«ΣΠΟΥΔΑΙ», Τόμος 59, Τεύχος 3ο-4ο, (2009) / «SPOUDAI», Vol. 59, No 3-4, (2009), University of Piraeus, pp. 49-60

THE COMPILATION OF A GREEK ENVIRONMENTAL INPUT-OUTPUT TABLE FOR 2005

By

Charalambos Economidis, Dimitrios Keramidas*, Aggeliki Demertzi*, Nikos Stromplos**, Athanasios Sfetsos****
*Department of Public Administration, Panteion University
**Director of National Accounts, National Statistical Service of Greece
***Environmental Research Laboratory, INT-RP, NCSR Demokritos

Abstract

This paper discusses the compilation of an Environmental Input-Output Table for Greece for the year 2005. The objective of this work is to discover the relationships and interdependencies between activities disaggregated in economic branches on a country level and air emissions through a series of indicators. The relationship between economic activity and the environment is determined through a set of indicators that include direct and indirect emission intensity coefficients and the effect of emission factor intensity on the components of final demand. The basic data on air emissions were prepared by the Greek Ministry of the Environment and Public Works. The economic data are from the 2005 Input-Output Table for the Greek Economy produced by the National Statistical Service of Greece. JEL Classifications: D570, Q500.

Keywords: Environmental input-output analyses, NAMEA tables, intensity coefficients of emissions, air emissions.

1. Introduction

The EU's Sixth Environment Action Programme (EAP), "Environment 2010: Our future, Our choice" (European Commission, 2002, page: 4), sets Environment & Health as one of the four main target areas requiring greater effort - and air pollution is one of the key issues highlighted in this area. Air pollution is of major interest both at a national and an international level. In the European Union, member states are required to comply with the Clean Air for Europe (CAFÉ) objectives and new directives on air quality. Underlying trends in the allocation of GDP and consumptions patterns are important in the context of attaining certain environmental goals (European Environmental Agency, 2003, page: 11).

The National Accounting Matrix with Environmental Accounts (NAMEA) is a statistical information system that combines conventional national accounts and environmental accounts, but neither includes any modelling assumption nor estimate of money value imputed to natural flows and assets. The NAMEA was identified by the European Union as a relevant part of the framework for environmental satellite accounts of the national accounts (Commission for the European Communities, 1994, page: 4).

The aim of the present paper is to estimate the relationships between disaggregated economic activities and related environmental impacts in Greece for the year 2005, by means of environmental input-output analysis. The economic activities of final demand, which produce the higher values of emissions, are determined through a series of indicators such as direct coefficients and total emissions intensity of pollutants per unit of production.

2. Environmental Input-Output Matrices: Theoretical Framework

2.1 Economic Data

Accounting for sustainable development requires a broadening of scope of the conventional System of National Accounts (United Nations *et al.,* 1993). This wider perspective is necessary to account for the priceless environmental and social externalities, which are important in a sustainable development context. The environmental accounts show the interactions between producer and consumer (household) activities and the natural environment. These interrelationships occur as a consequence of the environmental requirements of these activities: natural resource inputs and residual outputs. These requirements are appointed to these activities when and where they actually take place. This direct recording is consistent with prevailing national accounting practices. By providing economic and environmental data in a consistent Leontief-type framework, the NAMEA is particularly suited for analytical purposes. (De Haan M., 1996, page: 131).

The NAMEA consists of a National Accounting Matrix (NAM) extended with Environmental Accounts. All accounts are presented in matrix format. This format reconciles supply-use tables and sector accounts, creating a comprehensive accounting framework that can be presented at various levels of detail. The economic accounts in the NAM-part of the NAMEA present the complete set of accounts of the SNA

The environmental accounts in the NAMEA are denominated in physical units and focus on the consistent presentation of material input of natural resources and output of residuals for the national economy. These inputs and outputs are the environmental requirements of the economy. Environmental requirements generally are not related to market transactions, and therefore they are not represented in the standard national accounts. By presenting economic accounts in monetary terms and environmental accounts in the most relevant physical units, the NAMEA maintains a strict borderline between the economic sphere and the natural environment.

