

Belegri-Roboli, Athena; Demertzi, Aggeliki; Markaki, Maria; Michaelides, Panayotis

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## An Input-Output Analysis of Environmental Effects of Infrastructure Investments in the Greek Economy: The Case of - Attiki Odos - motorway

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# **An Input-Output Analysis of Environmental Effects of Infrastructure Investments in the Greek Economy: The Case of ‘Attiki Odos’ motorway**

Athena Belegri-Roboli, Aggeliki Demertzi\*, Maria Markaki & Panayotis G. Michaelides

Laboratory of Theoretical and Applied Economics  
Department of Humanities, Social Sciences and Law  
School of Applied Mathematics and Physics  
National Technical University of Athens  
157.80 Zographou Campus, Athens, Greece

## **Abstract**

This paper calculates the environmental effects of the Attiki Odos (AOD) motorway investment expenditures in the Athens Metropolitan Area (AMA), Greece. The AOD is incorporated in the Trans-European Networks (TEN) and is a priority project aimed at developing the AMA. Input – output analysis is applied to assess the environmental impacts of the investments expenditures. More precisely, we apply the environmental input-output life cycle assessment (EIO-LCA) method to estimate *ex-post* the environmental burden associated with the investment vector of AOD. In this context, we calculate each type of emission caused by the AOD investments expenditures (direct, indirect and induced), by sector of economic activity during the construction phase (1999-2004). The investment vector is assembled from figures calculated based on corporate data. Next, in order to estimate the impact of technological change on our estimates, we use *ceteris paribus* the 2005 input – output table, which expresses, in a nutshell, the production technology of 2005. The domestic input-output tables for 2000 and 2005 come from EUROSTAT. In this framework, the main finding of the paper is that technological change between 2000 and 2005, as expressed through each year’s technical coefficients matrix, provided significant results with respect to total output and emissions. Roughly speaking, total output increased approximately by 7% and emissions decreased approximately by 19%.

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\* Fax: +302107721618; email: [aggeldem@yahoo.gr](mailto:aggeldem@yahoo.gr) (corresponding author).

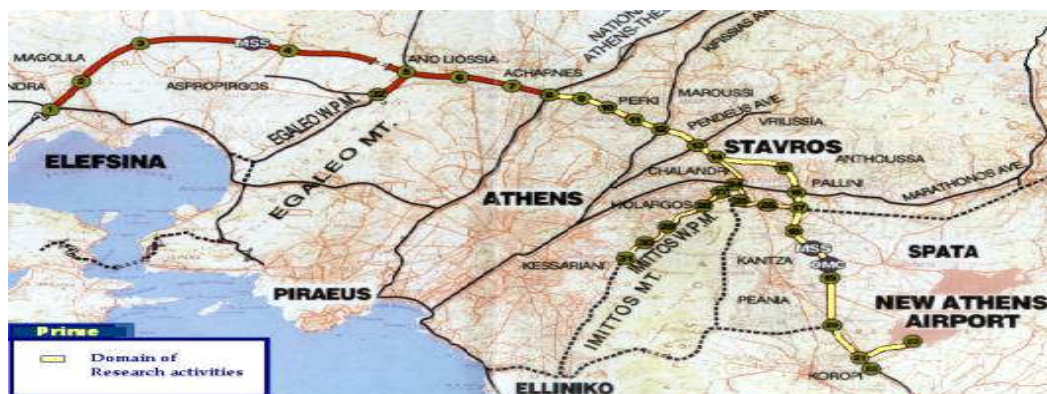
## 1. Introduction

The idea for constructing a peripheral ring in Athens and its metropolitan area (AMA) was introduced in 1960. However, the first feasibility study for a peripheral ring road creating a bypass of Athens, was conducted 1995 and the construction was completed during 1999-2004.

This peripheral ring is called *Attiki Odos* (AOD). The AOD is incorporated in the Trans-European Networks (TEN) and aims to develop the greater area of Athens and Greece, as a whole. The AOD motorway has assisted in easing traffic congestion in the greater area of Athens and reducing the traffic in the central arteries (see Figure 1). The motorway is 65.2 km long and consists of two main motorways: the 50.4km long Elefsina-Stavros-Spata Airport and the 12.9 long Imittos Peripheral Motorway (Zifou and Serraos, 2007). Also, it forms an important node between the transport infrastructure such as airports, suburban train stations, metro, logistic centres and freight villages. The AOD connects more than thirty municipalities. Meanwhile, it forms a backbone for the transport network, assisting the strategic layout of Attica's energy and communication networks and contributing to the integrated physical and urban planning of Attica.

The motorway has approximately 300,000 users per day or 65 millions per year. The decrease in travel times and the improved traffic conditions were estimated to produce savings of approximately 270.000 hours per day, of which 150.000 are productive hours (Zifou and Serraos, 2007).

The total cost was approximately €2 billion. The project was financed as follows: 40% from cohesion funds; 25% from the government; 10% from private funds, and 25% from structural funds (AOD, 2004).



**Fig. 1.** AOD Transportation System, **Source:** AOD, 2004.

This paper calculates *ex-post* the environmental impact of the high-speed toll motorway investment of Attiki Odos in the Athens Metropolitan Area in Greece, during the construction phase (1999-2004). Input – output analysis has been applied to assess the environmental impacts of the investments expenditures, by sector of economic activity. We apply the economic input-output life cycle assessment (EIO-LCA) method. The remainder of this paper is structured as follows: section 2 presents some stylized economic and environmental facts on the Greek economy; section 3 sets out the methodological framework; section 4 presents the data; section 5 analyzes the empirical results; section 6 concludes.

## **2. The Greek and Athens Economy: Stylized Economic and Environmental Facts**

Agriculture has traditionally been the driving force behind the Greek economy. During the first half of the 20th century, the economy depended on the export of agricultural products and had a performing shipping industry. Also, remittance sent home from Greeks working abroad was a major source of income. Natural resources are limited and there are some deposits only in the case of nonferrous metals. Fossil fuels are in short supply, except lignite, whereas oil production is limited. The country became more industrialized after World War II and the government policies were conducive for industrialization, while foreign aid grew considerably. Also, the country's heritage is well preserved and tourism has become a booming industry.

The Greek economy performed poorly from about 1970 to 1995, during which it was the poorest in the E.U. Part of the explanation lies with the collapse of macroeconomic policy that took the form of large fiscal deficits and high inflation rates. Also, reduced rates of capital formation, the shock of entry into E.U. and the presence of structural rigidities are regarded as contributors to the economic slowdown. But the deteriorating performance is also attributed to the country's poor economic institutions (Bosworth and Kollintzas, 2001).

