Environmental Emissions and the Role of Technological Change by Sector of Economic Activity in Greece: An Input – Output Analysis (1988-‘98)

Belegri-Roboli, Athena and MARKAKI, MARIA and Michaelides, Panayotis G.

National Technical University of Athens

2005

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ATHENA BELEGRI-ROBOLI
School of Applied Mathematics and Physics
National Technical University of Athens
9 Heroon Polytechneiou
Zografou Campus, 157.80
GREECE
belegri@central.ntua.gr

MARIA MARKAKI
School of Applied Mathematics and Physics
National Technical University of Athens
9 Heroon Polytechneiou
Zografou Campus, 157.80
GREECE
maniam@central.ntua.gr

PANAYOTIS MICHAELIDES
School of Applied Mathematics and Physics
National Technical University of Athens
9 Heroon Polytechneiou
Zografou Campus, 157.80
GREECE
pmichael@central.ntua.gr

Abstract: - This article presents measures of environmental emissions related to economic activity in Greece for the year 2000, using the environmental input-output approach. More precisely, two different technical coefficients matrices, i.e. for 1988 and 1998 respectively, are used for the calculations concerning year 2000. Any differences in the results have their roots in technological change and are expressed through each year's technical coefficients matrix. The application derives the air pollutant production intensities by sector of economic activity for the economy as a whole, as well as for each type of emission. The economic data and environmental data are obtained from the Greek NAMEA tables. The paper's findings demonstrate show that technological change has, in general terms, led to the decrease in emissions and, consequently, air pollution in the 1988-'98 time span.

Keywords: Environmental emissions, NAMEA tables, input-output multipliers, sectors, Greece

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* The project is co - funded by the European Social Fund (75%) and National Resources (25%) - (EPEAEK II) - PYTHAGORAS.

1. Introduction

The question of air quality is a very important issue in the European Union, and member states are required to implement new directives on air quality, which set long-term quality objectives introduced in the Treaty of Amsterdam. In this framework, the present attempts to measure the impact of a change in an industry's final output on air quality, as well as the role of technological change between 1988-1998. The paper is based on the environmental input-output approach. More precisely, the input – output approach implies the use of NAMEA tables (National Accounting Matrix Including Environmental Accounts). NAMEA tables consist of a conventional national accounting matrix extended to include environmental accounts in physical units.

The NAMEA table combines environmental and economic information. More specifically, the NAMEA tables, allow us to analyze the variations of emissions, caused by (a) variations in economic structure, (b) variations in volume, (c) variations in the efficiency of the ecosystems of producers and consumers and (d) variations in the energy supply ([1], p. 55).

The paper is organized as follows: section 2 describes, briefly, the methodological framework; section 3 presents the data used; section 4 presents the empirical results; section 5 concludes the paper.

2. Methodology

Several studies use the input-output framework for estimating the total emission coefficient per unit of production by sector of economic activity and for the final demand categories (i.e. [2], [3], [4], [5], [6]).

In the present paper we use the input-output approach in order to calculate emission multipliers for the various industries and kinds of pollutants. Leontief and Ford [7] consider the emissions of air pollutants as "negative inputs" of the production, because they are outputs or by-products of a given production process. However, Miller and Blair [8] point out that the negative sign is unnecessary if we interpret pollutant generation in terms of the services required to dispose of pollution.

The methodology for constructing embodied pollution indicators is as follows ([5], [6]):

Let **Z** be the matrix of intermediate deliveries, **X** the vector of gross outputs, and **Y** the vector of the final demands. The input coefficients matrix is obtained as follows:

(1) $A = Z x^{-1}$

where $\mathbf{x} = diag\mathbf{X}$ denotes the diagonal matrix with the elements of the vector **X** on its main diagonal.

The balance equation can be written as:

(2) $X = AX + Y$

Solving the balance equation for **X**, we obtain:

(3) $X = (I - A)^{-1} Y$

where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ denotes the Leontief inverse. The typical element l_{ij} of Leontief's inverse denotes the output of industry *i* that is required (directly and indirectly) per euro of final demand for product *j* [9].