The NAMEA table is a tool that links the environmental and economic data. More specifically, it presents a direct comparison between the environmental and the economic data. The NAMEA table enables an analysis of the variations of emissions in the time span, caused by: i) the variations of the economic structure, ii) the variations in volume, iii) the variations in efficiency of the ecosystems of producers and consumers and iv) the variations in the energy supply (Mylonas N. *et al*., 2000, page: 55).

Products are supplied by the economy and also used by it. One identity that is central to the satellite System of Integrated Environmental and Economic Accounting (SEEA) of United Nations and indeed to the System of National Accounts (SNA), is that when flows of products are measured *ex post*, total supply and total demand (or use) must balance exactly. New goods and services are supplied either by production in the current period from resident producers or come from producers in the rest of the world as imports.

2.2 Environmental Data

The air emissions data are estimated using the so-called 'air emissions inventory first approach'. At present, international agreements on air emissions include the CLRTAP (Convention on Long-Range Transboundary Air Pollution) with reporting to UNECE/EMEP and the UNFCCC (United Nations Framework Convention on Climate Change), with reporting based on the UNFCCC CRF (Common Reporting Format). The UNFCCC CRF covers 6 categories of greenhouse gases (CO_2, N_2O, CH_4, HFCs, PFCs and SF_6) plus 4 indirect greenhouse gases (NOx, CO, NMVOC, SO_2). The UNECE/EMEP reporting includes only NOx, CO, NMVOC and SO_2 plus NH_3 plus 9 heavy metals as well as 17 POPs (persistent organic pollutants).

The data utilized for this study are based on the official data reported by the Greek Ministry of Environment and Public Works. The data are based on the CORINAIR methodology and classified according to the Selected Nomenclature for sources of Air Pollution (SNAP). The original data were processed by deriving a NAMEA-consistent total and arranging process-oriented data in order to make them fit into the NACE-based classification, presently adopted for NAMEA. A hybrid approach was followed to attribute the SNAP-classified emissions to NACE-based economic activities or household consumption functions: simple (direct) and complex allocations. With regard to the later, some SNAP process emissions had to be split into several NAMEA activities. These emissions were attributed to NACE codes or household consumption functions using fuel consumption data, technical data contained in CORINAIR, experts' knowledge or other data.

The air emissions have been further grouped and aggregated by three environmental pressure variables, namely Global Warming Potential (GWP), Acidification (ACID) and Tropospheric Ozone Forming Potential (TOFP), in addition to the Particulate Matter (PM10) with diameter less than 10 mm, from the following set of equations:

$$GWP = CO_2 + 310 * N_2O + 21 * CH_4$$

$$ACID = SO_2 + 0.7 * NO_x + 1.9 * NH_3$$

$$TOFP = NMVOC + 1.22 * NO_x + 0.11 * CO + 0.014 * CH_4$$

The proposed grouping results from the combined effects that each primary pollutant has on ecosystems. GWP is a measure of climatic change, where ACID is primarily related to the effect of acid rain, eutrophication of ecosystems and cardiovascular diseases in humans. TOFP is related to the production of ozone in the lowest atmosphere and can be a major factor influencing the respiratory (e.g. asthma) and cardiovascular systems of humans. Both TOFP and ACID have been found to severely damage monuments of significant cultural heritage. PM10 is presently one of the most important pollutants associated with respiratory problem and carcinogenic potency. In a study conducted for 29 European cities (Katsouyanni *et al.*, 2001, page: 521), the result for the city of Athens showed that an increase in daily PM10 levels by 10 mg/m^3 results in an increase of the mortality rate by approximately 1.5%.