Now, Greece has a mixed capitalist economy with a relatively strong participation of the public area. The country became a full member of the E.U. in 1981 and its economy had improved over the last decades in the run-up to its entry into the Economic and Monetary Union (E.M.U.) in 2001. However, in 2010 the country faced a severe economic crisis and a bail-out package had to be signed.

The area of greater Athens, situated on the southern coast of mainland Greece, is 3,200 square kilometers including the port of Piraeus. It concentrates roughly one third of the population of Greece on about 2.8% of the country's total area. More precisely, over the 1991-2001 period, the population of Greece increased by 6.8% to reach 10,940,000 inhabitants, while the Athens (Metropolitan) Area grew also at 6.8%, to 3,761,810 inhabitants, mostly due to suburbanization driven by new infrastructure projects in outer areas confirming its dominant position as the main urban centre of Greece. It, thus, maintained its share of about one third of the total Greek population.

Moreover, the Athens region contributed more than 38% to the Gross National Product (G.N.P.) of Greece. More precisely, the primary sector in the Athens Region accounted for 0.6% compared with 8.2% for Greece as a whole; the secondary sector accounted for 18.3% versus 21.6% for Greece; and the tertiary sector accounted for 81.1% with 70.2% for Greece, as a whole. Consequently, the Athens region has a sectoral structure which corresponds to a modern local economy (O.E.C.D., 2004).

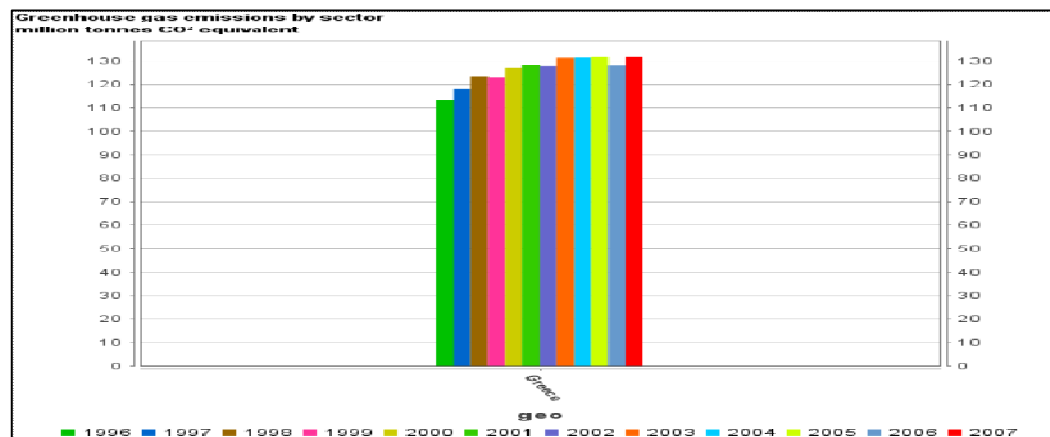
Since the late 90's, the Athens region was benefiting from a period of exceptional financing and promotion related to the Olympic Games of 2004 and the EU Support Funds (M.o.F., 2004), which had boosted investment in infrastructure (i.e. hotel sector, sports facilities, etc) and a modern region-wide transport network. This included a brand new international airport, urban highways and ring roads to decrease congestion, upgraded rail links, a new metro, a non-polluting bus fleet, and tramway lines which connect the city centre and the suburbs.

Athens needs clear strategic planning to take advantage of the opportunities that globalisation is bringing. In fact, Athens has considerable potential for development in its role as international gateway to Greece, the eastern part of the enlarged European Union and the Middle East. However, fulfilling this role will require strategic responses from the Greek government and the authorities of Athens and the surrounding region of Attica to a number of specific challenges (O.E.C.D., 2004).

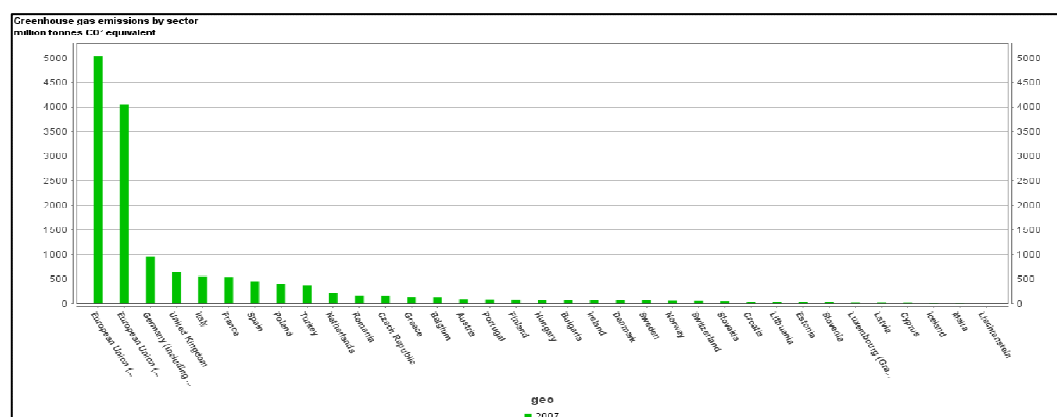
Thus, it is an important challenge for the economy's authorities to determine, as closely as possible, the impact of Public Works on the Greek and, more precisely, the environmental impact of the high-speed toll motorway investment of Attiki Odos. It should be noted that, to date, there has been no specific study that has

investigated relevant issues for the AOD investment, by sector of economic activity. Therefore, such an investigation is of great importance.

Regarding pollution in Greece, Green House Gases (GHG) fluctuate around average EU-27 levels. The average greek GHG emission for the time period 1990-2007 was equal to 119,839.68 thousands tonnes which represent 2.6% of total emissions, and thus holds the 9<sup>th</sup> position among EU-27. See figures 2 and 3.



**Fig. 2.** Greenhouse gas emissions by sector, Greece, 1996-2007, **Source:** Eurostat, 2010



**Fig. 3** Greenhouse gas emissions by EU-27 Country, **Source:** Eurostat, 2010

It can be inferred from Table A, below, that the major source of GHG emissions in Greece are Energy Industries, Transport and Road Transport. A great part of GHG emissions is generated by the following sectors: Industrial Process, Agriculture and Manufacturing Industries and Construction.

