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AN EMPIRICAL ANALYSIS OF THE CO_2 EMISSIONS IMPACT: EVIDENCE FROM ROMANIAN TOURISM SECTOR

This paper investigates the impact of changes of the final demand in tourism sector upon the carbon dioxide (CO_2) emissions, using the environmental input-output (IO) approach. The IO framework is used to reveal the changes in CO_2 emissions as a result of changes in CO_2 intensity of various economic sectors. The empirical analysis is developed for Romania, using economic and environmental data for two distinctive years – 2000 and 2006 respectively. Our results indicate that tourism sector generates medium-low emission multipliers, and the shocks in tourism final demand reveal that the environmental burdens transmitted throughout the economy are lower than the initial percentage change of 1%, 5% and 10% respectively. The second finding of the paper concerns the decrease in CO_2 emissions as a result of changes in CO_2 intensity in various productive sectors.

Keywords: *input-output analysis; CO_2 emissions; shocks; multipliers; tourism; Romania.*

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ЕМПІРИЧНИЙ АНАЛІЗ ВПЛИВУ ВИКИДІВ ВУГЛЕКИСЛОГО ГАЗУ: ЗА ДАНИМИ ТУРИСТИЧНОЇ ГАЛУЗІ РУМУНІЇ

У статті досліджено вплив змін в об'ємах туризму на кількість викидів вуглекислого газу, застосовано екологічний підхід "споживання – виробництво". Даний підхід використано для відстежування змін у газових емісіях у результаті змін в інтенсивності роботи різних галузей економіки. Для емпіричного аналізу використано дані по Румунії за 2 роки для порівняння – 2000 та 2006 років. Результати аналізу показали, що газові емісії, що припадають на туризм, можна оцінити як нижчі середнього. Стрибки у навантаженнях на навколишнє середовище від туризму на 1%, 5% та 10% у результаті дають значно менші газові викиди. Важливим спостереженням також є те, що зменшення газових емісій є результатом змін в інтенсивності споживання вуглекислого газу різними галузями економіки.

Ключові слова: *аналіз зв'язку "споживання – виробництво"; викиди вуглекислого газу; стрибки; туризм; Румунія.*

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ЭМПИРИЧЕСКИЙ АНАЛИЗ ВЛИЯНИЯ ВЫБРОСОВ УГЛЕКИСЛОГО ГАЗА: ПО ДАННЫМ ТУРИСТИЧЕСКОЙ ОТРАСЛИ РУМЫНИИ

В статье исследовано влияние изменений в объемах туризма на количество выбросов углекислого газа, использован экологический подход "потребление – производство". Данный подход применен для отслеживания изменений в газовых эмиссиях в результате изменений в интенсивности работы различных отраслей экономики. Для эмпирического анализа использованы данные по Румынии за два года для сравнения – 2000 и 2006 года. Результаты анализа показали, что газовые эмиссии, приходящиеся на туризм, можно оценить как ниже среднего. Скачки в нагрузках на окружающую среду от туризма на 1%,

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5% и 10% в результате дают значительно меньшие газовые выбросы. Важным наблюдениям также является то, что уменьшение газовых эмиссий является результатом изменений в интенсивности потребления углекислого газа различными отраслями экономики.

Ключевые слова: *анализ связи "потребления – производство"; выбросы углекислого газа; скачки; туризм; Румыния.*

1. Introduction. Climate changes is a debated topic nowadays, determining complex direct and indirect effects upon environment and human activities and influencing the activity of different economic sectors, in general, and tourism, in particular. Global warming is a demonstrated consequence of the greenhouse gas (GHG) emissions. Among them, carbon dioxide (CO_2) is one of the first mentioned in numerous studies on the topic, being next to carbon monoxide (CO), methane (CH_4), nitrous oxide (N_2O), nitrogen oxide (NO_x), and sulphur dioxide (SO_2) gases, one of the most frequently analysed elements by the alternative emissions trajectories spanning the years 1990 through 2100 for greenhouse-related gases within the IPCC emissions scenarios.

