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Understanding the economic impacts of sea-level rise on tourism prosperity: Conceptualization and panel data evidence

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Abstract

Sea-level rise is a long-term, intractable problem during which costly, large-scale inundation could occur in many countries; hence, tourism development should take this matter into account because ecology and biodiversity are the fundamentals underpinning tourism performance. This study conceptualizes an economic mechanism of the potential effects of sea-level rise on tourism development based on projected impacts for the 2001−2100 period. Data for 48 developing countries across Africa, Asia, and South America are analyzed. The theoretical framework proposes two hypotheses to determine the extent of contradiction between awareness and destruction in relation to environmental protection for tourism development. From the panel data regression results, although destructive effects are bound to dominate the entire 21st century, awareness is latent and has the potential to reverse the destructive outcomes. With evidence from essential economic elements, this study gives new insights into how severe the impacts of sea-level rise on tourism could be if shared values and adaptation measures to mitigate rising sea level are not substantively promoted around the globe. The new findings show a 0.95 standard-deviation decrease in tourism performance following a 1 standard-deviation increase in the economic loss related sea-level rise. Hence, in the main conclusions, we highlight that the projected effect of inundation-related deterioration on a country's tourism sector appears to be approximately on par with the costs of inundations to its economic growth.

Keywords: Developing countries; Economic growth; Inundation; Panel data; Sea-level rise; Tourism development

1. Introduction

Sea-level rise (SLR) impacts on tourism are a growing concern (e.g., López-Dóriga et al., 2019; Nidhinarangkoon et al., 2020), but the underpinning economic factors have largely been underexplored. SLR is one of the 13 sectors, with respect to understanding climate sensitivity, highlighted by Cline (1992) and further emphasized by Auffhammer (2018). Tourism development that causes climate change is a growing issue, such as the urbanization activities in coastal areas identified in eastern Thailand (Nitivattananon and Srinonil, 2019) and transportation emissions in Cyprus (Katircioglu et al., 2014). But the opposite effect seems to be a more essential concern, as shown by a number of recent investigations in Africa (Dube and Nhamo, 2019, 2020) and ski tourism that has a strong dependency on climate support (Steiger et al., 2019, 2020). As Scott et al. (2019) state, this is a particularly significant issue in countries in which the tourism sector makes the largest contribution to national income. Nevertheless, the tourism sector has been identified as being both vulnerable and resilient to climate change, although it is more vulnerable than the economy as a whole. Notably, tourism in countries with a lower income level was found to suffer more in terms of being less resilient and more vulnerable (Dogru et al., 2019). Even so, the drawback of past studies has been the absence of climate change issues in the hypothesis of growth-led tourism development. Economic growth promotes tourism development; however, the former is

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projected to be affected by climate change, particularly by flood damage.

As stated in Dogru et al. (2019), the implication on tourism development in the future is both urgent and substantive because SLR following climate change is not a speculation, as leading investigations show. There is no trend of major improvement in the emission of greenhouse gases from the latest data (Nordhaus, 2018). Nordhaus (2018) indicates that the international agreement on a 2 °C temperature limit seems to be unrealistic for one major reason—uncertainties. Following Meehl et al. (2005), even if stabilization of the concentration of atmospheric greenhouse gases had been in place at the beginning of this century, the world was already committed to increases in global warming and sea level. Moreover, the study predicts more SLR than further temperature increases, suggesting a higher commitment of SLR than that of global warming; for instance, SLR is expected to increase by 320% due to thermal expansion by the end of 2100. Climate change is not the only channel leading to SLR, however. Another problem is accelerated subsidence. For example, the Mekong Delta is recognized as one of the few regions with a substantial potential for tourism development in Vietnam (Jansen-Verbeke and Go, 1995), but land subsidence in combination with SLR may lead to a major threat of flooding, particularly in the middle delta and coastal areas (Dang et al., 2018). Thus, faced with the risk of inundation, tourism as an environmentally-oriented industry will certainly need to adopt adaptation measures and attract global attention.