NACE	2000		NACE	2005	
Other (energy)	0.09	9.01%	Other (energy)	0.11	11.06%
Road Transport	0.13	12.96%	Road Transport	0.15	14.82%
Other Transport	0.02	2.43%	Other Transport	0.03	2.65%
Energy Industries	0.43	43.34%	Energy Industries	0.44	43.99%
Manufacturing Industries and Construction	0.08	8.25%	Manufacturing Industries and Construction	0.07	6.85%
Transport	0.15	15.39%	Transport	0.17	16.76%
Industrial Processes	0.10	9.88%	Industrial Processes	0.09	8.66%
Agriculture	0.10	9.64%	Agriculture	0.09	8.82%
Waste	0.03	3.13%	Waste	0.02	2.42%

**Table A.** Allocation (%) of economic sectors to National Emissions, **Source:** Eurostat, 2010

Regarding pollution in Athens there are two types of air pollution: the first is characterized by a high concentrations of particles. The second type, i.e. photochemical smog, relates to an excess of nitrogen oxides, hydrocarbons, carbon monoxide (primary pollutants), ozone, and organic nitrates (secondary pollutant) coming from a series of chemical reactions driven by sunlight (EEA).

Throughout the 1990s, a series of strict measures were taken by the authorities of the city and finally resulted in a drastic improvement of air quality; the appearance of smog has nowadays become a relatively rare phenomenon.

Widespread measures taken by the Greek authorities throughout the 1990s have effectively improved the quality of air over the Attica Basin. Nevertheless, air pollution still remains an issue for Athens, particularly during the summer days.

	Motor Vehicles	Domestic Heating	Industry
Smoke	68	18	14
Nitrogen Oxides	15	40	45
Hydrocarbons	77	6	17
Carbon Monoxide	100	-	-
Sulphur Dioxide	75	-	25

**Table B.** Contribution (%) of various pollution sources to the photochemical pollution of Athens, **Source:** European Environmental Agency, 2000

### 3. Methodology

The significance of infrastructure in economic growth cannot be gainsaid. It derives from the characteristics of infrastructure output as both, a final good providing service directly to consumers, as well as an intermediate input that enters into the production of other sectors and raises the productivity of factors employed there. Additionally, there are two ways for the association between growth of output and economic infrastructure. Growth of infrastructure can result from the demand of other sectors and improve the facilities of industrial investment (Hirschman, 1958; Weiss, 1999).

Actually, in the 1990s, infrastructure investment became one of the most frequent topics for economic research. These researches are, usually, to be connected with the new growth theory (Barro, 1990; King and Rebelo, 1990). Of course, there is a large range of analytical approaches to estimate the effects of infrastructure investment such as: Spatial Computable General Equilibrium (SCGE) models (Shoven and Whalley, 1992), Economic Input Output – Life Cycle Assessment (EIO-LCA) models (Levine *et al.*, 2007), Regional Economic Modelling (REMI), Impact Analysis for Planning (IMPLAN), Regional Industrial Multipliers System (RIMS-II) (Lynch, 2000), or the production function approach (Aschauer, 1989; Gramlich, 1994).

Microeconomic analysis attempts to isolate a specific market and examine crucial factors that affect the equilibrium point without taking into account impacts on other markets. However, in a modern economy, every market responds directly or indirectly to changes occurring in other markets. General equilibrium methods are suitable for application as they simultaneously define prices and quantities at the equilibrium point. As we know, input-output analysis is one of many general equilibrium methods that have been widely applied.

Input-Output (IO) models contain information on inter-industry relationships and are best suited for measuring the impact of expenditure on the construction and operation of transportation facilities. They can also be used with exogenous inputs to calculate how changes in accessibility and transportation costs induce changes in levels of economic activity.

Taking into account the Environmental pollution, we can create a symmetric system in order to calculate the relation between emissions and economic activity. Environmental IO models enable us to analyze the variations of emissions in a time



span, caused by, for instance: (i) the variations of the economic structure, (ii) the variations in volume, (iii) the variations in the efficiency of the ecosystems of producers and consumers, (iv) the variations in energy supply. Environmental input-output tables, can also be used to estimate the direct and indirect atmospheric emissions (Mylonas et. *al.*, 2000).

We chose the popular IO model because its implementation is straightforward, the derived results directly interpretable and the data easy to access. However, a limitation of the IO model is that it does not account for long-term changes. In this context, the EIO-LCA (Environmental Input-Output Analysis-Life Cycle Analysis) methodology complements the economic input-output analysis by linking economic data with resource use (such as energy, ore, and fertilizer consumption) and/or environmental impacts categories (such as GHG emissions).

To calculate direct macroeconomic impacts, technological coefficients were derived from the original input-output table by dividing each element of the intermediate demand sub-table by the total sector specific production. Whenever the final demand of the  $j$ th product changes by one unit and the demand of all other products remains constant, the  $j$ th sector will change its production level by one unit to satisfy this new demand. This change in production level will affect the level of primary inputs which is measured by the direct coefficients.

Varying the final demand of a sector also causes indirect changes to all other sectors, because production in one sector is, usually, an input for other sectors. Estimation of these indirect impacts is one of the main goals of input-output analysis and is done by using the Leontief inverse matrix:

$$X = (I-A)^{-1} F \quad (1)$$

where

$X$  is the vector of total production,

$I$  the unit matrix,

$A$  the technology matrix,

$(I-A)^{-1}$  is the Leontief inverse matrix,

$F$  is the vector of final demand.

Furthermore, output also changes and the direct and indirect impacts are also measured by using the Leontief inverse:

$$X_{AOD} = (I-A)^{-1} F_{AOD} \quad (2)$$

where:

$X_{AOD}$  expresses both the direct and indirect impacts on the output

$F_{AOD}$  is the vector of investment (final demand) for the construction of AOD.

The direct and indirect increase in output creates extra income and consequently an increase in consumption expenditures by households, which constitutes a new extra final demand and a new increase in output and emissions. This effect is called induced effect, and for its estimation we expand the matrix  $A$  to include the private expenditure vector (by households) as a new column and the total wages row vector as a new row.

Thus, we calculate the direct, indirect and induced effect cause by the investment, using the following equation:

$$X'_{AOD} = (I-A')^{-1} F'_{AOD} \quad (3)$$

where

$X'_{AOD}$  expresses the direct and indirect and induced impacts on the output

$(I-A')^{-1}$  is the Leontief inverse matrix which includes the household consumption and the value added

$F'_{AOD}$  is the vector of investment for the construction of AOD.

It should be noted that when calculating the induced effect we add in  $F_{AOD}$  vector an extra cell which is equal to zero, so the calculations are plausible.

