55
Chihuahua	75.4	130.31	105.77	109.83
Distrito Federal	672.18	903.61	821.49	792.56
Durango	18.64	24.15	21.82	23.48
Guanajuato	109.21	193.21	205.04	230.3
Guerrero	4.37	5.98	5.94	5.87
Hidalgo	53.76	70.52	64.91	75.08
Jalisco	162.41	208.31	180.63	190.35
Mexico	507.36	654.38	599.43	626.51
Michoacan	29.32	45.67	40.17	41.34
Morelos	55.3	60.24	61.14	60.72
Nayarit	2.61	2.74	2.45	2.38
Nuevo Leon	195.65	305.38	297.95	319.67
Oaxaca	39.2	42.79	43.36	44.37
Puebla	80.68	143.19	143.36	133.02
Queretaro	60.52	121.72	112.6	123.29
Quintana Roo	1.87	2.27	2.49	2.48
San Luis Potosi	32.4	55.59	53.46	56.19
Sinaloa	8.73	10.81	10.88	11.8
Sonora	34.55	56.8	41.17	44.85
Tabasco	10.09	10.8	9.73	10.6
Tamaulipas	92.98	153.16	150.32	165.43
Tlaxcala	23.82	32.013	28.66	30.08
Veracruz	170.73	154.14	145.45	149.56
Yucatan	11.6	18.1	17.07	17.87
Zacatecas	1.82	3.14	3.16	3.41
National	2627.57	3736.12	3487.71	3617.49

Note: Annual risk weighted tons of pollution according to the linear acute human toxic intensity.

3.1 Model

It has been reported that Lucas, Wheeler and Hettige (1992) related production with pollution through the following model:

$$Ln(N)_k = \alpha + (\beta_1 + \beta_2 Y_k)t + (\beta_3 + \beta_4 Y_k)Y_k + \varepsilon_k \quad (1)$$

Where: N_k is the toxic intensity calculated relative to total manufacturing production in each country (k) studied; Y_k is real income per capita and t is time. The coefficient β_1 represents the intensity growth tendency; β_2 is the tendency of the intensity growth with respect to the income; β_3 is the contribution of the income per capita to the toxic intensity; β_4 is the coefficient that goes with the squared real income per capita, which is to capture possible decreases in pollution emissions with greater income levels, and ε_k is the error term.

Frankel and Rose (2002) used a similar model as the one described above, but included other variables, resulting in the following model:

$$\begin{aligned} Envdamage_{it} &= \alpha + \beta_1 (GDP/Y)_{it} + \beta_2 (GDP/Y)^2{}_{it} + \beta_3 Openess_{it} \\ &+ \beta_4 Dem_{it} + \beta_5 (Pop/Y) + \varepsilon_{it} \end{aligned} \quad (2)$$

Where the independent variables are the following: income per capita, income *per capita* squared, one variable for trade openness, another for the level of democracy, and finally, population density.

The model used in the current study is similar to the two models shown above. It is very similar to the one Frankel and Rose (2002) used, but it does not include the last two variables mentioned. The variable of level of democracy was not included because it is not studying different countries, although a further study might include the political divergence between states or regions (northern and southern). Furthermore, Frankel and Rose (2002) used the variable of population density to evaluate how personal waste contributes to pollution. Using this variable is not valid in this study because the dependent variable, the volume of pollutants, was constructed based on the level of manufacturing pollution and not on the total amount of pollution in the atmosphere.

The model used in this study is based on a dependent variable, manufacture pollution volume, and the following three independent variables: a) level of trade openness; b) income *per capita* and c) income *per capita* squared. Given the high differences between the 32 states in Mexico, it was chosen to estimate the model using panel data and weighted least squared (WLS) methods. Two years, 1993 and 2000, were considered to capture the effect before and after trade liberalization (NAFTA).

3.2. Variables

The dependent variable is manufacturing Pollution Volume index (PV) measured in risk weighted tons per each million of real dollars worth of manufacturing production, with base year of 1993.

There are three proxies for the degree of openness variable: Trade openness Index (TI), an Export Index (EI) and an Export Specialization Index (ESI). The first is the sum of exports and imports of each state divided by the corresponding state's total GDP. The export index equals exports divided by total GDP for each state. The export specialization index equals the quotient of exports of each state divided by the manufacturing GDP of each state, over national exports divided by national manufacturing GDP. These three openness measures have been used by several authors as referred by Rodríguez and Rodrik (1999), and recently by Ortiz (2003). Frankel and Romer (1999) caution the possible endogeneity problem implicit in using the trade openness index as a determinant of economic growth. They suggest the use of instrumental variables, in particular the orthodromic distance. However this variable has not been found for Mexico, therefore the use of a trade openness index is one of the limitations of the present study and an opportunity for future investigations.