We elaborate further on the phenomenon of subsidence here, as a complement to climate change underlying SLR, in leading to the risk of river flood hazard. By 2100, the sea level in the Nile and Bengal Deltas may be 3 m higher, which could destroy more than 25% of the habitable land in the two countries, Egypt and Bangladesh (Milliman et al., 1989). Milliman et al.'s (1989) understanding of SLR emphasizes natural and accelerated subsidence (e.g., groundwater removal). River deltas become vulnerable to inundation and SLR following a reduction in sediment supply, which is important for maintaining shoreline position and subsidence balance (Ericson et al., 2006; Syvitski et al., 2009; Anthony et al., 2015). Human activities, particularly dams and large-scale river-bed sand mining, have created vulnerability in the Mekong Delta in Southeast Asia, leading to subsidence and erosion (Anthony et al., 2015). Venice, the tourist hub of Italy, is already susceptible to frequent tidal floods due to land subsidence of 1−2 m in the Po Delta following extensive groundwater extraction between 1950 and 1970 (Sestini, 1992, 1996). According to projections by Carbognin et al. (2010), considering both climate dynamics and geodynamics, Venice will be at risk of incurring flood events higher than 1.1 m at a frequency of 250 times each year as of 2100, with a relative SLR of 53 cm. In a global-scale study by Winsemius et al. (2016), analyses for 2030 and 2080, with respect to socio-economic development and climate change, indicate that the global economic damage from river floods is predicted to grow more rapidly than global economic wealth. Such damage would worsen a country's creditworthiness in the global financial market because natural hazard risk is an essential factor in such ratings. Hence, as Winsemius et al. (2016) postulate, adaptation measures are essential. This suggests that the river mechanism of SLR, which will impact tourism development in the long run, will require adaptation measures to safeguard future tourism-related prosperity.

Changes in sea level in the Arctic and Antarctic, in terms of future projections, have also been emphasized. McLean and Rock's (2016) investigation highlights the values of seven characteristics of the Antarctica: it being a component of the climate system; it representing a laboratory that benefits humankind; it being a tourist destination; it being a depository of mineral resources; it being the last great wilderness; it being a habitat for wildlife; and it having a special place in the history of human exploration. Their study indicates that common values exist between Antarctica researchers and their public audience, signaling the potential to inspire understanding and engagement to influence future climate action. The origins and impacts of climate change are a global issue, hence an effective response must be cultivated through international understanding and collaboration (Stern, 2008). Pollution is on the rise, followed by climate warming, ice melting, and SLR; to date, all of these suggest an insignificant level of shared appreciation. If the emission of greenhouse gases is not controlled, it has been predicted that Antarctica will have the potential to cause SLR above 1 m by 2100, and likely 15 times that by 2500 (DeConto and Pollard, 2016). In particular, the restoration of melted ice will be substantially delayed in the face of extended ocean warming. As for the Arctic, climate change is motivating more aggressive tourism activities, which rely on its unique marine ecosystem, which in turn is speeding up deleterious physical and ecological changes (Palma et al., 2019).

The tourism sector is relatively more vulnerable to climate change than the entire economy, particularly in low-income countries (Dogru et al., 2019). Accordingly, the core issue here is the potential effects of SLR on growth-led tourism development in 48 developing countries during the 21st century. Considering the implications of SLR pinpointed in the conceptual framework, the current study sheds light on two sides of the potential effects of SLR: destruction versus awareness. The focus of previous studies has been on climate change and tourism prosperity; however, the prominent hypothesis of growth-led tourism development has not been explored in terms of the impacts of SLR through the growth-essential economic factors. The destructive effects can be directly quantified by the model developed in this study, whereas the effect of awareness can only be proxied by the growth-essential economic variables due to unavailable data. This study is also limited to 48 developing countries due to the limited available data on the variables for some countries, although this comes with the advantage of a balanced panel dataset.

The research question goes beyond the direct relationship between climate change and tourism development: specifically, how will economic-growth aspects underlying tourism development be affected by SLR? The six important

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economic-growth aspects—agricultural area, land area, population, national income, urban area, and wetland area—have mostly been unexplored as a mechanism for understanding the effects of SLR on tourism development. Therefore, the core issue this study aims to address is the SLR problem in the growth-led tourism hypothesis, whereby the six aspects of economic growth serve as the channeling factors. The aim to incorporate economic elements in the SLR−tourism relationship is also motivated by the knowledge that sustainability in tourism development has become more important following increases in climate change, environmental damage, depletion of natural resources, fair trade, human rights, and over-tourism (Yu and Hwang, 2019). This is the core issue that the current study aims to investigate, specifically the nature of changes under an economic mechanism bridging SLR impacts and tourism development.