For each industry *i*, we then define the direct intensity coefficients ($\mathbf{a_{ik}}$) of the pollutant as emissions ($\mathbf{E_{ik}}$) per gross output (**Xi**), where *k* denotes the type of emission:

(4) $a_{ik} = E_{ik} / Xi \quad (i = 1, 2, \ldots, n)$

In other words, to satisfy one euro of final demand for product *j*, industry *i* produces l_{ij} which embodies $r_i l_{ij}$ of pollution, where r_i denotes the direct intensity (i.e. pollutant to sales ratio).

The next step is to calculate the total induced emission, including the direct effects, as follows:

(5) $e_{ik}' = a_{ik}'(I - A)^{-1}$

where an accent denotes transposition.

Thus, summation over the industries *i*, yields the total amount of pollution embodied per euro of final demand, known as the backward multiplier [10].

3. Data

The data used come from "Natural Recourse Accounts and Environmental Input-Output Tables for Greece, 1988-1998" as well as from the National Accounts of the National Statistical Service of Greece (various years) [1]. These data include NAMEA tables of the Greek economy for the corresponding years. The NAMEA tables also embody the domestic matrix of the intermediate goods (symmetric matrix) for year 1994. This matrix is constant for each year over the period 1988-1998.

The domestic matrix refers to a 7x7 industry classification (Table I, Appendix). The pollutants, for which data are available, are: CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrogen monoxide), NOx (nitrogen oxides), CO (carbon monoxide), NMVOCs (non methane volatile organic compositions) and SO_2 (sulphur dioxide).

4. Empirical Results and Discussion

The direct coefficients for the year 2000 are calculated via equation (4) and the total coefficients are calculated via equation (5) using the relevant data, except for the Leontief inverse matrix. More specifically, we utilize – alternatively – the 1988 and 1998 Leontief inverse matrices, respectively, for the calculations concerning year 2000 (since no recent matrices are available) under the assumption that production technology remains constant.

The results are presented in Table 1, by industry and type of emission.

Table 1: Total, Direct and Indirect Coefficients, 2000

	CO_2	N_2O	CH_4	NO_x	SO_2	NMVOC	CO
	Total						
01-05	1,8E-03	3,3E-02	6,3E-03	5,4E-02	2,3E-03	9,3E-03	2,5E-03
10-11	7,4E-06	4,3E-06	2,7E-06	7,1E-06	5,4E-07	1,2E-06	6,9E-07
15-37	5,8E-05	4,7E-06	1,8E-05	3,4E-06	5,2E-06	6,5E-06	1,7E-05
40	4,7E-06	7,4E-05	1,5E-05	7,7E-05	9,2E-06	6,7E-05	4,9E-06
50-52	1,1E-05	2,2E-04	4,0E-05	3,5E-04	9,8E-06	2,0E-05	1,1E-05
60-64	1,8E-06	7,7E-06	4,7E-06	1,7E-05	7,7E-06	6,4E-05	6,0E-06
Not allocated	2,8E-05	2,3E-05	2,4E-05	5,3E-05	4,1E-05	3,6E-04	2,6E-05
Total	2,0E-03	3,4E-02	6,4E-03	5,5E-02	2,4E-03	9,8E-03	2,5E-03
	Direct						
01-05	4,3E-05	2,7E-02	9,0E-04	4,7E-02	1,1E-04	6,7E-03	7,2E-04
10-11	5,7E-06	3,3E-06	1,4E-07	6,0E-06	1,4E-08	6,7E-07	1,2E-07
15-37	4,5E-05	7,3E-07	3,1E-07	3,3E-07	2,8E-09	2,4E-06	1,2E-05
40	6,7E-07	6,3E-05	3,3E-06	6,3E-05	8,4E-08	5,8E-05	5,3E-07
50-52	2,9E-07	1,9E-04	5,7E-06	3,0E-04	2,5E-07	7,9E-06	1,2E-06
60-64	5,0E-08	3,6E-06	7,6E-07	1,4E-05	5,5E-09	5,7E-05	3,5E-06
Not allocated	1,6E-05	4,7E-06	2,3E-06	4,1E-05	5,9E-08	3,2E-04	1,3E-05
Total	1,1E-04	2,8E-02	9,1E-04	4,7E-02	1,1E-04	7,1E-03	7,5E-04
	Indirect						
01-05	1,8E-03	5,8E-03	5,4E-03	7,2E-03	2,2E-03	2,6E-03	1,8E-03
10-11	1,7E-06	1,0E-06	2,6E-06	1,1E-06	5,3E-07	5,4E-07	5,8E-07
15-37	1,2E-05	3,9E-06	1,8E-05	3,1E-06	5,2E-06	4,1E-06	4,9E-06
40	4,0E-06	1,1E-05	1,2E-05	1,4E-05	9,1E-06	8,9E-06	4,4E-06
50-52	1,1E-05	3,6E-05	3,4E-05	4,7E-05	9,5E-06	1,2E-05	1,0E-05
60-64	1,7E-06	4,1E-06	3,9E-06	3,0E-06	7,7E-06	6,8E-06	2,5E-06
Not allocated	1,2E-05	1,9E-05	2,2E-05	1,2E-05	4,1E-05	3,6E-05	1,3E-05
Total	1,8E-03	5,9E-03	5,5E-03	7,3E-03	2,3E-03	2,6E-03	1,8E-03