TABLE 1

NACE* Activities according to the 2005 Greek Input-Output Table

Code	NACE Activity Rev. 1	Code	NACE Activity Rev. 1
01 & 02	Agriculture	**37**	Recycling
5	Fisheries	**40-41**	Electricity, gas and water supply
10,11&12 / 13-14	Mining and quarrying	**45**	Construction
15-16	Manufacture of food products, beverages and tobacco	**50-52**	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
17-19	Manufacture of textiles and textile products	**55**	Hotels and restaurants
20A	Manufacture of wood and wood products	**60-64**	Transport, storage and communication
21-22	Manufacture of pulp, paper and paper products; publishing and printing	**65-67**	Financial intermediation
23	Manufacture of coke, refined petroleum products and nuclear fuel	**70-74**	Real estate, renting and business activities
24-25	Manufacture of chemicals, chemical products and man-made fibres	**75 & 90**	Public administration and defence; Sewage and refuse disposal
26	Manufacture of other non-metallic mineral products	**80-84**	Education
27	Manufacture of basic metals and fabricated metal products	**85**	Health and social work
28	Manufacture of fabricated metal products, except machinery and equipment	**91**	Activities of membership organizations n.e.c.
29-36	Manufacture of machinery and equipment	**92, 93, 95 & 99**	Recreational, cultural and sporting activities; Activities of households; Extra-territorial organizations

** NACE (National Association of Colleges and Employers).*

3. Estimation of Eco-Indicators

3.1 Methodology

The methodology of Miller and Blair (1985) has been followed to calculate emission multipliers. The Leontief inverse matrix is an operator converting the multiplied vector or matrix into a quantity that contains the same information but in terms of unit of production, i.e. a matrix of total impact coefficients.

The total emission coefficient per production unit in each economic sector, as well as for final demand categories, has been estimated on the basis of input-output modelling in a number of recent studies including Cadarso & Fernandez-Bolanos (2002, pages: 2-3), Braibant (2002, pages: 5-6), Mylonas N. *et al*. (2000, pages: 55-59) and Belegri-Roboli A., Tsolas I. (2005, pages: A-167-168). Input-output analysis is used in this paper for the calculation of emission multipliers for the various industries and pollutant types. The embodied pollution indicators have been constructed using the following methodology.

We can express the input-output model in matrix terms

$$X= AX+Y \qquad (1)$$

The matrix A is known as the matrix of the technical coefficients, X the vector of total resources of the sector and Y the vector of final use of the products. Solving the equation (1) for X, we obtain

$$X= (I-A)^{-1} Y \qquad (2)$$

where $(I-A)^{-1}$ is often referred to as the Leontief inverse. We applied a domestic oriented model, starting from final demand and quantifying the direct and indirect effects on production and emissions activated by final demand. The results can be presented as a re-attribution of the domestic production, which is derived from the basic Leontief model

$$(I - A^d) X = (Ft - M) \qquad (3)$$

where A^d is the matrix of the domestic technical coefficients ($A^t=A^d + A^m$), Ft the vectors of total (domestic + imported) final demand by industry and M the import vector by industry, which is subtracted from total final demand. The direct emission intensity coefficients (a_{kj}) of the k type of emission by industry (j) are defined by

$$a_{kj}=E_{kj} / X_j \; j = 1........n \qquad (4)$$

where E is the vector of emissions data (physical quantity), k denotes each type of emission by industry (j) and X_j the industry (j) domestic value of output. These coefficients show the extent to which each industry generates a certain direct emission intensity factor and describe the physical quantity of emission directly caused by the production of goods as a ratio of the value of domestic production at basic prices.

We also compute the total environmental dependencies

$$\varepsilon_{kj} = \hat{a}_{kj} (I-A^{d})^{-1} \qquad (5)$$

where ε_{kj} is the matrix of induced emission coefficients showing the emission intensity, including the induced emission in other industries indirectly affected by a change in final demand of a given industry. (Mylonas N. *et al.*, 2000, page: 60).