The level of technology changes and this poses a constraint for the use of input-output analysis in the long-run. However, one may safely assume that over a period of five years, the technology matrix remains practically unchanged. Since all investment expenditures for the construction of the AOD have been estimated in 2000 prices including the vector of emissions, we use the input-output table of the Greek economy for the year 2005.

$$B_{AOD} = b \cdot X = b \cdot (I-A)^{-1} F_{AOD} \quad (4)$$

where

$b$  is the direct coefficient diagonal matrix of emissions (GHG), expressing the emissions per unit of sectoral output

$B_{AOD}$  is the vector of the direct and indirect emissions given out during the construction of AOD.

The induced impacts on environment are calculated as follows:

$$BAOD' = b' \cdot (I-A')^{-1} \cdot F' AOD \quad (5)$$

where:

$B'_{AOD}$  is the vector of direct, indirect and induced emissions caused by the construction of AOD.

Finally, in order to estimate the impact of technological change on our estimates, we use *ceteris paribus* the 2005 input – output table, which expresses, in a nutshell, the production technology of 2005.

#### 4. Data

As mentioned above, to apply input-output analysis, the input-output table and a vector of emissions per unit of output are needed with the appropriate dimensions. The domestic input-output tables come from Eurostat with an analysis in 59 sectors, reduced to 25 sectors. All the environmental data for 2000 come from the Hellenic Statistical Authority (EL.STAT.).

When incorporating the induced effects on output and emissions we use a 26x26 input-output table. Data regarding total wages and household consumption by sector are included in input-output tables. The use of a domestic input-output table for the estimation of the impact of a local infrastructure usually overestimates the results. But, in the case of AOD the domestic table expresses a significant percentage of raw materials “imported” to the region of Attica from other regions.

Next, we develop the final demand vector. As a first step (i), we used the original elements of AOD highway originating from corporate sources to calculate the total quantity of materials and related projects needed for each task. In the second step (ii), the materials and projects from step one were arranged according to the corresponding economic sectors using the *make matrix* (123 x 123) and the input-output table (59 x 59). In the third step (iii), from step two we have the sectoral vector of demand (1x59) in physical units. In the fourth step (iv), the elements of vectors (1x59) were expressed in monetary units in constant 2000 prices. In the fifth step (v), the 1x59 vector of the fourth step applying Pareto analysis is aggregated in a 1x25 vector according to the 25x25 input–output table (see Table 1 and Table 3 for the classification). This vector (1x25) is equal to about 70% of the total cost of the investment. Finally, in the sixth step (vi), according to the schedule of public works, the expenditures for the time period under survey (1999-2004) are allocated.

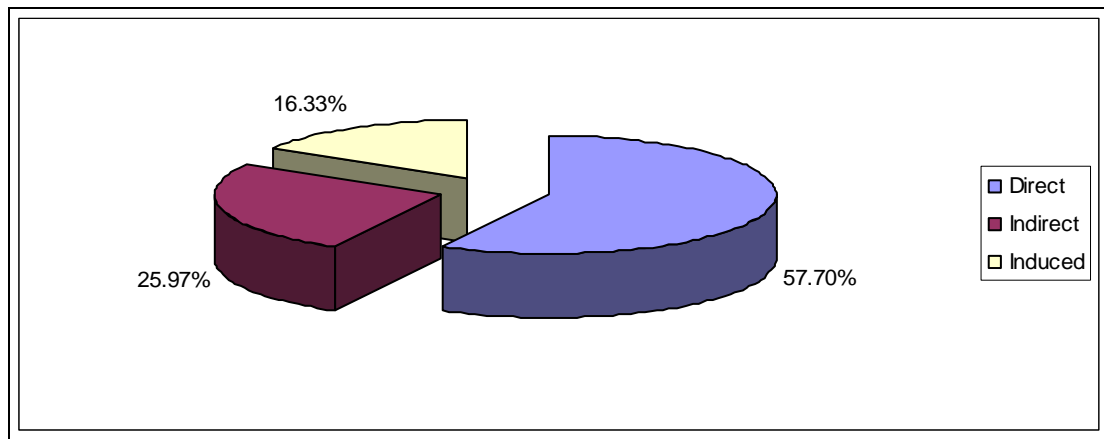
Here, it should be noted that studies of this type need to be implemented by empirical evidence from *ex-post* evaluation, as it is extremely difficult to measure the exact relationship between infrastructure and development (OECD, 2002).

## 5. Empirical Analysis

The highway investment produces economic benefits of many kinds, such as time savings, enhanced safety and vehicle operating cost reductions experienced by highway users. Highway investments reduce congestion and improve the levels of service that can boost the productivity of firms by lowering their shipping and logistics costs. However, construction and maintenance of highway facilities also help local, regional, and national economies grow by attracting new businesses and by providing access to new markets. Increase in public and local highway capital investment helps to generate employment in the highway construction industry as managers, engineers, specialists, and labourers are called upon to construct new roads or perform capital improvements to enhance highway service levels.

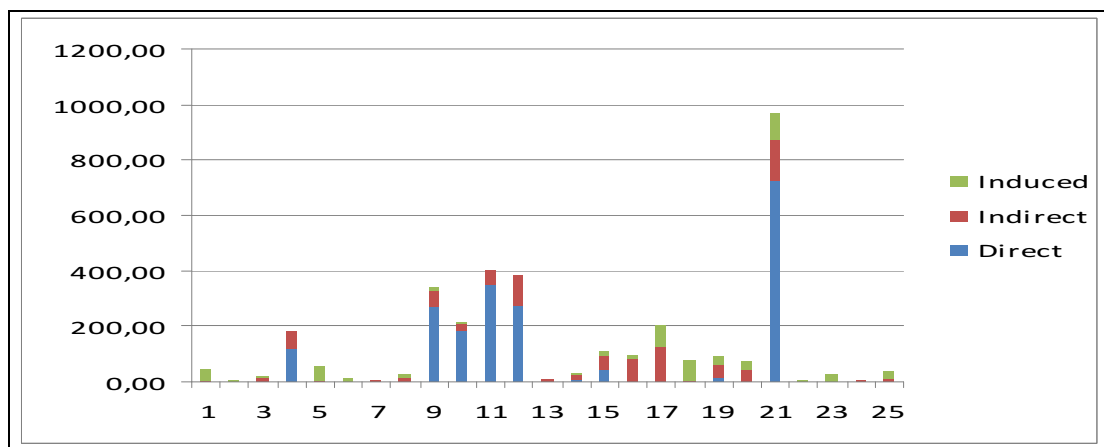
Following the steps in Table 1 (Appendix), the total cost of the investment is equal to €2.000,80 in 2000 prices (Table 1). This amount accounts for about 70% of the project's total cost. It is evident from Table 1 that the sectors of the Greek economy that supply directly materials and services for the project are eleven (11). Among them, sectors 9, 10, 11 and 12 accounts for about 54% of the materials, while sectors 15, 19 and 21 account for 39% of the services that are needed, including electricity.

