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The compilation of a Greek Environmental Input Output matrix for 2005, and its application as a methodological framework for assessing emission reduction options

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Abstract

This paper discusses the compilation of an Environmental Input Output matrix for Greece for the year 2005. The objective of this work is to discover relationships and the interdependencies between activities disaggregated in economic branches on a country level and air emissions through a series of indicators.

The starting point were estimations of emission inventories prepared by the Greek Ministry of the Environment and Public Works in order to fulfil the country's commitments to CLRTAP (Convention on Long-Range Transboundary Air Pollution) and the UN Framework Convention on Climate Change (UNFCCC). The economic data are obtained from the 2005 Input Output Matrix for the Greek economy produced by the National Statistical Service of Greece, disaggregating the available data into 26 distinct branches.

The estimated indicators include the direct emission intensity coefficient, the direct and indirect emission intensity coefficients and the emission factors intensity on the

components of the final demand that will provide insight about the real structure of the Greek economy and the consumption characteristics in relation to the environment.

Keywords: Environment, Input Output matrix, Emissions.

1. Introduction

The EU's Sixth Environment Action Programme (EAP), "Environment 2010: Our future, Our choice", includes Environment and Health as one of the four main target areas requiring greater effort - and air pollution is one of the main issues highlighted in this area. Air pollution is of major interest both in national and 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. The underlying trends in the allocation of GDP and consumptions patterns are of importance to attain certain environmental goals (EEA 2003).

The 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. 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). 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. By providing economic and environmental data in a consistent Leontief-type framework, the NAMEA is particularly suited for analytical purposes (de Haan 1996).

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 the final demand, which produce the higher values of emissions, are determined through a series of indicators such as the direct coefficients and the 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 (SNA; 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.

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 the presentation of the economic accounts in monetary terms and the 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 linking the environmental and economic data. More specifically it comprises the direct comparison between the environmental and the economic data. The NAMEA table, allow us to analyze 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 2000).

Products are supplied by the economy and used by it also. An identity which is central to the SEEA (and in fact to the SNA also) is that when flows of products are measured *ex post*, total supply and total demand (or use) must exactly balance. 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’. Presently 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 (CO2, N2O, CH4, HFCs, PFCs and SF6) plus 4 indirect greenhouse gases (NOx, CO, NMVOC, SO2). The UNECE/EMEP reporting only includes NOx, CO, NMVOC and SO2 plus NH3 plus 9 heavy metals as well as 17 POPs (persistent organic pollutants).

The utilized data for this study are based on the official data reported by the Greek Ministry of Environment and Public Works to fulfil the country’s obligations. 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 in deriving a NAMEA-consistent total and in arranging process-oriented data in order to make them fit into the NACE-based classification, presently adopted for NAMEA. A hybrid approach were followed to attribute the SNAP-classified emissions to NACE-based economic activities or households' consumption functions: simple (direct) and complex allocations. Concerning the later, some SNAP processes emissions had to be split into several NAMEA activities. These emissions were attributed to NACE codes or households' consumption functions using fuel consumption data, technical data contained in CORINAIR and the NSSG, experts' knowledge or other data.