The elasticity of emissions intensity with respect to final consumption e_j^c is estimated as the row sum of ε_{kj}, $e_j^c = \sum_j \varepsilon_{kj}$, including direct and indirect emissions for the j-th industry. These emissions are produced in the whole economy after the increase of a unitary expansion of the final demand of the specific industry. The column sum of ε_{kj}, $e_k^p = \sum_k \varepsilon_{kj}$ is an estimate of the total emissions of the pollutants in the whole economy owing to a one unit increase of a given industry production, termed as the elasticity of the emissions intensity with respect to production.

The direct and indirect emission intensity per unit of final demand categories is computed by the following operation

$$\varepsilon^{d} = \hat{\varepsilon}_{kj} F^{t} \qquad (6)$$

where ε^{d} is the sectoral extent of each emission factor intensity on each final demand component of the Greek economy for the year 2005.

3.2 Results

Table 2 shows the estimated coefficients by industry for the four environmental stressors examined.

TABLE 2

Emission intensity coefficients by industry and pollutant

	GWP			TOFP			ACID			PM10		
	akj	ekp	ejc	akj	ek p	ejc	akj	ek p	ejc	akj	ek p	ejc
01 & 02	1.180817	1.65	2.1096	0.008247	0.0104	0.0145	0.010332	0.0142	0.0184	0.000359	0.0005	0.0006
5	0.285558	0.3418	0.2533	0.008244	0.008	0.0073	0.002958	0.0035	0.0027	0.000758	0.0007	0.0007
10,11& 12 / 13-14	1.333808	0.3947	0.5694	0.021351	0.0043	0.0091	0.00654	0.0024	0.0023	0.00176	0.0003	0.0006
15-16	0.063389	0.8019	0.071	0.001255	0.0054	0.0012	0.000276	0.0066	0.0003	7.12E-06	0.0003	0
17-19	0.024523	0.5094	0.0167	0.002952	0.0041	0.002	0.000245	0.0043	0.0002	1.79E-05	0.0001	0
20A	0.027891	0.3936	0.0225	0.007466	0.0071	0.0059	0.000158	0.0031	0.0001	5.28E-05	0.0001	0
21-22	0.091502	0.3498	0.102	0.002271	0.0028	0.0022	0.00115	0.0032	0.0011	0.000697	0.0007	0.0007
23	0.551182	0.6983	0.7445	0.004719	0.0059	0.0062	0.005583	0.0061	0.0078	3.25E-05	0.0002	0
24-25	0.499915	0.4632	0.3579	0.003234	0.0023	0.0022	0.004901	0.0042	0.0032	0.000181	0.0002	0.0001
26	3.679021	3.6759	3.5111	0.016011	0.0154	0.015	0.0143	0.0168	0.0135	0.001535	0.0015	0.0014
27	0.630604	1.403	0.7845	0.002258	0.0043	0.0027	0.00635	0.0124	0.0077	0.000635	0.0008	0.0007
28	0.360382	0.7318	0.3806	0.000862	0.0022	0.0008	0.00213	0.0055	0.002	8.12E-05	0.0003	0.0001
29-36	0.439045	0.2322	0.1846	0.000881	0.0006	0.0003	0.00317	0.0017	0.001	1.73E-05	0	0
37	0.266535	0.4495	0.2587	0.000374	0.0014	0.0003	0.000292	0.0022	0.0002	6.65E-06	0.0002	0
40-41	11.49947	12.4758	17.1902	0.026879	0.0301	0.0403	0.096393	0.1044	0.144	0.003717	0.0041	0.0055
45	0.011035	0.5693	0.0132	0.002101	0.0044	0.0023	0.000334	0.0037	0.0003	7.35E-05	0.0003	0.0001
50-52	0.012418	0.1674	0.0277	0.000487	0.0014	0.0005	5.75E-05	0.0015	0.0001	1.22E-06	0	0
55	0.011062	0.3845	0.0108	0.00032	0.0022	0.0003	0.000111	0.0031	0.0001	7.95E-06	0.0001	0
60-64	0.210795	0.3994	0.3107	0.005609	0.0062	0.0084	0.003889	0.0052	0.0056	9.25E-05	0.0001	0.0001
65-67	0.002492	0.2045	0.005	0.000272	0.0013	0.0004	5.45E-05	0.0017	0.0001	0	0.0001	0
70-74	0.0021	0.0648	0.0043	5.04E-05	0.0003	0	9.75E-06	0.0004	0	1.53E-06	0	0
75&90	0.183601	0.3967	0.1836	0.001014	0.0018	0.001	0.000356	0.0021	0.0004	5.28E-05	0.0001	0.0001
80-84	0.028036	0.1157	0.0272	0.000685	0.001	0.0007	0.000247	0.0008	0.0002	1.94E-05	0	0
85	0.014712	0.1654	0.0148	0.000448	0.0008	0.0004	0.000131	0.0013	0.0001	1.13E-05	0	0
91	0.02143	0.1423	0.027	2.71E-05	0.0003	0	2.63E-05	0.001	0	1.56E-05	0	0
92, 93, 95 & 99	0.078288	0.0783	0.0783	0.011111	0.0111	0.0111	0.001472	0.0015	0.0015	5.51E-05	0.0001	0.0001