It is ambiguous of what the expected sign of the coefficient for the variable of trade openness should be. From the literature review, those that believe the hypothesis that free trade improves the environment would expect a negative sign, because the greater the degree of openness the lower the pollution levels. On the other hand, a positive sign is expected if greater trade openness leads to greater pollution levels.

The income *per capita* variable is GDP *per capita*. Therefore, the EKC hypothesis predicts that the coefficient of the squared income *per capita* variable should be negative, indicating that the curve will eventually begin to fall and there will be an improvement in the environment while income increases, see Frankel and Rose (2002, 14). The sign of the coefficient of the income *per capita* variable depends on where a state is located on the curve. It will be positive on the first part of the curve, indicating more environmental damage, and it will be negative if it is located on the second part of the curve where pollution emissions decrease as income increases. The data was obtained from the electronic web page of the bank of economic information (BIE) in Mexico's *Instituto Nacional de Estadistica Geografía e Informatica*[5] *(INEGI).* Table 3 presents a summary of the variables and

[5] One of the complexities of estimating the GDP per state is in assigning the correct value of production done by units of companies that have different geographical divisions around the country. In relation to this, INEGI follows the standard procedure which

Table 4 shows the descriptive statistics of the different variables used in this study.

Table 3
Description of the Variables

Variable	Description	Source
PV: Pollution Volume Index	Estimation of the emissions risk weighted to human health, measured in annual tons per million of U.S. dollar production. The variable was estimated using the linear acute human toxic intensity of the IPPS. (Risk weighted tons per million dollars of production)	Author`s construction based on the IPPS procedure of Hettige, Martin, Singh and Wheeler (1994).
ESI: Export Specialization Index	Quotient of exports of each state divided by the manufacturing GDP of each state, over national exports divided by national manufacturing GDP.	Author`s construction with information from Secretaría de Economía for export data and bank of economic information (BIE) in Mexico's Instituto Nacional de Estadistica Geografía e Informática (INEGI) for GDP data.
TI: Trade Openness Index	Sum of exports and imports of each state divided by the corresponding state's total GDP.	Author`s construction with information from Secretaría de Economía for export and import data and bank of economic information (BIE) in Mexico's Instituto Nacional de Estadistica Geografía e Informática (INEGI) for GDP data.
EI: Export Index	Exports divided by total GDP for each state.	Author`s construction with information from Secretaría de Economía for export data and bank of economic information (BIE) in Mexico's Instituto Nacional de Estadistica Geografía e Informática (INEGI) for GDP data.
INC: GDP *per Capita* in U.S. dollars 1993=100	GDP in millions of U.S. dollars divided by the population.	Author`s construction with information from the bank of economic information (BIE) in Mexico's Instituto Nacional de Estadistica Geografía e Informática (INEGI) for GDP data.

dictates that the correct assignment is to record values of production depending on where they are produced and not where the headquarters are. This is understood from part 5 section C paragraph 5.29 in the "Sistemas de Cuentas Nacionales de México" 1993.

Table 4
Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
PV	99.43277	169.3941	0.8404	903.6086
ESI	72.7492	106.3485	1.037619	502.3435
TI	0.220576	0.296659	0.005484	1.173067
EI	0.114351	0.167799	0.001611	0.701711
INC	0.00443	0.002101	0.001904	0.012268

Note: 64 panel type observations. Quantities are in millions of U.S. dollars.

4. Findings

Two models are proposed. The first one, equation (3), assumes that the coefficients of the slope and of the intercept are the same between states. The first model is written below, where *i* represents each state and *t* is time.

$$Log\ PV_{it} = \alpha + \beta_1\ TO_{it} + \beta_2\ INC_{it} + \beta_3\ INC^2_{it} + a_i + \varepsilon_{it} \qquad (3)$$

$i = 1, 2, ..., 32$; $t = 1, 2$, where $t = 1$ corresponds to the year 1993 and $t = 2$ is for the year 2000.