From the application of the input – output analysis, the results are presented for 2000 and 2005. For the industry classifications see Table 4 (Appendix). In the total economy (Tables 2 and 3, appendix), the output that was created directly in 2000 was equal to €2001  $10^6$ , while the indirect was equal to €900.67  $10^6$  and the induced equal to 566.33  $10^6$ . In other words, the direct results are equal to the cost of investment and represent the 57.7% of total output (Figure 4). What is also important is the ratio of indirect results to the total. In our case the indirect output, is equal to 25.9% of total output. This ratio is an expression of the internal dynamics of the economy and its capability to expand the economy's production capacity (and income), related to this investment. Finally, the induced effects account for about 16.3% of total output representing the consumption of households.



**Fig. 4.** Percentage Contribution of direct, indirect and induced effect at total output for 2000

The sectors experiencing the highest direct results are the sectors included in Table 1, which satisfy the demand for investment. However, from Table 2 (Appendix) and Figure 5 it is evident that the indirect effects of the investment are transmitted, to a certain extent, to all the sectors of the economy.

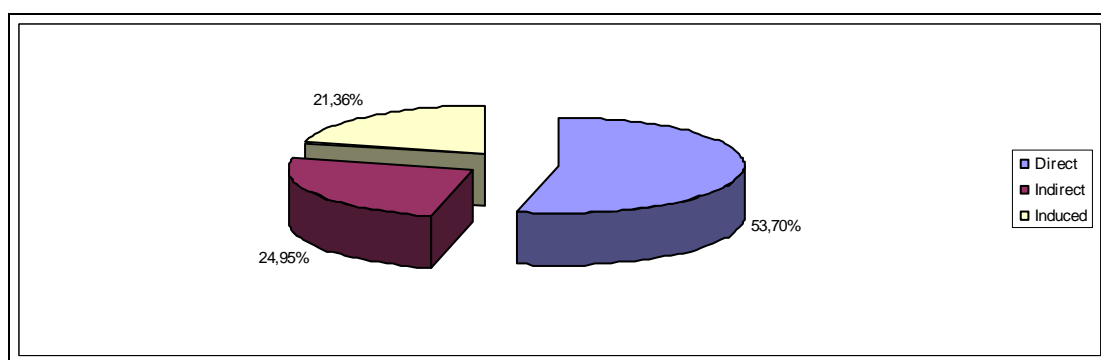


**Fig. 5.** Total Output created from the construction of AOD for 2000 (million €)

As a measure of indirect effects, the following sectors, in spite of not contributing directly to the realization of the investment, they create significant indirect results: basic metals and fabricated metal products, whole sale and retail sale of motor vehicles, whole sale and retail sale except vehicles, retail trade and real estate services, renting services of machinery and equipment, computer and related services, research and development services, other business services. These are the positive effects of the AOD investment on the Greek economy.

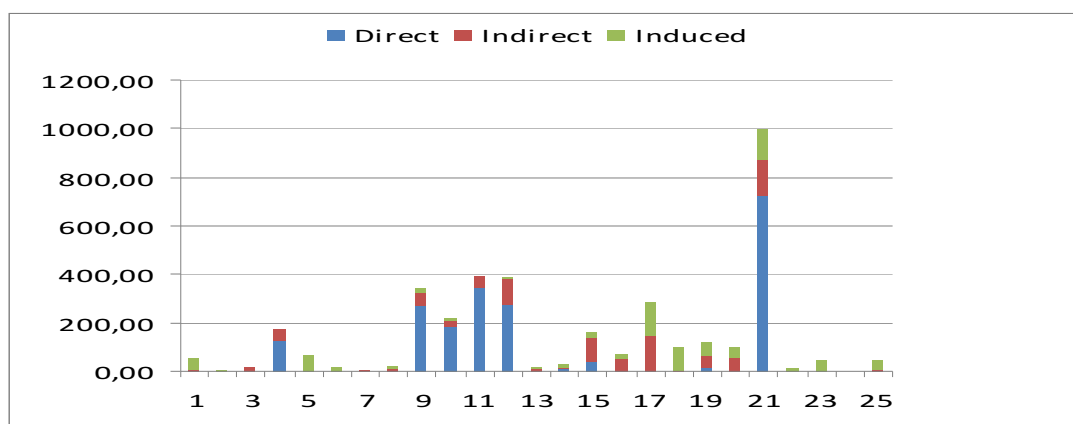
The output that was created directly in the year 2005 was equal to €2001  $10^6$ , while the indirect was equal to €929.49  $10^6$  and induced effect to €795.79  $10^6$  while the total output comes up to €3,726.07  $10^6$ . In other words, the direct results are equal to the cost of investment and represent the 53.7% of total output (Figure 6). On the other hand, the indirect output represents the 24.9% of total output. However, the indirect results are 16% higher than the direct.

Finally, the induced effects account for about 21.4% of total output representing the consumption of households.



**Fig. 6.** Percentage Contribution of direct, indirect and induced effect at total output for 2005

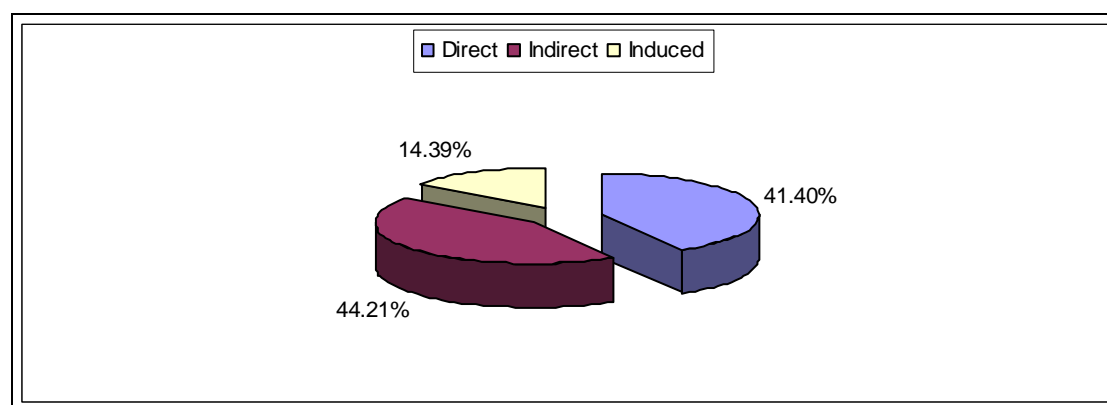
For the year 2005, the results show (Figure 7) that the sectors experiencing the highest direct results are the sectors included in Table 3. The highest indirect effects are found for the following sectors: basic metals and fabricated metal products, whole sale and retail sale of motor vehicles, whole sale and retail sale except vehicles, retail trade and real estate services, renting services of machinery and equipment, computer and related services, research and development services, other business services. The changes between 2000 and 2005 are due to technological change.