Regarding akj the direct emission intensity coefficient, the most important environmental stressor appears to be GWP and in particular CO_2, which dominates the emissions in this category. As expected, the energy production sector exhibits the highest direct emission intensity coefficient, which is in line with similar studies (Tarancon Moran, 2008, page: 1915). Other significant parameters are found in the non-metallic mineral products sectors (NACE activity 26) and mining (10-14), which involve fuel combustion in the transformation process, and mining activities. Of the other stressors, TOFP and ACID exhibit lower values mainly associated with domestic services and agriculture.

As for $e_k{}^p$, GWP appears to be the most important stressor. The highest values are found in the electrical energy, non-metallic mineral products, mining, agriculture, basic metals and petroleum sectors. However, the biggest indirect effect is from the manufacturing and construction industries, due to the extensive intermediate inputs. The impact of other environmental parameters does not seem to influence economic activities.

The quantity e_j^c represents the total emission intensity of the industry induced directly and indirectly by the increase of 1000 units of final demand in all industries. The results are in accordance with the other indices estimated previously, with only GWP having an impact on the economy.

TABLE 3

Percentage attribution of final demand

	Final consumption of Households	Final consumption of non-profit organizations	Final consumption of Government	Gross fixed capital investment	Changes in inventories	Exports
GWP	61.52617	0.078376	8.486528	16.06733	0.052643	13.79109
TOFP	55.88979	0.027045	6.825528	18.0911	0.054935	19.11458
ACID	64.12676	0.068685	6.004563	13.52338	0.064571	16.21453
PM10	58.63597	0	5.480253	20.8484	0.0956	14.94191

Table 3 presents e^d the sectoral extent of direct and indirect emissions intensity factors per 1000 units on each of the final demand components. Household final consumption is the major category in all air emissions, followed by investment and exports. This finding suggests that any significant effort to reduce air emissions in Greece must seriously take into account demand side management and energy efficiency measures.

4. Conclusions

This paper discussed the compilation of an Environmental Input-Output Table for Greece for the year 2005. The Table was constructed using estimations of emission inventories prepared by the Greek Ministry of the Environment and Public Works and economic activity data from the 2005 Input-Output Table for the Greek economy, disaggregating the available data into 26 distinct branches.

The estimated indicators included the direct emission intensity coefficient, the direct and indirect emission intensity coefficients and the emission factors intensity on the components of final demand.

The analysis of the results showed that from a production perspective the most important environmental stressor in economic terms appears to be Global Warming Potential, which is directly related to CO_2. An in-depth analysis of economic activity found that the worse emitting industries are energy producing ones and other manufacturing industries based on combustion of fuels.

Household consumption appeared to have the highest impact on air emissions from a demand perspective, which may point to the need for a more rational distribution of energy production.

References

Braibant, M. (2002), “Environmental Accounts in France: NAMEA pilot study for France”, *Fourteenth International Conference on Input- Output Techniques*.