2. Conceptual framework

This study's theoretical proposition for growth-led tourism development with SLR impacts is depicted in Fig. 1. The hunt for economic growth contributes to global warming because an intensive amount of greenhouse gases is continuously emitted from various development activities. The subsequent impact is the expansion of sea level. Moreover, rising sea level worsens the situation of river deltas that are also at risk of land subsidence. This is a prevalent occurrence, as discussed in the introduction. Inundation following SLR has been projected for five levels, labeled 1−5 in Fig. 1. Following Mercer's (1978) postulation that a rise in sea level toward 5 m is already in progress, the five levels proposed in this conceptualization are equated to those 5 m of SLR. Furthermore, according to Horton et al.'s (2020)survey, which solicited scientific perspectives from sea-level experts' estimations, a range of 0.88−7.83 m by 2300 is possible. The current study considers the six aspects of SLR impact investigated by Dasgupta et al. (2006, 2007). These aspects—namely, land area, population, gross domestic product (GDP), urban extent (replaced as urban expansion here due to possible migrations from rural areas to urban cities), wetland area, and agricultural extent (replaced as agricultural decline here to capture the extent of depopulated rural areas)—are considered to be intermediate factors in tourism performance, hereafter referred to as impacted variables or growth-essential variables (i.e., important factors of economic growth). Although the theoretical framework is not specific in terms of a time dimension, the empirical framework assumes the 21st century (2001−2100), as in Dasgupta et al. (2006, 2007). Thus, the economic mechanism implies the possibility that SLR will affect tourism through the six impacted (growth-essential) variables.

According to Dasgupta et al. (2006, 2007), the following variables are measured at the country level, with the SLR inundation zones projected at 1−5 m. Further explanation of data construction is provided in the subsection on sea-level rise data. The impact-related variables are as follows:

1) Impacted land area: share of land area impacted (km^2)
2) Impacted population: share of population impacted (number of people)
3) Impacted GDP: share of GDP impacted (million USD)
4) Impacted urban expansion: share of urban expansion impacted (km^2)
5) Impacted wetland: share of wetland impacted (km^2)
6) Impacted agricultural area: share of agricultural decline impacted (km^2)

Conceptually, destruction due to SLR comes in the form of massive flooding across agricultural, land, urban, and wetland areas, thereby destroying many socioeconomic activities and livelihoods of populations in these areas that will need some time to fully recover. In turn, this negatively and significantly affects the country's GDP. In contrast, awareness of SLR takes effect in the reverse direction. Economic development with a sustainable growth of GDP could encourage the country's population to put more weight on factors that affect the quality of life and will help sustain socioeconomic activities, such as the implementation of green technology that will slow global warming and suppress further SLR on agricultural, land,

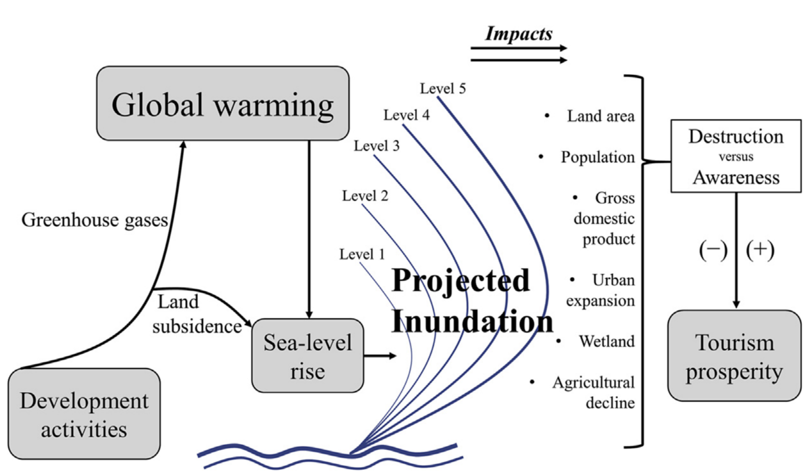

Fig. 1. Economic mechanism: conceptualizing the effects of sea-level rise on tourism prosperity.