Global climate changes scenarios have particular effects on each continent, Europe being one of the most affected. On the sectoral level, the impacts of climate change on tourism became certitude, as climate plays an important role in tourist destination choices, not being perceived anymore as something already granted or constant (Berittella et al., 2006). At the same time, it is generally agreed that tourism, through its activities and particularly through transport (aviation especially), contributes to a great extent to the global GHG emissions inducing a cause-effect cycle with certain economic implications. Climate changes become more acutely felt and manifest themselves in a number of different ways according to local conditions of tourism industries.

In Romania climate change effects have already marked their presence, especially at the level of winter sport industry by the difficulties met by consecrated middle and low level altitude resorts with snow optimum conditions in some of the recent years (Surugiu et al., 2010). Other case studies clearly emphasize that climate changes have economic impact on leisure sector. (Koch and Rudel, 1990; Breiling, 1993a, 1993b; Abegg and Froesch, 1994; Koenig, 1994; Abegg, 1996; Mohnl, 1996; Koening and Abegg, 1997; Meier, 1998; Burki, 2002; Guilpart, 2006; Bigano and Bosello, 2007). As a result of the importance of the topic, a significant number of journal papers and scientific researches have been published (Tol, 2010). Different methods were used to estimate climate changes on tourism sector, progressively evolving from simple and/or multiple linear regressions (Koenig and Abegg, 1997; Breiling, 1998; Breiling et al, 1999; Bigano et al., 2005; Scott et al., 2004; Surugiu et al., 2010) to input-output models (IOM) (CLAVIER, 2008) and even to Computable General Equilibrium (CGE) models (Berritella et al., 2006; Pham et al., 2010). However, they appear as punctual studies on different methods and approaching various aspects of the complex climate-tourism relation. More complicated models on the relation tourism-climate-tourism from the perspective of cost-benefit analysis and on the double or cyclical sense relation tourism-climate-tourism are still to be developed, as modeling focused either on projections of emissions from international tourism

(Mayor and Tol, 2009; Peeters and Dubois, 2009; Dubois et al., 2009) or on the climate changes impact on tourism.

The rest of the paper is organized as follows. Section 2 reviews the literature investigating the impact of GHG emissions using IO models. Sector 3 describes the methodology and the data used. Section 4 presents the empirical results of the IO analysis to estimate the CO_2 emissions multipliers and develops various shocks in tourism demand. Section 5 concludes the paper.

2. Literature review. In scientific literature it is underlined that one of the main determinants of climate change are the CO_2 emissions, environmental pollution being a topic approached by theoreticians, politicians, economists, ecologists etc. involved in the continuing race to determine solutions to the crisis that might appear due to unwanted effects of the GHG emissions on society, economy, environment etc. One of the methods of estimating the level of CO_2 emissions is the input-output model (IOM), being an important tool which may help formulating relevant proposals for environmental policy and not only. The IOM is also a framework to analyse various issues and impacts, taking into consideration aspects related to the economy and environment. In Table 1 previous discussions and results are summarized, along with the overview of the literature in the field.

Table 1. **Overview of the literature on input-output & GHG estimation analysis**

Model/method	Aspects under investigation	Main discussions/results	Source
IO SDA; Two-tiered KLEMM	Impact of various influences on CO_2E	CO_2Ev generated by substitution effect in E and between E and OI; E price^ and structural shift are more effective than productivity improvement in E and OI.	Casler and Rose (1998)
IO SDA	Sources of CO_2EC; CO_2E from FF combustion	~ in emissions due to ≈ in industrial added value; ~ in CO_2II; ~ in technical coefficients; ~ in FD of various industries; Total joint effect of CO_2E.	Mukhopadhyay (2001)
IOM	International effect of the development proposals	IOA enhances EIA (national and international effects considered in the decision making process).	Lenzen et al (2003)
Extended IOM	CO_2Es; Sources of CO_2E; sectors' contribution to CO_2E.	MI highest and A&H lowest CO_2E and CO_2 responsibility	Tunc et al (2006)
Extension of EIOM	Composition of emissions; GHG; sectoral demand; exogenous shock.	Differences in the effects of sectors on the composition of GHG; Final impact on RCP will depend on the activity that receives exogenous shock in FD; Differences in the way an activity affects GHG.	Butnar and Llop (2007)
EIOM	Regional economy; Alpine region; ecosystem services	Economic activities should be encouraged to use ecosystem services more intensively.	Gret-Regameya and Kytzia (2007)