Belegri-Roboli, A. and Tsolas, I. (2005), “Estimation of intensity coefficients of total emissions in Greece (1988-96): An environmental input-output analysis”, *Proceedings of the 9th International Conference on Environmental Science and Technology,* Rhodes Island, Greece 1-3 September 2005, pp. A-166-172.

Cadarso, A. and Fernandez-Bolanos, A.F. (2002), “Patterns of growth and consumption and their influence on the environment in Spain”, *Fourteenth International Conference on Input-Output Techniques*.

Commission of the European Communities (1994),“Direction for the EU on Environmental Indicators and Green National Accounting. The Integration of Environmental and Economic Information Systems”, Brussels.

De Haan, Mark and Steven, J. Keuning (1996), “Taking the Environment into Account: The NAMEA Approach”, *The Review of Income and Wealth.* Series 42, No. 2, June 1996, pp. 131-148.

De Haan, M. and Kee, P. (2004), “ Accounting for sustainable Development. The NAMEA-based Approach”, *Statistics Netherlands, OECD*.

European Environmental Agency (2003), *Europe’s Environment: The Third Assessment. Environmental assessment report, No 10*, European Environmental Agency, Copenhagen.

European Environmental Agency (2006), *Environmental Input-Output Analyses based on NAMEA data*, European Environmental Agency.

European Commission (2002), “The Sixth Environment Action Programme of the European Community 2002-2012, Environment 2010: Our future, our choice”, *European Community,* Luxemburg.

Eurostat (2007), *NAMEA for Air Emissions. Compilation Guide*, Preliminary Draft Version to be discussed and further developed by the ESTAT NAMEA TF, European Community.

Leontief, W. (1970), “Environmental repercussion and the economic structure: an input-output approach”, *Review of Economics and Statistics,* V. 52, No. 3, pp. 262-271.

Leontief, W. and D. Ford. (1972), “Air Pollution and the economic structure: empirical results of input-output computations”, *In Input-Output Techniques, Eds. A. Brody and A. Carter. New York: American Elsevie,* pp. 9-30.

Katsouyanni, K., Touloumi, G., Samoli, E. *et al.* (2001), “Confounding and effect modification in the short-term effects of ambient particles on total mortality: Results from 29 European cities within the APHEA2 project”, *Epidemiology* 12, pp. 521-531.

Miller, R.E. and Blair P.D. (1985), *Input–Output Analysis Foundation and Extensions*. Prentice-Hall, Englewood Cliffs, New Jersey.

Medina, S., Plasencia, A., Ballester, F., Mücke, H.G. and Schwartz, J. (2004), "Apheis: public health impact of PM10 in 19 European cities", *J. Epidemiol. Community Health 58b,* pp. 831-836.

Mylonas, N., Economakou, M., Frankopoulos, N., Krasadakis, A., Molfetas, K., Stromplos, N. and Vlachos, P. (2000), *Natural Resource and Environmental Input-Output Tables for Greece, 1988-98.* Eurostat and Institute of Computer and Communications Systems (ICCS) of National Technical University of Athens.

National Statistical Service of Greece (2005), "Input-Output Table for 2005", *Piraeus, mimeo*.

ECMT/OECD (1995), *Urban Travel and Sustainable Development*, OECD, Paris.

ECMT/OECD (2002), *Implementing Sustainable Urban Travel Policies Final Report",* OECD.

Tarancon Moran, M.A., Del Rio, P. and Callejas Albinana, F. (2008), "Tracking the genealogy of CO_2 emissions in the electricity sector: An intersectoral approach applied to the Spanish case", *Energy Policy 36,* pp. 1915-1925.

United Nations (2000), *Handbook of National Accounting. Integrated Environmental and Economic Accounting. An operational manual*, Series F, No. 78, New York.

United Nations (1993), *"Handbook of National Accounting. Integrated Environmental and Economic Accounting"*, Series F, No. 61, New York.