**Fig. 7.** Total Output created from the construction of AOD for 2005 (million €)

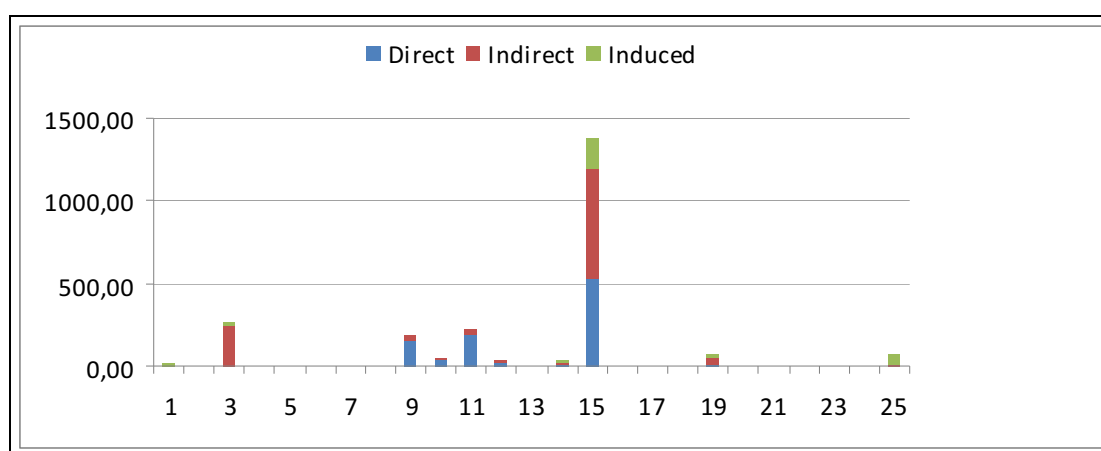
Regarding air pollution by GHG for the year 2000 (Figures 8 and 9), the direct emissions are equal to about 982.9 million tones, the indirect equal to about 1049.8 million tones, the induced to 341.7 million tones and the total to 2,374.5 million tones. We note that the sectoral linkages created in the Greek economy for the construction of the project contribute, indirectly, to the environmental burden an amount equal to 44.2% of total emissions, approximately. This results in the dispersion of the emissions (Table 2, Appendix) to most of the sectors of the Greek economy e.g., mining of coal and lignite and extraction of peat, extraction of crude oil and natural gas, mining of nuclear materials, manufacture of coke, refined petroleum products and nuclear fuel, electricity, gas, steam and hot water, collection purification and distribution of water, transports, water transport services, air transport services, post and telecommunications.

Despite the fact that direct GHG emissions of those sectors are practically negligible (except for sector 15 electricity etc.), they contribute significantly to pollution. This finding is very important for the Greek and Athenian economies, respectively, given the significant air pollution pressure that they are already facing.



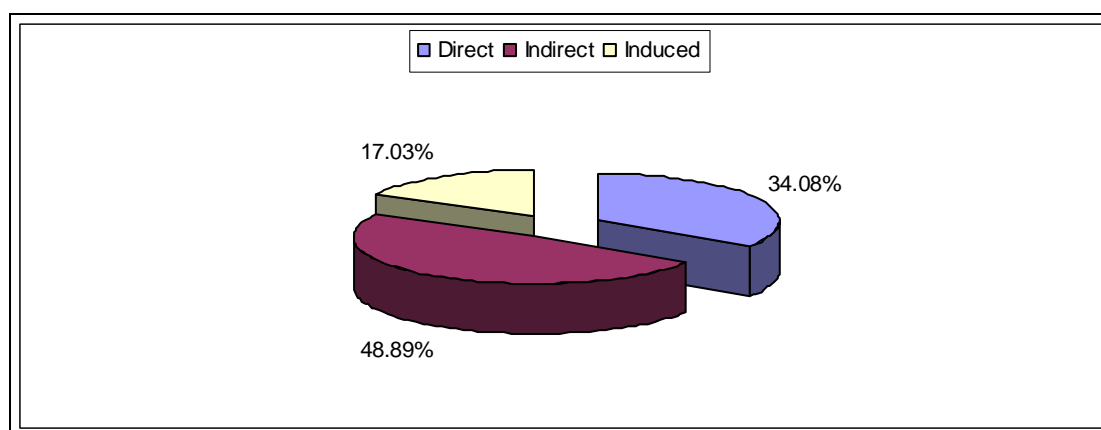
**Fig. 8.** Percentage Contribution of direct, indirect & induced effect at total emissions (2000)

Moreover, the induced effects account for about 14.3% of total emissions, representing the consumption of households.



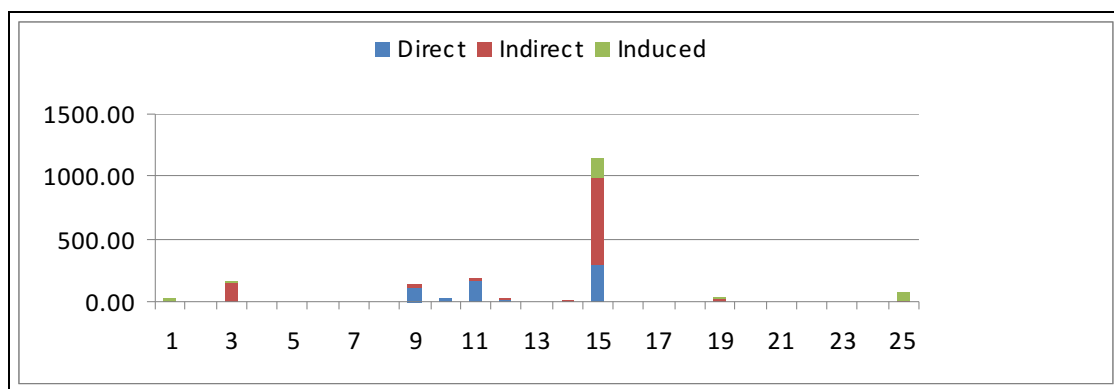
**Fig. 9.** Total Emissions created from the construction of AOD for 2000 (million tones)

The results for 2005 are similar. The direct emissions for 2005 are equal to 655.2 million of tones which represent 34% of total emissions (in contrast to 41% of 2000). The indirect emissions for the same year are equal to 939.8 million of tones and represent 48.8% of total emissions (Figures 10 and 11). Finally, the induced effects are equal to 327.3 million tones or 17% of total emissions. The most remarkable sectors indirectly effected, are the following: mining of coal and lignite and extraction of peat, extraction of crude oil and natural gas, mining of nuclear materials, manufacture of coke: refined petroleum products and nuclear fuel, electricity, gas, steam and hot water, collection purification and distribution of water, transports, water transport services, air transport services, post and telecommunications.