We notice that the agricultural-hunting-forestry-fishing, etc sectors of economic activity demonstrate the highest coefficients, followed by the manufacturing sector.

Table 2 presents the numerical difference when using the 1988 and 1998 Leontief inverse matrices, respectively, a difference which is attributed to production technology.

Table 2: Differences attributed to Production Technology (1988-1998 Inverse Leontief Matrices)

	CO_2	N_2O	CH_4	NO_x	SO_2	NMVOC	CO
	Total						
01-05	2,56E-03	3,99E-02	1,21E-02	1,18E-01	5,46E-03	2,33E-02	6,83E-03
10-11	1,17E-05	5,29E-06	4,82E-06	1,54E-05	1,15E-06	2,91E-06	1,78E-06
15-37	9,12E-05	9,61E-06	3,12E-05	7,31E-06	1,10E-05	1,48E-05	5,62E-05
40	7,57E-06	9,29E-05	2,94E-05	1,67E-04	2,50E-05	1,88E-04	1,28E-05
50-52	1,49E-05	2,69E-04	7,48E-05	7,54E-04	2,06E-05	3,85E-05	2,82E-05
60-64	3,37E-06	1,17E-05	1,03E-05	3,91E-05	2,19E-05	1,83E-04	1,90E-05
Not allocated	4,79E-05	4,14E-05	5,28E-05	1,25E-04	1,19E-04	1,02E-03	7,99E-05
Total	2,74E-03	4,03E-02	1,23E-02	1,19E-01	5,66E-03	2,48E-02	7,02E-03
	Direct						
01-05	6,84E-05	3,55E-02	1,44E-03	1,13E-01	2,85E-04	2,01E-02	2,48E-03
10-11	9,04E-06	4,23E-06	2,18E-07	1,43E-05	3,68E-08	2,02E-06	4,03E-07
15-37	7,16E-05	9,52E-07	5,01E-07	7,86E-07	7,36E-09	7,15E-06	4,27E-05
40	1,07E-06	8,18E-05	5,23E-06	1,52E-04	2,24E-07	1,75E-04	1,82E-06
50-52	4,62E-07	2,44E-04	9,18E-06	7,22E-04	6,70E-07	2,36E-05	4,29E-06
60-64	7,99E-08	4,65E-06	1,23E-06	3,39E-05	1,47E-08	1,73E-04	1,20E-05
Not allocated	2,54E-05	6,13E-06	3,64E-06	9,93E-05	1,58E-07	9,70E-04	4,49E-05
Total	1,76E-04	3,58E-02	1,46E-03	1,14E-01	2,87E-04	2,15E-02	2,58E-03
	Indirect						
01-05	2,49E-03	4,41E-03	1,07E-02	5,13E-03	5,18E-03	3,23E-03	4,35E-03
10-11	2,68E-06	1,06E-06	4,61E-06	1,10E-06	1,11E-06	8,88E-07	1,38E-06
15-37	1,97E-05	8,66E-06	3,07E-05	6,52E-06	1,10E-05	7,69E-06	1,35E-05
40	6,50E-06	1,11E-05	2,42E-05	1,48E-05	2,47E-05	1,26E-05	1,10E-05
50-52	1,45E-05	2,44E-05	6,56E-05	3,20E-05	2,00E-05	1,49E-05	2,39E-05
60-64	3,29E-06	7,02E-06	9,10E-06	5,16E-06	2,19E-05	9,90E-06	7,05E-06
Not allocated	2,26E-05	3,52E-05	4,92E-05	2,59E-05	1,19E-04	5,32E-05	3,50E-05
Total	2,56E-03	4,50E-03	1,09E-02	5,22E-03	5,38E-03	3,33E-03	4,44E-03

It is evident that pollution emissions have, in general terms, significantly decreased when using the 1998 instead of the 1988 Leontief Inverse Matrix, a fact which implies that the level of production technology has increased and has lead to the corresponding decrease.

