A Kaya decomposition analysis of tourism-energy-related CO2 emissions

The purpose of this note is to provide a *Kaya* decomposition analysis of CO_2 emissions in Italy considering energy and tourism among its determinants. *Kaya*'s identity is a variant of the IPAT identity that has been applied in studies of energy-related carbon emissions. The general IPAT specification corresponds to an identity with Impacts (*I*) on the left side and Population (*P*), Affluence (*A*) and Technology (*T*) on the right side. The terms on the right-hand side are connected by a multiplicative relationship. Until now, the literature has delivered various specifications of the *Kaya*'s identity. The simplest considers CO_2 emissions as a measure of the impacts and three ratios to decompose the amount of total emissions in its determinants. In detail, the first ratio is normally used to measure the carbon intensity of energy use, the second ratio denotes the energy intensity of economic activity. The results show that in Italy, among the driving forces behind CO_2 emissions, a significant role can be given to tourism.

1. Introduction

International tourism has seen rapid growth in recent years bearing high potentials contribution on growth and poverty reduction. The most common approach to describe the link between tourism and growth is the so-called Tourism-Led Growth Hypothesis (TLGH), firstly introduced by Balaguer and Cantavella-Jorda (2002).

However, unprecedented tourism growth, besides positive economic outcomes, also brings with it a number of severe negative consequences. Actually, rapid tourism development means environmental and social pressure, stressed infrastructures, overcrowded major attractions and capacity constraints in major cities. Among these impacts, the relationship between tourism activities and CO_2 emissions, that was relatively underexplored until the last decade, is now gathering increasing attention among researchers. According to recent data (Lenzen et al., 2018), CO_2 emissions generated by the tourism sector are at around 8% across the globe and increased from 3,9 to 4,5 billion between 2009 and 2013. The great majority of these emissions (75%) depends on transportation (40% air transport, 30% car transport, and 5% other transport), while 21% and 4% depend on accommodation and other tourist activities (UNWTO, 2008). However, this is not all. Calculations of the impact of tourism on CO_2 emissions should also take into account its role on economic growth that is considered the main driver of environmental pollution.

For these main reasons, today the evaluation of CO_2 emissions led by tourism has become one of the fundamental steps to judge tourism sustainability. Inevitably, this theme becomes a part of the wider debate concerning the study of the determinants of CO_2 emissions at global level.

From this point of view, an interesting approach proposed by a recent strand of literature provides attempts to decompose the CO_2 emissions in its main determinants by applying the so-called IPAT decomposition technique. The IPAT model was firstly proposed by biologists and ecologists to describe the relationship between environmental impacts, population, economic factors and technology. Later, it has been often used as a basis for the Kaya identity suitable for investigations on the role of the various factors that drive carbon emissions (Dietz and Rosa, 1994). In these studies, the role of tourism is poorly considered.

The aim of this chapter is to provide a Kaya decomposition analysis of CO_2. We also highlight the possible re-interpretation of the analysis to include the impact of transportation services in the creation of polluting emissions. Data for examples can be drawn from the World Development Indicators.

2. General framework

The impact of tourism on CO_2 emissions is a topic that only recently has captured the interest of researchers. The discussion concerns both the direct effects generated by the tourism industry on CO_2, and the indirect effects that tourism can generate through its impact on economic growth. At industry-level, tourism development increases energy use and related CO_2 emissions due to the expansion of all tourism-related economic activities, such as transportation, catering, accommodation, water supply, and the management of tourist attractions. Gössling (2000) was the first to propose a methodical approach to examine the consumption of energy and the related emissions of carbon due to the implementation of a tourism industry. Along these footsteps, many scholars developed an extensive bulk of research at both country and regional level. Numerous representative figures appeared (Becken, 2013; Cainelli and Mazzanti, 2013). In particular, Becken (2013) proposed several studies including various tourist activities and accommodation types, tourist resorts, air travel and other transportation methods. Becken and Simmons (2002), for instance, report that tourism is an important driver of global climate change, and find that tourist activities (e.g., scenic flights, jet boating or air travel) used more energy than tourist attractions (e.g., museums).