**Fig. 10.** Percentage Contribution of direct, indirect and induced effect at total emissions (2005)





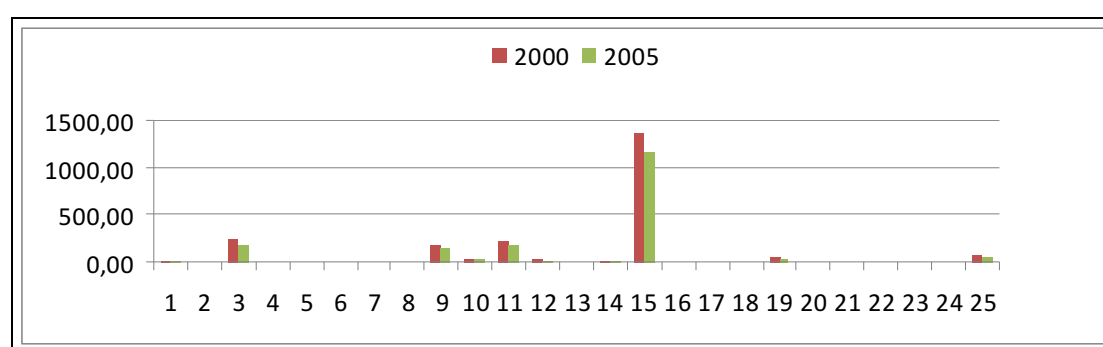
**Fig. 11.** Total Emissions created from the construction of AOD for 2005 (million tonnes)

Technological change, between 2000 and 2005 provides significant results with respect to total output and GHG emissions (Figure 12). Roughly speaking, total output increased approximately by 7% and GHG emissions decreased approximately by 19%. More specifically, the sectors with the higher increases are the following: agriculture, hunting and related service activities, products of forestry, logging related services (12%), manufacture of food products and beverages, tobacco products (13%), manufacture of textiles, manufacture of clothes process and dyeing of fur, manufacture of tanning and dressing of leather (25%), wood and wood products (16%), fabricated metal products except machinery and equipment (55%) electricity, gas, steam and hot water, collection purification and distribution of water (45%), whole sale and retail sale of motor vehicles, whole sale and retail sale except vehicles, retail trade (40%), transports, water transport services, air transport services, post and telecommunications (22%), recreational, cultural and sporting services, other services n.e.c, domestic services (41%).

On the other hand, and despite the important indirect GHG emissions, the total results have decreased. Among the sectors that experience major decreases are the following: mining of coal and lignite; extraction of peat, extraction of crude oil and natural gas, mining of nuclear materials (-31%), manufacture of coke, refined petroleum products and nuclear fuel (-27%), manufacture of chemicals and chemical products, manufacture of rubber and plastic products (-27%), basic metals and fabricated metal products (-33%), fabricated metal products except machinery and equipment (-31%), machinery and equipment, office machinery and computers, electrical machinery and apparatus, radio, television and communication equipment and apparatus, medical precision and optical instruments (-32%), transports, water

transport services, air transport services, post and telecommunications (-26%). Meanwhile, the sectors: agriculture, hunting and related service activities, products of forestry: logging related services wood and wood products and manufacture of textiles, manufacture of clothes process and dyeing of fur, manufacture of tanning and dressing of leather present noticeable increase in emissions equal to 4%, 42% and 15% respectively.

Conclusively, the sector of electricity, gas, steam and hot water, collection purification and distribution of water, which has one of the highest emission levels in Greece, experiences a decrease in emission.



**Fig. 12.** Changes in GHG Emissions owing to Technological Change

## 6. Conclusion

This paper applied IO analysis to calculate the environmental effects of the Attiki Odos motorway investment in the Athens Metropolitan Area (AMA), a matter of great importance for the Athenian and the Greek economies, respectively. Input – output analysis is applied to assess the environmental impacts of the investments expenditures. We found that the construction of the Attiki Odos grid created significant direct, indirect and induced results in the Greek economy in terms of air pollution. More precisely, a main finding of the paper is that air pollution has decreased in terms of direct effects, but has slightly increased in terms of indirect and induced effects. Furthermore, to asses the impact of technological change, we used *ceteris paribus* the domestic input-output tables for 2000 and 2005, respectively, expressing two different production technologies. Another major finding is that technological change between 2000 and 2005, provided significant results with respect to total output and emissions. Roughly speaking, total output increased approximately by 7% and emissions decreased approximately by 19%.

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## Appendix

### Tables

**Table 1:** Investment expenditures for highway construction

No	Industry Classification (see Table 5)	Industries	Cost ( <i>million euros –2000 prices</i> )
A	4	Mining of metal ores, other mining and quarrying products etc	123.42
B	7	Wood and wood products	0.02
C	9	Manufacture of coke: refined petroleum products etc	271.64
D	10	Manufacture of chemicals and chemical products, manufacture of rubber and plastic products	183.33
E	11	Manufacture of other non-metalic mineral products	349.24
F	12	Basic metals and fabricated metal products	275.33
G	13	Fabricated metal products except machinery and Equipment.	1.07
H	14	Machinery and equipment, office machinery and computers, electrical machinery and apparatus, radio, television and communication equipment and apparatus, medical precision and optical instruments, watches and clocks, motor vehicles trailers and semi-trailers	10.17
I	15	Electricity, gas, steam and hot water, collection purification and distribution of water	43.67
J	19	Transports, water transport services, air transport services, post and telecommunications	17.36
K	21	Real estate services, renting services of machinery and equipment, computer and related services, research and development services, other business services	725.53
Summation			2,000.80

Source: AOD Highway, 2004 (authors' elaboration)