The End of *Table 1*

Model/method	Aspects under investigation	Main discussions/results	Source
IO&EFA	EF; EEI; international trade	Adopting MRIOAA is the most appropriate method of calculating EF	Turner et al (2007)
IOM	CO_2Es	The highest E intensive sectors are: PR&GSP, RFT, El and C, but the highest total GHG emitters are: El, OT and C	Kofoworola and Gheewala (2008)
IOM	CO_2E; SS	TA has the highest level of direct emissions generated in the Ps; Ps sold to Os causes more emissions than its own FD.	Alcantara and Padilla (2009)
SIOS	Embodied CO_2E originated in FF combustion	Most developed economies avoid their responsibility via importing CIG from developing economics, shifting CO_2E to economies in transitions.	Chen et al (2010)
IOM	GHG; carbon emission inventory	Highest GHG emissions are: EPSHWPS, SPFNM, NMP, Ag, and CMD; Ct has the highest GHG in domestic production &consumption.	Chen and Zhang (2010)
IOM	PU; GHG; T	Atr, Els & Otr are the key economic activities responsible for GHG associated with FF use.	Konan and Chan (2010)
Combined use of econometric modeling tools in a supply–use system	CO_2E; climate changes	Eco-efficient sectors in transmitting CO_2E abroad by importing foreign products are sectors WT, OMC, ME, FP, CRP; Dem may vary according to different import share; Elasticity has a role in the capacity of sectors to v its CO_2E via external trade.	Rueda-Cantuche and Amores (2010)

Note: Ag – Agriculture; A&H – agriculture & husbandry; Atr – Air transportation; CIG – carbon intensive goods; CMD – Coal Mining & Dressing; CO2E – CO2 emissions; CO2EC – CO2 emission changes; CO2Es – CO2 estimation; CO2II – CO2 intensity of industries; CRP – chemicals, rubber & plastics; C – Cement; Ct – Construction; Dem – domestic emission multiplier; E – energy; EEI – embodied environmental impact; EIOM – Environmental IOM; EF – ecological footprint; EIA – Environmental Impact Assessment; El – Electricity; EPSHWPS – Electric Power/Steam & Hot Water Production & Supply; FD – final demand; FF – fossil fuels; FP – food products; GHG – greenhouse gas emission; IOA – IO Analysis; IOM – IO model; IO&EFA – IO and ecological footprint analysis; IO SDA – IO structural decomposition analysis; KLEM – translog production function model (capital, labour, energy & material aggregates); ME – machinery & equipment; MI – manufacturing industry; MRIOAA – multi-region IO accounting approach; NMP – Non-metal Mineral Products; OI – other inputs; OMC – office machinery & computers; Os – other sectors; Otr – other transportation; OT – Ocean Transport; PR&GSP – Petroleum Refinery & Gas Separation Plant; Ps – production of the sector; PU – petroleum use; RCP – relative contribution of pollutants; RFT – Road Freight Transport; SIOS – systems IO simulation; SPFNM – Smelting & Pressing of Ferrous & Nonferrous Metals; SS – service sector; T – tourism; TA – transport activity; WT – water transport; ~ – changes; ↓ – decrease; ↑ – increase; ≈ – variation.

The literature is rich in valuable papers which used the IO framework to account for the GHG emissions, pollution, environmental impact and so on, the analyses were employed taking into consideration various sectors of the economy and the production processes. Nowadays, in the context of the level of pollution, as a real threat to environmental preservation, an understanding of the possibilities to alleviate the

negative impact of CO_2 emission is necessary. An important topic to address is the assessment of the sectors having the highest effects on the environment, contributing with an increased burden on the environment, society and economy. In particular, our paper tries to shed light on the topic of the impact of CO_2 emissions in the case of Romanian economy sectors, our IOM helps to conceive conclusions which may be used in sustainable development policies at national and local levels.

3. Methodology and data description. The analytic framework for assessing the impact of CO_2 emissions is based on the IO approach. The standard representation of the IO equation can be expressed as follows:

$$X = AX + Y = (I - A)^{-1}Y, \quad (1)$$

where X is the vector of final production in every sector, A is the matrix of IO coefficients for all industries, also called the technology matrix, Y is the vector of final demand, I is the identity matrix, $(I\text{-}A)^{-1}$ is the Leontief inverse or total requirements matrix. The Leontief inverse is used to derive the output multipliers by summing the entries in the column under each industry. The output multipliers show the overall effects (direct and indirect) on sectoral production, induced by one unit change in the final demand of sectors.