As for the indirect channel, as said above, the impact of tourism on polluting emissions is explained because of its role in leading economic growth that, in turn, is considered the main driver of CO_2. Theoretical literature discusses the role of tourism for growth in terms of the so-called *Tourism Led Growth Hypothesis*, firstly introduced by Balaguer and Cantavella-Jorda (2002). From an empirical viewpoint, most of this research is framed within the Environmental Kuznets Curve (EKC), revisited to include the hypothesis of tourism development (De Vita et al 2015, Katircioglu, 2014a, 2014b; Katircioglu et al., 2014; Lee and Brahmasrene, 2013). This allows also to investigate the way tourism development, by fostering economic growth, might help the economy to eventually achieve the desired level of output growth after which polluting emissions are expected to decline. In this regard, however, the EKC original specification suffers the limit to omit important variables that could be among the determinants of CO_2 emissions.

In an attempt to develop the EKC model beyond growth, some authors have extended the conventional EKC framework by including additional variables, such as energy use (Apergis and Payne, 2009), trade (Ang, 2008; Halicioglu, 2009) and population density (Akbostanci et al., 2009). In spite of that, recent empirical and theoretical works argue that, even if extended to include energy use, the EKC approach still remains overly simplistic because CO_2 emissions depend both on the level of energy consumption and on the characteristics of the energy mix (cf., inter al., Henriques-Borowiecki, 2017). This literature provides attempts to consider all these factors in order to decompose the resulting CO_2 emissions in the vein of the so-called IPAT decomposition technique (Ma and Stern, 2008). Until now, however, this new approach has devoted very little attention to the tourism sector.

3. The IPAT-Kaya Identity

The Kaya identity is a variant of the IPAT identity (Kaya, 1990), appropriately defined in order to account for energy consumption in studies on carbon emission determinants (Ma and Stern, 2008). The IPAT model was first proposed by biologists and ecologists to formalize the impact of population, human welfare and technology on the environment (cf., among others, Commoner, 1972, 1992; Elulich and Ehrlich, 1990). Its general formulation corresponds to the following identity:

$$Impact = Population \cdot Affluence \cdot Technology$$

As mentioned, a variant of the IPAT identity is referred in the literature as the Kaya identity (Kaya, 1990), which responds to the next standard specification:

$$C = \frac{C}{E}\frac{E}{Y}\frac{Y}{P}P \qquad (1)$$

where C is carbon emissions, E is energy use, Y is economic output and P is population.

In detail, the first term on the right-hand side (C/E) represents the carbon intensity of energy use and the second term (E/Y) denotes the energy intensity of economic activity. These two terms correspond to the Technology factor. The last two terms (Y/P and P) correspond to the Affluence and Population factors, respectively, which jointly provide the effect of economic scale. Starting from this basic specification, several variants have been proposed in the attempt to explore the driving forces behind the complex phenomenon of CO_2 emissions (cf. inter al., Ma and Stern, 2008).

4. **An application of the Kaya identity**

This section exploits the analysis of the CO_2 determinants by using an extended version of the Kaya technique in Eq. (1), which decomposes the changes in polluting emissions in all the factors that contribute to the emergence of such emissions. As deeply specified by Stern (2004), different specifications of this decomposition can be assumed. Here, we consider a variant of the standard model version, and introduce the role of tourism, joint with other energy factor, among the determinants of CO_2 (Ma and Stern, 2008). Therefore, we adopt the following identity:

$$C = \frac{C}{F}\frac{F}{E}\frac{E}{Y}\frac{Y}{T}\frac{T}{P}P \quad (2)$$

where, in addition to the aforementioned Eq. (1), F stands for fossil fuel consumption, and T is the number of tourist arrivals. The shares expressed on the right-hand side of Eq. (2) represent a useful specification of different economic phenomena. In particular, the ratio C/F represents the *substitution* effect between fossil fuels and carbon emissions; instead, F/E measures a *penetration* effect of fossil fuels energy on total energy use; and, finally, E/Y provides an *intensity* scale of energy use on the output of the economy. Additionally, the term Y/T is a standard measure of average productivity of tourism, whereas T/P indicates the incidence of tourism over population.

The identity in Eq. (2) can also be written as follows:

$$C = S_C S_F S_I S_G S_{TP} P \quad (3)$$

where the S_i stand for the shares specified above.