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

$GWP = CO2 + 310 * N2O + 21 * CH4$

$ACID = SO2 + 0.7 * NOx + 1.9 * NH3$

$TOFP = NMVOC + 1.22 * + 0.11 * CO + 0.014 * CH4$

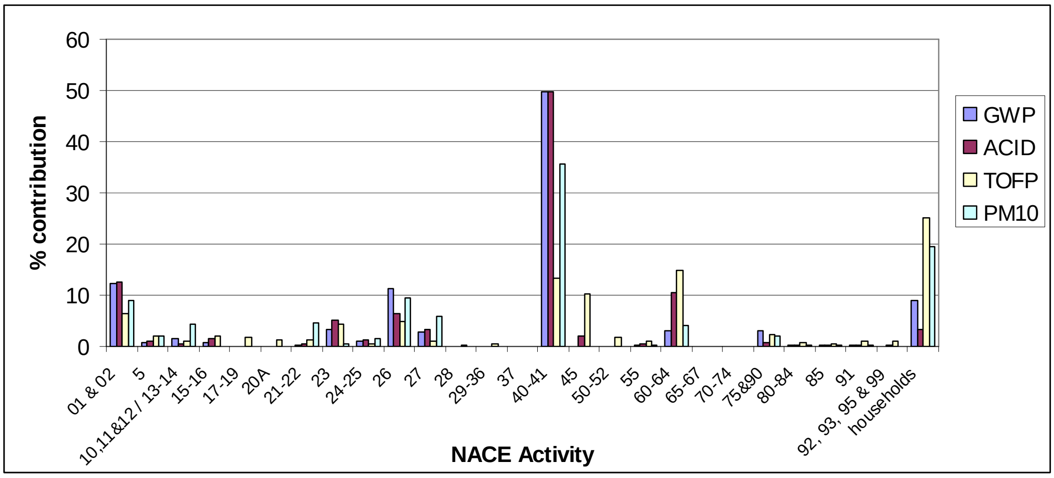

Fig 1. Percentage contribution of environmental stressors by economic activity

Table 1. NACE Activities according to the 2005 Greek Input Output Matrix

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

3. Estimation of Eco-Indicators

3.1 Methodology

The way of calculating emission multipliers is explained by Miller and Blair (1985). The Leontief inverse matrix is an operator converting the multiplied vector or matrix into something that contains the same information but in total terms by unit of production; that is, it is a matrix of total impact coefficients.

Several recent studies have used input-output modelling for estimating the total emission coefficient per unit of production in each economic sector and for the final demand categories, i.e. Cadarso & Fernandez-Bolanos (2002), Braibant (2002).

In this paper the input-output analysis is used to calculate emission multipliers for different industry and kinds of pollutants. The methodology for constructing embodied pollution indicators is built as follows (Cadarso & Fernandez-Bolanos 2002, Braibant 2002).

The balance equation in the input-output modelling can be written as:

$$x = Ax + y \qquad (1)$$

Where A is the matrix of the technical coefficients, x is the vector of the total resources of the sector and y denotes the vector of the final use of the products. Solving the balance equation (1) for x, we obtain:

$$x = (I-A)^{-1} y \qquad (2)$$

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

$$(I - A^d) X = (F^t - M) \qquad (3),$$

where F^t and M are the vectors of final demand and imports by industries respectively. The direct coefficients (a_{kj}) of the pollutant air intensity as emissions expenditures per gross output for each industry (j) are defined by:

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

Where E is the vector of emissions (physical quantity) and k denotes each type of emissions. These coefficients show the extent to which each industry generates a certain direct emission intensity factor. These matrices describe the physical quantity of emission directly caused by the production of goods as a ratio of the value of domestic production in basic prices. In a second step we compute the total environmental dependencies given by:

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

where ε_{kj} is the matrix of the total induced emission including the indirect effects and A^d the matrix of the technogical coefficients of the domestic production. Any element of the multiplier matrix ε is the total pollution impact generated per monetary unit of final demand. The elasticity of the emissions intensity with respect to the final consumption, e_j^c is estimated as the row sum of ε_{jk}, $e_j^c = \sum_j \varepsilon_{jk}$, 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_{jk}, $e_k^p = \sum_k \varepsilon_{jk}$, is an estimate of the total emissions of the pollutants in the whole economy owing to 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:

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

The ε^d is the matrix coefficients of extent of each emission factor intensity on each of the final demand category.

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 pollutants

	GWP			TOFP			ACID			PM10		
	a_{jk}	e_j^p	e_j^c	a_{jk}	e_j^p	e_j^c	a_{jk}	e_j^p	e_j^c	a_{jk}	e_j^p	e_j^c
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

Concerning the direct emission intensity coefficient the most important environmental stressor appears to the GWP and in particular CO2 which dominates the emissions in this category. The energy production sector exhibits the highest direct emission intensity coefficient as expected and in accordance to other similar studies (Tarancon Moran, 2008). Other significant parameters are found in the non-metallic mineral products sectors (NACE activity 26) and mining (10-14), that involve fuel combustion in the transformation process, and mining activities. From the other stressors TOFP and ACID exhibit lower values mainly associated with domestic services and agriculture.

Concerning e_j^p GWP appears to be the most important stressor. The highest values are found in the electric energy, non-metalic mineral products, mining, agriculture, basic metals, petroleum sectors. However, the biggest indirect effect is found from the manufacturing and the construction industries due to the extensive intermediate inputs. The impact of other environmental parameters does not seem to influence the 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

	Households	Non-profit organis	Public administration	Investment	Changes in Stocks	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 the sectoral extent of direct and indirect emissions intensity factors per 1000 units on each of the final demand components. The household final consumption is the major category in all air emissions followed by investments and exports.

4. Conclusions

This paper discussed the compilation of an Environmental Input Output matrix for Greece for the year 2005. The matrix 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 Matrix 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 the final demand.

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

The households consumption appeared to be in the highest degree of influence on air emissions from the demand perspective, which can be interpreted as a need for more orthological distribution of the energy production.

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