To understand the factors that underlies the generation of CO_2 emissions within a production system, this paper develops the previous research approach of Butnar and Llop (2007) and Mukhopadhyay (2001). Butnar and Llop (2007) used the environmental IO approach to quantify changes in the levels of GHG emissions caused by changes in the final demand for production activities. Mukhopadhyay (2001) investigated the forces responsible for changes in CO_2 emissions during various periods of time, using IO approach.

According to Butnar and Llop (2007), IO model provides instruments to assess the environmental pollution associated with production. Thus, the sectoral CO2 emissions associated with a given level of final demand can be calculated as follows:

$$T = C(I - A)^{-1}Y, \quad (2)$$

where C is the matrix of sectoral CO_2 emissions per unit of output, in which the diagonal elements is the amount of CO_2 (in physical units) per monetary unit of final production and T is the vector of i sectors CO_2 emissions. The elements in matrix $C(I - A)^{-1}$ are the CO_2 emission multipliers which express the amount of CO_2 emissions caused by changes in the final demand of sector j.

Following the equation (2), the impact of final demand on CO_2 emissions can be calculated as follows:

$$dT = C(I - A)^{-1}dY, \quad (3)$$

where dT is the changes in the amount of sectoral CO_2 emissions, dY – changes in the final demand of activities. As the final demand for the intensive pollutant industries increases, at the same time the CO_2 emissions increase. Equation (3) captures the shocks in sectoral demand and the results on pollutant emissions, generating global warming.

According to Mukhopadhyay (2001), changes in total CO_2 emissions between two years (year t and year 0) can be expressed following the bellow equation:

$$TE = C_t(I - A_0)^{-1}T_0 - C_0(I - A_0)^{-1}Y_0, \quad (4)$$

where TE is the total industrial CO_2 emissions. Equation (4) reflects the CO_2 emissions changes due to the changes of CO_2 intensity in various industries.

In this paper, most statistical data come from Eurostat database covering the IO table for domestic output at basic prices, and CO_2 emissions accounts by activity, NACE industries (thousands of tons) for two years, 2000 and 2006.

For this paper, the IO transaction table is aggregated in 13 branches (P13) (see Table 2), considering 'tourism branch' as 'Hotels and restaurants and supporting and auxiliary transport activities, activities of travel agencies'. Also, the impact of transportation activities on the CO_2 emissions will be emphasized as a component of wider travel industry.

Table 2. **Aggregation of the NACE activities**

NACE activities	No.
Agriculture, hunting, forestry, fishing	1
Mining and quarrying	2
Manufacture of food products, beverage, tobacco	3
Manufacture of textiles, leather, wood and similar products	4
Manufacture of pulp, paper and paper products; publishing and printing; coke, refined petroleum products and nuclear fuel; chemicals, chemical products and man-made fibres; rubber and plastic products; other non-metallic mineral products; basic metals and fabricated metal products; machinery and equipment n.e.c.; electrical and optical equipment; manufacture of transport equipment; n.e.c.	5
Electricity, gas and water supply	6
Construction	7
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	8
Hotels and restaurants; supporting and auxiliary transport activities; activities of travel agencies	9
Transport, storage and communication, except for supporting and auxiliary transport activities; activities of travel agencies	10
Financial intermediation	11
Real estate, renting and business activities	12
Public administration and defence; compulsory social security; education; health and social work; other community, social and personal service activities	13

4. Empirical results. The first part of this empirical analysis will deal with output multipliers and CO_2 emission multipliers, especially underlining the effects on CO_2 emissions generated by exogenous inflows to final demand of tourism sector. Electricity, gas and water supply (6) amount to slightly more than 57.5% of total CO_2 emissions in 2006, while in 2000 the ratio raised to 58.8%. Manufacturing (3, 4 & 5) contributed more than 21% and 20% respectively, while transport, storage and communication (10) accounted for11.02% and 12.33% respectively, to total CO_2 emissions.

Tourism sector such as hotels and restaurants supporting and auxiliary transport activities; activities of travel agencies accounted for very small shares of the CO_2 emissions, below 1%. Still, the emissions of tourism sector (9) increased from 0.17% in 2000 to 0.53% in 2006.