As suggested by Ang and Zhang (2000) and Ang (2004), the identity specified in Eq. (3) can be further put into natural logarithms, and consequently transformed into the following standard integrated form:

$$D_{tot} = D_C D_F D_I D_G D_{TP} D_P \quad (4)$$

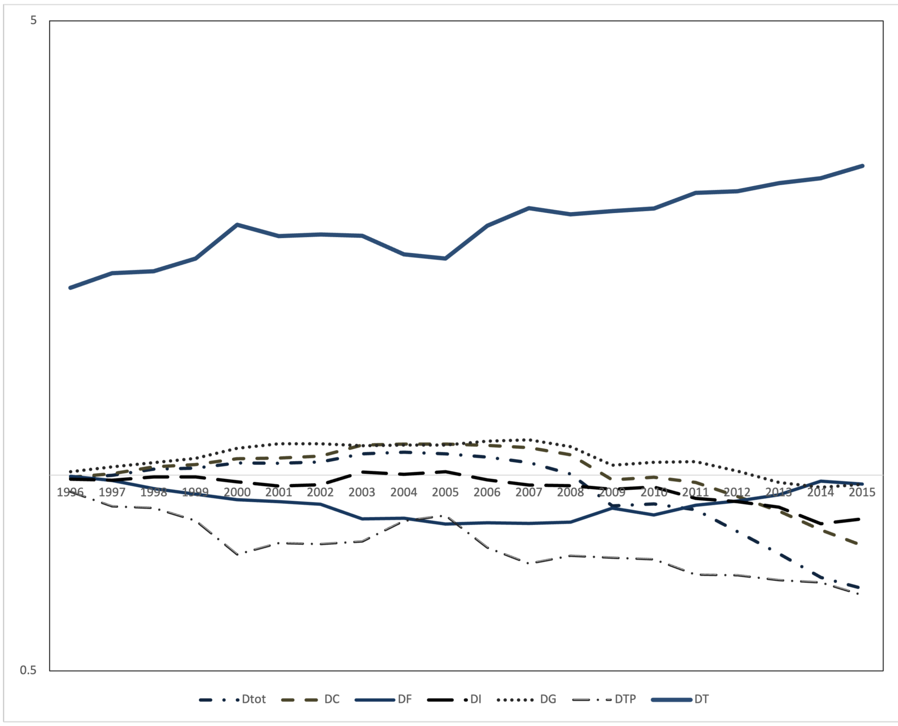
where the various D's are given by:

$$\frac{C_t}{C_{t-1}} = \frac{S_{Ct}}{S_{Ct-1}}\frac{S_{Ft}}{S_{Ft-1}}\frac{S_{It}}{S_{It-1}}\frac{S_{Gt}}{S_{Gt-1}}\frac{S_{TPt}}{S_{TPt-1}}\frac{P_t}{P_{t-1}} \quad (5)$$

representing all factors expressed in growth rate terms.

The possible accumulated effects derived from Eq. (5) are reported in Figure 1, where it clearly appears that despite the large positive scale effect due to tourism growth (DT), the negative effects produceb by the tourism-population growth (DTP) results as the driver to the decreasing path of D_{tot}.

Figure 1: The Kaya decomposition



5. The role of Transports

Given the role that aircrafts are shown to have in the production of CO_2 pollution emissions, we may find convenient to reconsider the previous analysis by taking the number of tourists that reach the place by served airlines. The scope is to show whether the impact of air travels needs is a real driver for pollution in the region under analysis, and if related policy actions are thus need at the scope. To this end, we reconsider the Kaya identity in the form:

(6) $$C = \frac{C}{E}\frac{E}{T}\frac{T}{Y}\frac{Y}{P}P$$

where again *C* stands for polluting emissions, *E* is the energy variable, *T* is the ratio between the total amount of tourist arrivals and those coming by airplanes. Finally, *Y* is the standard measure of GDP, and *P* is the population. Eq. (6) can be re-written as

(7) $$C = S_E S_T S_S S_G P$$

where S_E represents the impact of energy use on carbon emissions, measuring the *degree of energy efficiency* in the economy; S_T measures the incidence of energy use on tourism arrivals, and suggests the possibility of energy dependent transportation services for tourists, which negatively impact on the amount of pollution loads; we may call it as a *degree of transport efficiency*. Finally, S_S describes the impact of tourism on national income; we may call it as a *degree of tourism efficiency*; whereas S_G is the measure of *per-capita growth rate.* If we repeat the analysis described in Eq. (5) for our model in Eq. (7), we can show the impact of each driving force in the production of pollution, and thus design the appropriate policy action for the sector that appears to be the higher driver.