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urban, and wetland areas. As tourism prosperity is stemmed substantively and substantially from a population's socioeconomic activities, SLR destruction and awareness that affect these socioeconomic activities will certainly affect tourism prosperity. However, it is unclear whether the effect of destruction or the effect of awareness would be more dominant—the essence of the six impacted variables to capture these effects are further elaborated in the following subsection.

Adopted from the economic reasoning of the environmental Kuznets curve (EKC), environmental degradation will eventually decrease as economic development reaches a certain level, particularly when technological advancement in terms of green (environmental or clean) technology begins to dominate owing to people's awareness. This phenomenon, however, is not deemed dominant enough in most developing countries, including China, which has demonstrated substantial economic development. The implication here is the awareness of people relative to their destructive tendency toward environmental quality. While climate change destruction is commonly demonstrated with empirical evidence, the understanding of climate change awareness (and risk perception) is rudimentary due to data unavailability (Lee et al., 2015), suggesting that it is a significant dimension to explore. Based on Lee et al. (2015), the unique context of each country is an important aspect to consider when tailoring awareness programs for citizens at the national and regional levels. In the current study's argument, such a context can be represented by the six SLR-impacted variables examined by Dasgupta et al. (2006, 2007), as these variables are fundamental resources of economic development and each is associated with a unique context in different countries. Further details are provided in the following subsection of theoretical and practical implications with respect to each impacted variable amid SLR; spatial movement, nature of changes, technological advancement, and awareness. According to the scenario investigated by Chen et al. (2019) based on more than 60 less-developed countries, a higher level of environmental awareness allows a country to reach the EKC turning point sooner as income grows. From this scenario, we observe that awareness and economic development (e.g., an increase in GDP) work together to improve environmental quality. When SLR causes damage to fundamental resources of economic development in the future, environmental protection will be adversely affected; consequently, this will foster 'enhanced environmental awareness' in the people. Suppose urban cities are badly flooded due to SLR; when such a phenomenon is found with a positive effect on tourism performance, it is a proxy of enhanced environmental awareness that favors tourism development. For instance, more substantive efforts might be devoted to popularizing green technology and green tourism. To justify this conjecture, the term 'enhanced environmental awareness' is used by Teng and He (2020) to indicate that such awareness (of pollution, for example) can shape psychological effect and behavior, urging people to be concerned about air quality.

Based on the theoretical elaboration above, two hypotheses are proposed as follows:

Hypothesis 1. The impacted variables of SLR have a negative effect on tourism prosperity, as awareness of environmental quality is latent (i.e., present, but not substantive).

Hypothesis 2. The impacted variables of SLR foster enhanced environmental awareness, thereby contributing positively to tourism prosperity.

We generally realize that 2100 is a distant projection, which implies unavailability of data (except the projected SLR data). The theoretical framework here aims to understand the relative awareness or destruction that would occur over this century in relation to the impact effects projected for five levels of sea-level expansion. This generates a hypothetical implication based on the early 2000s (2001–2012), that available data are supposedly embedded with the information of awareness and destruction. We carry this implication through the next 88 years (2013–2100), meaning that the relative awareness and destruction generalized from the 2001–2012 period (a 12-year cycle) is assumed to repeat itself until 2100. This implication based on the early 2000s involves possible cumulative effects from the impacted variables of SLR. This hypothetical case is expected to approximate what will happen to the tourism industry; if ongoing development activities behave unfavorably toward global warming, the SLR predictions (5 m or higher) previously mentioned could materialize. The general expectation from this theoretical framework is mixed outcomes among the six impacted variables of SLR, with respect to the two hypotheses. This expectation suggests that an awareness to protect the environment is exhibited through some impacted variables (positive effects). For example, if SLR-impacted population is found to have a positive effect on tourism performance, that is an indication of awareness. However, awareness could be latent (i.e., present, but not substantive) or it could outweigh the destructive behaviors; this needs to be ascertained empirically.