Ranking in terms of direct CO_2 emission coefficients (tons per unit of production) leads to different results in terms of pollution intensity, except for electricity which also ranks the first, having the greatest value (5447.7), followed on the second position by mining and quarrying (1092.2) (see Table 4). Tourism sector has the sixth position with the emission coefficient of 73.2 tons per output, which represents a 6.9% decrease as compared with 2000.

Table 3. **Direct contribution to CO_2 emissions, %**

	2000	2006
1	2.07	1.14
2	4.62	4.37
3	0.04	0.01
4	1.40	0.44
5	19.61	19.58
6	58.80	57.50
7	1.16	1.19
8	0.28	0.57
9	0.17	0.53
10	11.02	12.33
11	0.09	0.33
12	0.44	0.94
13	0.31	1.08
Total	**100.0**	**100.0**

Applying the above described methodology, the results reveal that the highest outputs and CO_2 emission multipliers are registered by electricity, gas and water supply. Sector 6 has high contribution in terms of direct and indirect effects, but it also has an intensive pollutant activity. In 2006, the top-four list, in terms of output multipliers, is completed by manufacture of food products, beverages, tobacco (1.792); mining and quarrying (1.678); construction (1.676). Tourism sector is ranked the eighth and respectively the seventh in the analysed years, expressing medium interlinkages with other sectors of the economy. An increase of 1 Ron in the demand for tourism sector result in a change in the economy's total output by 1.659 Ron.

In terms of emission multipliers, the direct and indirect CO_2 emission estimated through the Leontief inverse matrix based calculations, the top-four list changes significantly, except for the first position. Also, between 2000 and 2006 an exchange in ranking positions does not occur, the second place being occupied by sector 2 – mining and quarrying (2.199), sector 5 – manufacturing of pulp, paper and paper products etc. (1.372), sector 10 – transport, storage and communication etc. (1.296).

Table 4. **Output and emissions multipliers**

	Output multipliers		CO_2 emission coefficients		CO_2 emission multipliers	
	2000	2006	2000	2006	2000	2006
	1	2	3	4	5	6
1	1.691	1.629	203.4	71.6	0.930	0.338
2	1.638	1.678	2058.4	1,092.2	4.071	2.199
3	1.946	1.792	3.9	0.9	1.029	0.398
4	1.492	1.518	341.0	60.1	1.130	0.431
5	1.787	1.666	1117.5	529.2	3.342	1.372
6	1.977	1.800	10202.7	5447.7	15.448	7.444
7	1.678	1.676	213.2	72.0	1.524	0.460
8	1.371	1.443	37.3	33.2	0.464	0.224
9	1.567	1.659	78.6	73.2	1.143	0.391
10	1.595	1.500	1331.0	803.8	2.531	1.296
11	1.433	1.432	78.6	116.6	0.794	0.490
12	1.474	1.533	53.1	43.7	0.921	0.466
13	1.472	1.418	31.5	48.3	0.853	0.421
Total	21.12	20.75			34.18	15.93

Still in terms of emission multiplier in 2006, tourism is ranked eleventh, becoming less pollutant. New demands for hotels and restaurants, transport and travel agencies cause insignificant increase in emissions (0.391 as compared with 1.143).

The above analysis shows that tourism sectors shifted its direct and total contribution to CO_2 emissions. In 2000, the direct impact on CO_2 emissions through production accounts for 0.17% of national emissions; while the total tourism impact on the emissions reached 3.35% of the national total. In 2006, the direct contribution rose up 0.53%, but the total contribution declined 2.45%. The direct contribution to CO_2 emissions of tourism sector 804 tons per unit of output, while if including the indirect effects, the total contribution increases to 1296 tonnes of CO_2 per exogenous and unitary inflow received

According to Butnar and Llop (2007), the sum of columns 5 and 6 of Table 3 shows the increase in CO_2 emissions caused by one unitary injection in the final demand of all the activities simultaneously. Therefore, this total value reflects the pollution effects of CO_2 emissions caused by the joint inflows in all the sectors of the economy, which in 2006 decreased to 15.93 from the previous 34.18 in 2000.