**Table 2:** Total Effects of the Project at year 2000

Industry	Changes in output				Changes in emissions			
	Direct	Indirect	Total	Induced	Direct	Indirect	Total	Induced
1	0	4.62	48.20	43.59	0.00	2.22	23.21	20.98
2	0	0.11	3.05	2.94	0.00	0.00	0.00	0.00
3	0	17.66	19.44	1.78	0.00	236.40	260.20	23.80
4	123	63.05	187.45	0.98	0.00	0.00	0.00	0.00
5	0	3.22	57.65	54.43	0.00	0.27	4.84	4.57
6	0	1.77	15.05	13.28	0.00	0.24	2.01	1.78
7	0	3.76	5.03	1.26	0.01	1.11	1.49	0.37
8	0	15.42	24.69	9.26	0.00	2.16	3.46	1.30
9	272	55.47	339.73	12.62	158.97	32.47	198.82	7.38
10	183	27.25	219.23	8.65	41.04	6.10	49.08	1.94
11	349	54.15	406.02	2.62	196.33	30.44	228.25	1.47
12	275	112.02	389.62	2.26	26.69	10.86	37.77	0.22
13	1	7.10	10.91	2.74	0.27	1.80	2.76	0.69
14	10	14.66	31.14	6.31	9.88	14.24	30.25	6.13
15	44	53.52	112.07	14.88	537.09	658.22	1378.27	182.96
16	0	85.70	97.92	12.23	0.00	0.00	0.00	0.00
17	0	128.42	206.61	78.19	0.00	3.75	6.03	2.28
18	0	3.62	78.87	75.25	0.00	0.00	0.00	0.00
19	17	44.08	96.59	35.15	12.66	32.14	70.42	25.63
20	0	39.90	76.71	36.81	0.00	0.00	0.00	0.00
21	726	150.61	970.02	93.88	0.00	0.00	0.00	0.00
22	0	2.31	6.37	4.05	0.00	0.00	0.00	0.00
23	0	1.17	26.34	25.17	0.00	0.00	0.00	0.00
24	0	3.09	3.51	0.43	0.00	0.00	0.00	0.00
25	0	7.98	35.58	27.60	0.00	17.40	77.62	60.21
<b>Sum</b>	<b>2,001</b>	<b>900.67</b>	<b>3,467.79</b>	<b>566.33</b>	<b>982.94</b>	<b>1,049.83</b>	<b>2,374.49</b>	<b>341.72</b>

Source: authors' elaboration

**Table 3:** Total Effects of the Project at year 2005

Industry	Changes in output				Changes in emissions			
	Direct	Indirect	Total	Induced	Direct	Indirect	Total	Induced
1	0.00	4.31	53.88	49.57	0.00	1.93	24.10	22.17
2	0.00	0.06	4.08	4.02	0.00	0.00	0.00	0.00
3	0.00	16.04	18.36	2.31	0.00	157.63	180.37	22.74
4	123.42	52.70	176.94	0.82	0.00	0.00	0.00	0.00
5	0.00	2.35	65.20	62.86	0.00	0.17	4.67	4.50
6	0.00	1.97	18.78	16.81	0.00	0.30	2.85	2.55
7	0.02	3.19	5.83	2.62	0.01	0.93	1.71	0.77
8	0.00	12.21	24.23	12.02	0.00	1.47	2.92	1.45
9	271.64	54.97	343.10	16.49	115.02	23.28	145.28	6.98
10	183.33	25.07	219.68	11.28	29.99	4.10	35.94	1.85
11	349.24	44.72	396.93	2.97	167.75	21.48	190.65	1.42
12	275.33	110.32	388.96	3.31	18.05	7.23	25.50	0.22
13	1.07	10.28	16.93	5.58	0.12	1.16	1.91	0.63
14	10.17	10.16	30.83	10.51	6.81	6.80	20.65	7.04
15	43.67	95.44	162.89	23.78	309.80	677.05	1155.54	168.69
16	0.00	56.04	69.03	13.00	0.00	0.00	0.00	0.00
17	0.00	149.15	289.89	140.74	0.00	2.60	5.06	2.45
18	0.00	4.50	102.21	97.71	0.00	0.00	0.00	0.00
19	17.36	50.58	117.93	49.99	7.65	22.29	51.97	22.03
20	0.00	62.11	102.43	40.32	0.00	0.00	0.00	0.00
21	725.53	149.25	1004.51	129.74	0.00	0.00	0.00	0.00
22	0.00	2.50	10.50	8.00	0.00	0.00	0.00	0.00
23	0.00	1.20	49.75	48.55	0.00	0.00	0.00	0.00
24	0.00	2.56	2.91	0.35	0.00	0.00	0.00	0.00
25	0.00	7.84	50.30	42.46	0.00	11.41	73.25	61.84
<b>Sum</b>	<b>2,001</b>	<b>929.49</b>	<b>3,726.07</b>	<b>795.79</b>	<b>655.20</b>	<b>939.84</b>	<b>1,922.36</b>	<b>327.33</b>

Source: authors' elaboration

**Table 4: Industry Classification**

1	Agriculture, hunting and related service activities, products of forestry: logging related services
2	Fish and other fishing products
3	Mining of coal and lignite; extraction of peat, extraction of crude oil and natural gas, mining of nuclear materials
4	Mining of metal ores, other mining and quarrying products
5	Manufacture of food products and beverages, tobacco products
6	Manufacture of textiles, manufacture of clothes process and dyeing of fur, manufacture of tanning and dressing of leather
7	Wood and wood products
8	Pulp, paper and paper products publishing printing and reproduction of recorded media
9	Manufacture of coke: refined petroleum products and nuclear fuel
10	Manufacture of chemicals and chemical products, manufacture of rubber and plastic products
11	Manufacture of other non-metallic mineral products
12	Basic metals and fabricated metal products
13	Fabricated metal products except machinery and equipment.
14	Machinery and equipment, office machinery and computers, electrical machinery and apparatus, radio, television and communication equipment and apparatus, medical precision and optical instruments, Watches and clocks, motor vehicles trailers and semi-trailers
15	Electricity, gas, steam and hot water, collection purification and distribution of water
16	Construction works
17	Whole sale and retail sale of motor vehicles, whole sale and retail sale except vehicles, retail trade
18	Hotel and restaurant services
19	Transports, water transport services, air transport services, post and telecommunications
20	Financial intermediation services, insurance and pension funding services, services auxiliary to financial intermediation
21	Real estate services, renting services of machinery and equipment, computer and related services, research and development services, other business services
22	Public administration and defence services, sewage and refuse disposal services sanitation
23	Membership organization services n.e.c.
24	Membership organization services n.e.c.
25	Recreational, cultural and sporting services, other services n.e.c, domestic services

Source: Eurostat, 2010 (author's elaboration)