Although the SLR is specified to occur at five levels, the theoretical hypotheses do not assume that a higher level is associated with greater effects on the six impacted variables of tourism performance, although more significant impacts could supposedly cause more damage to the six impacted variables. A possible explanation is that the effects may be indistinguishable between two or more levels of SLR because of closely-related impacts. The theory's implication, however, is also to identify possible patterns among the six impacted variables. For instance, some impacted variables could become significant on tourism performance at the fourth level of SLR, but the effect may be indistinguishable from that of the fifth level, whereas other impacted variables may begin to exhibit significant effects at the first level, but the effects may be indistinguishable until the third level.

2.1. Theoretical and practical implications

The scenario elaborated in this part is based on Dasgupta et al. (2006, 2007) that involves 84 developing countries.

According to the implications that the study highlights, the current concentration of greenhouse gases is strong enough to extend global warming into the 22nd century. Consequently, SLR will likely displace 'hundreds of millions of people,' although countries will likely incur the impacts in differing degrees of severity. This is reiterated as not a speculation. Moreover, as identified based on the six impacted variables, the catastrophic phenomenon underpins severe economic and ecological devastation. Based on this scenario, there are practical implications facing developing countries. However, what will the practical implications for tourism development be in the future and how should this sector cope with the problems?

The conceptual framework carries significant future implications in a practical sense, particularly for developing countries. Although the impacts might not be equivalently observed across geographical areas in each affected country, the overall impact on tourism prosperity will likely be felt at the country level. Due to the spatial nature of tourism activities, these activities might shift away from affected areas to unaffected areas. However, such spatial movement involves both implicit (or opportunity) and explicit costs, suggesting that there are two essential types of economic costs that firms and tourists will need to consider. Approximated from the perspective of migration in terms of opportunity costs, Levy and Wadycki (1974) attribute three types of opportunity costs: transportation costs, job search costs, and earnings if the activity does not move. In practice, tourism businesses generally aim at profit maximization in the chosen destinations. As for firms directly or indirectly involved in tourism activities, the opportunity cost of moving involves all three types mentioned above. In particular, job search costs come from the time spent to recruit new employees as the firms might not be able to retain existing employees. Moreover, profit-maximizing fundamentals (or earnings if the activity does not move), such as existing networks with local businesses and suppliers, existing marketing and advertisement, and existing business practices, among others, are significantly impacted or lost. Adapted from McCann et al. (2010), such migration could also involve the psychological and emotional costs of separation from the previous business location and network. As for consumers (tourists), all phases of experience in tourism activities are determined by the degree of happiness (Ram et al., 2013). Hence, having to let go of a preferred destination or activity for a different one can be a huge opportunity cost. In terms of explicit costs, moving to a new destination to avoid SLR risk due to climate change implies the need to re-establish the business, including costs to find new locations, relocate employees (e.g., rental and transportation costs), recruit new employees (which could be more expensive), renew marketing and advertisement, establish business strategy (could be different from the old strategy due to different locations), and upgrade business due to competition with existing firms in the new location, among others. Both types of costs elaborated above imply the difficulty for firms and tourists to change destinations for tourism activities, which might also discourage tourists from traveling to the country at all, thus reducing the overall number of tourists. For these practical implications, geographical differences seem indifferent as the entire country's tourism prosperity will likely be affected as long as the Dasgupta et al. (2006, 2007) scenario of climate change and SLR stated above is a concern.

The six impacted variables adopted from Dasgupta et al. (2006, 2007) serve as the channel underpinning the nature of changes from SLR to tourism performance. We can observe this from the perspective of the growth-led tourism hypothesis, one of the substantive hypotheses underlying the tourism−growth relationship. The six impacted variables are the foundation of economic growth, each serving one or more functions in favor of tourism development: GDP implies the capacity of resources for development; agricultural, land, and wetland areas serve multiple functions (e.g., green economy, resources, and recreation); urban cities are locations where diversity of businesses concentrate; and the population implies the demand and supply of goods and services and also labor input in an economy. Therefore, when these six aspects are negatively affected by climate change problems (i.e., SLR), this in turn alters growth-led tourism development. Because growth is led by technological progress (e.g., research and development), as is commonly recognized with economic growth models (e.g., Jones, 1995), the impacts of SLR on the six variables reflect the essence of technological progress (e.g., green technology) that is critical to circumventing SLR impacts. This implies awareness pertaining to technologically oriented approaches—more details about awareness have been elaborated above with respect to the second hypothesis of the conceptual framework.