Table 5 shows to what extent a shock in tourism sector final demand of 1%, 5% and 10% respectively, has a large impact on the CO_2 emissions of the productive sectors due to the activity interlinkages and extensive use of intermediate pollutant inputs. Consequently, an 1% inflow to sector 9 final demand generates an increase of 0.729% in CO_2 emissions, while a 5% injection is followed by a 3.643% increase in CO_2 emission of tourism sector.

The highest growth rates in terms of emissions generation caused by a 10% increase in tourism final demand are on wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (0.278%), financial intermediation (0.250); manufacture of food products, beverages, tobacco (0.200), while the lowest influences were felt in 4 and 5 manufacturing sectors.

Table 5. **Changes in CO2 emissions**

	dT (%)			TE (thousand tons)
	Shocks in final demand of sector 9 — tourism, 2006 base year			
	1%	5%	10%	
1	0.020	0.099	0.198	-1122.7
2	0.011	0.056	0.112	-1813.3
3	0.020	0.100	0.200	-24.5
4	0.003	0.017	0.033	-965.3
5	0.004	0.021	0.042	-8639.4
6	0.017	0.086	0.172	-22936.5
7	0.007	0.033	0.066	-642.3
8	0.028	0.139	0.278	-25.8
9	0.729	3.643	7.285	-9.9
10	0.014	0.072	0.145	-3654.8
11	0.025	0.125	0.250	34.6
12	0.007	0.035	0.070	-64.7
13	0.004	0.022	0.044	139.6

Changes in the intensity of CO_2 emissions present the largest decrease in 2000-2006 for electricity, gas and water supply (-22936.5 thousand tons), manufacture of pulp, paper and paper products (sector 5) (-8639.4 thousand tons) and transport,

storage and communication, except for supporting and auxiliary transport activities; activities of travel agencies (-3654.8 thousand tons). It has been observed that during 2000-2006 only two sectors had an increase in CO_2 emissions, though not significantly, namely financial intermediation and public administration and defence; compulsory social security; education; health and social work; other community, social and personal service activities. Hotels and restaurants and supporting and auxiliary transport activities; activities of travel agencies are ranked the lowest among other sectors which have decreased CO_2 emissions, with only 9.9 thousand tons.

An important finding of this paper relates to the most pollutant productive sectors, which concentrates over 68% of the total emission multipliers, and these sectors are electricity, gas and water supply, mining and quarrying and transport, storage and communication (except for supporting and auxiliary transport activities; activities of travel agencies). According to Butnar and Llop (2007), the concentration of CO_2 emissions in just a few productive sectors may make it easier for decision-makers in environmental protection to adopt appropriate measures to reduce the level of GHG emissions.

5. Conclusion. The CO_2 emissions represent a significant source of GHG emissions into the atmosphere which could produce global warming. The assessment of environmental burdens of production processes has captured the interest of the academia which develops various environmental IO approaches. Tourism sector has registered considerable growth rates in the last decades, contributing to income and employment, but also having significant contribution to CO_2 emissions.

The IO approach can be used for assessment of the pollutant emissions, analysing how changes in the final demand for productive activities influence the composition of CO_2 emissions. Applying the environmental IO modelling for Romanian economy in two distinctive years, 2000 and 2006, the results underline that tourism sector has a medium to low contribution to the total CO_2 emissions.

In 2006 the direct contribution of tourism sector to CO_2 emissions accounted for 0.53% of the total emissions in Romania, while total contribution to direct, indirect and induced effects (i.e. total effects) caused by tourism is estimated to nearly 2.45% of the national total emissions. The greatest direct and indirect contribution to the CO_2 emissions has energy, electricity, gas and water supply, which generate 7,444 tons of CO_2 per exogenous and unitary inflow received, while their direct contribution counts for 5448 tonnes of CO_2 per unit of output.

A shock in the tourism sector final demand (1%, 5%, and 10% respectively) determines changes in the levels of direct CO_2 emissions of tourism, below the initial percentage change (0.73%, 3.64% and 7.29% respectively), but also indirect emissions in other productive sectors, especially in wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods; financial intermediation; manufacture of food products, beverage, tobacco, sectors which are not intensive pollutants.

Consequently, it is important to stress that tourism not only generates economic benefits for local destinations and at national level, but it has environmental impact, being a contributor to CO_2 emissions, assimilated as a negative externality, which may cause global warming.

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