References

Akbostanci E, Türüt-Asik S, Tunç GI (2009), The relationship between income and environment in Turkey: is there an environmental Kuznets curve?, in «Energy Policy» vol. 37, pp. 861–867.

Ang J.B. (2004), Decomposition analysis for policymaking in energy: which is the preferred method?, in «Energy Policy», vol. 32, pp. 1131-1139.

Ang B.W., Zhang F.Q. (2000), A survey of index decomposition analysis in energy and environmental studies, in «Energy», vol. 25, pp. 1149-1176.

Ang J.B. (2008), Economic development, pollutant emissions and energy consumption in Malaysia, in «Journal of Policy Modeling», vol. 30, pp. 271-278.

Apergis N., Payne J. (2009), Energy consumption and economic growth: evidence from the Commonwealth of Independent States, in «Energy Economics», vol. 31, pp. 641-647.

Balaguer J., Cantavella-Jorda M. (2002), Tourism as a long-run economic growth factor: the Spanish case, in «Applied Economics» , vol. 34, pp. 877-884.

Becken S. (2013), A review of tourism and climate change as an evolving knowledge domain, in «Tourism Management Perspectives», vol. 6, pp. 53-62.

Becken S., Simmons D. G. (2002), Understanding energy consumption patterns of tourist attractions and activities in New Zealand, in «Tourism Management», vol. 23, pp. 343- 354.

Cainelli G., Mazzanti, M. (2013), Environmental innovations in services: Manufacturing–services integration and policy transmissions, in «Research Policy», vol. 2, pp. 1595-1604.

Commoner B. (1972), The Environmental Cost of Economic Growth, in Population, «Resources and the Environment», Washington, DC Government Printing Office, pp. 339-63.

Commoner B. (1992), Making Peace with the Planet, The New Press, New York.

De Vita G., Katircioglu S., Altinay L., Fethi S., Mercan M. (2015), Revisiting the environmental Kuznets curve hypothesis in a tourism development context, in «Environmental Science and Pollution Research», vol. 22, pp. 16652-16663.

Dietz T., Rosa E.A. (1994), Rethinking the environmental impacts of population, affluence and technology, in «Human Ecology Review», vol. 1, pp. 277-300.

Ehrlich P.R., Ehrlich. A.H. (1990), The Population Exclusion, Simon and Schuster, New York.

Gössling S. (2000). Sustainable tourism development in developing countries: Some aspects of energy use, in «Journal of Sustainable Tourism», vol. 8, pp. 410-425.

Halicioglu F. (2009), An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey, in «Energy Policy», vol. 37, pp. 1156–1164.

Henriques T., Borowiecki K.J. (2017), The drivers of long-run CO2 emissions in Europe, North America and Japan since 1800, in «Energy Policy», vol. 101, pp. 537–549.

Katircioglu S.T. (2014), Testing the tourism-induced EKC hypothesis: the case of Singapore, in «Economic Modelling», vol. 41, pp. 383–391.

Katircioglu S.T. (2014b), International tourism, energy consumption, and environmental pollution: the case of Turkey, in «Renewable and Sustainable Energy Reviews», vol. 36, pp. 180–187.

Katircioglu S.T., Feridun M., Kilinc C. (2014), Estimating tourism-induced energy consumption and CO2 emissions: the case of Cyprus, in «Renewable and Sustainable Energy Reviews», vol. 29, 634–640.

Kaya Y. (1990), Impact of carbon dioxide emission control on GNP growth: interpretation of proposed scenarios, in «Paper presented at the IPCC Energy and Industry Subgroup, Response Strategies Working Group», Paris, France.

Lee J., Brahmasrene T. (2013), Investigating the influence of tourism on economic growth and carbon emissions: evidence from panel analysis of the European Union, in «Tourism Management», vol. 38, pp. 69-76.

Lenzen M., Sun Y., Faturay F., Ting Y., Geschke A., Malik A. (2018), The carbon footprint of global tourism, in «Nature Climate Change», vol. 8, pp. 522-528.

Ma C., Stern D.I. (2008), Biomass and China's carbon emissions: A missing piece of carbon decomposition, in «Energy Policy», vol. 36, pp. 2517-2526.

Stern D.I. (2004), The Rise and Fall of the Environmental Kuznets Curve, in «World Development», vol. 32, pp. 1419-1439.

UNWTO (2008), Climate Change and Tourism, World Tourism Organization, Madrid.

World Development Indicators (2016), World Bank, Washington (DC).