For the degree of trade openness (TO), three indicators (ESI, EI and TI) are proposed. INC_{it} is the state's *per capita* GDP at time *t*. The term $a_i + \varepsilon_{it}$ is the combined error. The variable a_i captures all the non-observable factors and constants throughout the time that affect $Log\ PV_{it}$.. Given that *i* denotes differences between states, a_i indicates a non-observable state effect. The term ε_{it} represents the idiosyncratic error, because it changes through time as well as between states. This model was estimated using ordinary least squares (OLS).

The second model, equation (4), assumes the parameters of the slope are the same between states, but that the coefficients of the intercept are different for each state. Therefore, this model can be written as:

$$Log\ PV_{it} = \alpha_i + \beta_1\ TO_{it} + \beta_2\ INC_{it} + \beta_3\ INC^2_{it} + a_i + \varepsilon_{it} \qquad (4)$$

Considering one intercept for each state allows us to take into account the effects of the specific omitted variables of each state (Hsiao, 2003). Given the state divergence in Mexico, the second model is expected to be a better specification to explain the dependent variable. One of the benefits of using panel data information is to control for individual heterogeneity (Baltagi, 2001).

Given the structure of the available information and the possible different intercepts in the models, there are three methods of estimation: Fixed Effects (FE), Random Effects (RE) and Ordinary Least Squares (OLS). Since three measures for trade openness (ESI, EI and TI) are included and three methods of estimation (OLS, FE and RE), nine models are estimated. Table 5 shows the results of the estimations. One interesting result concerning the relation between pollution and level of trade openness is that there is a positive relation in all of the nine models, regardless of what trade openness variable or estimation method was used. However, with OLS estimation, the expected sign for the coefficients of the income and income squared variables were not obtained.

A Chow test was performed to evaluate if the method of fixed effects is more appropriate in explaining the variations in pollution, where the non-restricted model is FE and the restricted model is OLS. Given the three variables for the level of trade openness, this test was done for each of these cases. The F-statistic resulted highly significant, so the null hypothesis of a common intercept in the model was rejected. This result was confirmed by the relatively low levels of the adjusted R^2 coefficients in the OLS estimations, which can be seen in Table 5.

There is still disagreement about which estimation method (FE or RE) is more appropriate. Therefore, a Hausman test was conducted where the results were significant (with p-values of 0.0018, 0.0036 and 0.0096, respectively). The null hypothesis establishes that the appropriate method to use is RE, was rejected. However, the results from this test should be handled with caution (Wooldridge, 2002). As the null hypothesis is rejected, this does not mean that the alternative hypothesis is automatically accepted (Hsiao and Sun, 2000). Because of the weaknesses of the Hausman test, and using economic reasoning as the main decision criterion, it was decided to use RE method and TI as the variable describing the level of trade openness.

Table 5

Results of the three estimation methods and those of the three alternative indicators for trade openness

(Dependent Variable: Log PV)	OLS	FE	RE	OLS	FE	RE	OLS	FE	RE
C	4.4707***	0.0524	0.3478	4.7160***	0.315	0.8168*	4.5244***	0.3487	0.6994
	(0.9957)	(0.3803)	(0.4591)	(0.9536)	(0.4015)	(0.4662)	(0.9778)	(0.3659)	(0.4493)
ESI	0.0068***	0.0004	0.0003						
	(0.0021)	(0.0007)	(0.0007)						
TI				3.0916***	0.395	0.9197**			
				(0.7327)	(0.4475)	(0.4059)			
EI							4.7813***	0.9197	1.4198**
							(1.3157)	(0.6086)	(0.5662)
INC	-699.6364 *	956.9268***	865.9414***	-824.1861***	870.3509***	690.8943***	-711.3344*	874.2594***	761.4484***
	(388.9226)	(125.1494)	(120.2311)	(373.1792)	(145.782)	(137.0724)	(380.0237)	(126.3746)	(121.3492)
INC^2	64687.39**	-37779.12***	-33125.25***	69579.14***	-35171.00***	-27768.38***	62353.96**	-38055.05***	-34218.93***
	(31278.22)	(8988.478)	(8775.534)	(29767.11)	(9179.57)	(8927.911)	(30453.07)	(8666.613)	(8491.689)
R^2 aj.	0.166	0.9941	0.6253	0.2424	0.9942	0.6422	0.1948	0.9945	0.6663
F-Statistic	5.1801	312.1041	36.04666	7.7181	317.2506	38.6918	6.0802	333.3258	42.3646
P-value	0.003	0.0000	0.0000	0.0002	0.0000	0.0000	0.0011	0.0000	0.0000
DW	0.1777	3.8788	1.6034	0.0848	3.8788	1.704	0.095	3.8788	1.711

Notes: *,**,*** Statistically significant at a level respectively of 10%, 5% y 1%. Standard errors are reported in parentheses.
Log PV: Natural Logarithm of Pollution Volume Index.
C: Constant.
ESI: Export Specialization Index
TI: Trade Openness Index ((Exports+ Imports)/GDP)
EI: Export Index (Exports/GDP)
INC: GDP per Capita in US dollars 1993=100.