Continuously, Table 3 shows the contribution (%) of technology in the decrease of air pollution.

Table 3: Contribution (%) of Technology

	CO_2	N_2O	CH_4	NO_x	SO_2	NMVOC	CO
	Total						
01-05	58,1	54,6	65,7	68,6	70,3	71,6	73,4
10-11	61,4	55,3	64,0	68,6	67,9	70,6	72,0
15-37	61,3	67,3	63,5	68,4	67,8	69,6	76,5
40	61,6	55,8	65,7	68,5	73,1	73,6	72,1
50-52	57,2	54,5	65,3	68,5	67,8	65,4	71,6
60-64	65,7	60,2	68,8	69,6	74,0	74,0	76,0
Not allocated	63,5	64,0	68,7	70,3	74,2	74,0	75,7
Total	58,3	54,6	65,7	68,6	70,3	71,7	73,4
	Direct						
01-05	61,3	56,5	61,6	70,6	72,7	75,0	77,6
10-11	61,3	56,5	61,6	70,6	72,7	75,0	77,6
15-37	61,3	56,5	61,6	70,6	72,7	75,0	77,6
40	61,3	56,5	61,6	70,6	72,7	75,0	77,6
50-52	61,3	56,5	61,6	70,6	72,7	75,0	77,6
60-64	61,3	56,5	61,6	70,6	72,7	75,0	77,6
Not allocated	61,3	56,5	61,6	70,6	72,7	75,0	77,6
Total	61,3	56,5	61,6	70,6	72,7	75,0	77,6
	Indirect						
01-05	58,0	43,1	66,3	41,6	70,1	55,8	71,2
10-11	61,8	51,1	64,1	49,8	67,7	62,4	70,5
15-37	61,4	68,7	63,5	68,1	67,8	65,3	73,2
40	61,7	51,4	66,6	52,1	73,1	58,7	71,3
50-52	57,0	40,5	65,9	40,6	67,7	54,4	70,6
60-64	65,8	63,0	70,0	63,3	74,0	59,2	73,6
Not allocated	66,1	65,5	69,3	69,1	74,2	59,5	73,3
Total	58,1	43,3	66,3	41,7	70,2	55,9	71,2

We notice that the largest decreases in emissions are to be found, in general terms, for the direct coefficients and for the following pollutants: CO, SO_2, NMVOC. Also, an important decrease in emissions took place in the transport, storage and communication industry, followed by the manufacturing industry. Also, we notice that the agricultural-hunting-forestry-fishing, etc sectors which have high emissions coefficients do not seem to be influenced by technological change considerably.

5. Conclusion

The present paper has derived measures of environmental emissions related to economic activity in Greece for the year 2000, utilizing the environmental input-output framework. Alternatively, two different technical coefficients matrices, i.e. for the years 1988 and 1998 respectively, have been used and the difference observed in the results originates in technological change and is expressed directly through each year's technical coefficients matrix.

The empirical results show the air pollution intensities by industry (direct and total) for each type of emission. The empirical findings show that technological change over the 1988-1998 time span has, in general terms, led to a significant decrease in emissions and, consequently, air pollution.

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Appendix

Table 1: Industry Classification

No	NACE classification	Description
1	01-05	Agriculture, hunting, forestry and fishing
2	10-11	Mining of coal and lignite; extraction of peat, extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying
3	15-37	Manufacturing
4	40	Electricity, gas, steam and hot water supply
5	50-52	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
6	60-64	Transport, storage and communication
7	Not allocated	12 Mining of uranium and thorium ores 13 Mining of metal ores 14 Other mining and quarrying 41 Collection, purification and distribution of water 45 Construction 55 Hotels and restaurants 65-67 Financial intermediation 70-74 Real estate, renting and business activities 75 Public administration and defence; compulsory social security 80 Education 85 Health and social work 90-93 Other community, social and personal service activities 95 Private households with employed persons 99 Extra-territorial organizations

Source: [1].