All the estimated coefficients are statistically significant. The variable TI is economically significant. For example, the corresponding value of the elasticity (evaluated at the corresponding mean value) is 0.2029, that is, maintaining everything else constant, an increase of 10% in the trade openness index, the pollution volume index increases in 2.03%. The expected signs for the estimated income and income squared parameters were obtained. *Ceteris paribus*, the effect of the income *per capita* on the natural logarithm of the pollution volume is positive and declining. The inverted-U shape relation between these two variables indicates that the dependent variable reaches a maximum at a *per capita* income of approximately US$ 12,440 (1993 constant prices), which is above the maximum income *per capita* levels in each state. This indicates that even in the states with the largest levels of average income, the decreasing part of the EKC has not been reached.

Gallagher (2004) estimated the number of years that would take Mexico to reach different EKC turning points assuming that the Mexican economy grows twice the rate it did in *per capita* terms between 1985 and 1999. Gallagher did this calculations based on three turning points: US$ 7,500, US$ 10,000 and US$ 15,000 (at prices of 1985). The present study estimates a turning point at US$ 12,440 (at prices of 1993), which is between $US 10,000 and US$15,000, which Gallagher calculated Mexico to reach in the years 2057 and 2097 respectively. List and Gallet (1999, 410) claim that if estimated turning points occur at extremely high average levels of income, then environmental improvement with economic growth may not be achieved for some countries. This could be the case for Mexico.

Discussion and Conclusion

There is still debate about the effects international trade has on pollution levels. Two representatives of existing polar views are: Bhagwati, who believes that trade liberalization will help improve environmental quality, and Daly, who believes that the environmental degradation is greater than the economic growth a country experiences as it opens its borders to international trade.

There are studies that examine the relationship between international trade and pollution levels in Mexico at a national level, but very few analyze this relation at a state level. Other studies, such as that of Mercado and Fernández (1998), analyze the state-level pollution, but do not relate emissions to international trade. Several models were constructed in the current study to have a better understanding of this relation, given the fact that the theory is still not well defined about the effects international trade has on environmental degradation. In the current study, the pollution index adjusted to human health risks was examined as a form of environmental degradation.

Based on the period analyzed and the data obtained, it is concluded that international trade integration in Mexico had a positive relation with the manufacturing pollution levels between 1993 and 2000. Maintaining everything else constant, an increase of 10% in the trade openness index, increases the pollution volume index in 2.03%, this positive relation has also been found by Gallagher (2002). Although we found a positive coefficient for the openness variable, other authors like Frankel and Rose (2002) and Cole (2004) have found a negative relationship. Nevertheless we did not find any other calculation for this elasticity. Additionally, in the period analyzed, the increase in income had a positive effect on pollution, but this relation is expected to invert itself in the future. According to the results the point where EKC will start to decline is when the average level of income *per capita* reaches US$ 12,440 (at constant prices of 1993). Reaching this point may take many decades. In addition, this study confirms an EKC for a single developing country.

This study contributes to the understanding of some of the effects NAFTA has had by analyzing environmental degradation in the manufacturing sector in Mexico as a result of international trade liberalization. But more research is needed to have a complete understanding of this relation. Some of the limitations of this study are that emissions in Mexico are assumed to be similar to those in the U.S. by using the IPPS to calculated the pollution volume index. Even though this may not be accurate, it is the best estimation that could be calculate given the lack of information on pollution levels in Mexico. Furthermore, it would have been interesting to construct the pollution variable at a greater disaggregation than the nine divisions of the manufacturing industry, but calculation using subdivisions also holds important precision risks, given the fact that there is not sufficient data in Mexico to present weights at such subdivisions. Therefore the elaboration of more precise estimations of emissions is a challenge for future investigations. In order to revise the robustness of the results found in this paper, it could be considered more disaggregated information either by division of activity or/and by analyzing different economic units, such as regions or provinces instead of states.

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