As the scenario indicates that global warming over the 22nd century is already occurring, tourist numbers are likely to dwindle to avoid unnecessary risks. To cope with this situation, the tourism sector should be aided with investment plans at local, regional, and national levels—a technologically oriented move that requires constructive methods to achieve. For instance, following Marshall et al. (2013), four methods may be potentially adopted: risk and uncertainty management; planning, learning, and organizing skills; flexibility in finance and emotion; and interest to adapt. These methods are the actions of awareness concerning adaptive capacity. Additionally, according to Johnson et al. (2020), successful adaptive capacity requires collective action that is influenced by the degree of social capital, trust, and organization. Because awareness to avoid further climate change now will make adaptative measures less cumbersome in the future, the current study aims to understand the preventive measures developing countries have been taking on this front. We hope that the implications here will urge more research efforts to look into specific adaptation strategies to help the tourism sector remains sustainable.

In the following section, the empirical methods and data used to test the two hypotheses outlined above are discussed based on the theoretical framework.

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3. Empirical methods and data

3.1. Empirical methods

A newly-developed model is presented as Eq. (1) that aligns with the theoretical conceptualization described above. A random-effect specification is assumed—for detail, see Wooldridge (2013), (chap. 14), given the time-invariant data on the six impacted variables:

$$V_{i,t} = \alpha + \beta_j^s \sum_{j=1}^{J} M_{i,j}^s + \gamma_k \sum_{k=1}^{K} C_{i,t,k} + \omega_{i,t}, \tag{1}$$

where $V_{i,t}$ is the tourism prosperity at time t (t = 2001, 2002, …, 2012) and cross-section i (i = 1, 2, …, 48 developing countries), $M_{i,j}^s$ is an impacted variable j for SLR at s level (a time-invariant variable), $C_{i,t,k}$ is a control variable k, and $\omega_{i,t}$ is a composite error term (individual-specific error component and time-series and cross-section component). Breusch and Pagan's (1980) Lagrange multiplier test is used to test for the random-effect specification. The hypotheses are investigated using the *ceteris paribus* assumption, with its unique potential to shed new light on the underpinning economic mechanism. In line with Wooldridge's (2002) econometrics of cross section and panel data, a causal relationship can be established by holding other relevant factors unchanged.

The empirical procedure that this study introduces in relation to Eq. (1) is outlined in Fig. 2. The first estimation is aimed at comparing the effects of the impacted variables across the 5 m of SLR—namely, the disaggregated effects. The second and third steps utilize principal component analysis (PCA) in order to find two types of scores— type-A and type-B—among the impacted variables. Type-A scores capture the overall variance of a linear combination of all impacted variables and sea-rise levels. This score type is targeted at determining whether the overall effect of SLR represents more of the awareness of environmental protection in favor of tourism prosperity than destruction, or vice versa. Type-B scores capture the overall variance across the five sea-rise levels specific to each impacted variable. This second score type allows the study to compare the impacted variables in terms of overall variance in SLR. The tripartite nature of the empirical procedure is expected to shed light on the two hypotheses in the theoretical framework, whereby we aim to determine the economic mechanism underlying the effects of SLR on tourism prosperity. Prior to PCA, however, Bartlett's test for sphericity and the Kaiser−Meyer−Olkin measure of sampling adequacy (KMO) was performed, following the procedure outlined in Azevedo (2006).

3.2. Data

This study uses panel data from 48 developing countries for the 2001−2012 period (annually), obtaining a total of 576 observations for the empirical analysis. The projected data of SLR are for the 2001−2100 period, as also explained in the following subsection. The list of developing countries includes: Algeria, Angola, Argentina, Bahamas, Bangladesh, Belize, Benin, Brazil, Cambodia, Chile, China, Colombia, Costa Rica, Democratic Republic of Congo, Dominican Republic, Ecuador, Egypt, El Salvador, Gambia, Ghana, Guyana, Honduras, India, Indonesia, Jamaica, Kenya, Madagascar, Malaysia, Mexico, Morocco, Mozambique, Namibia, Nicaragua, Nigeria, Pakistan, Panama, Peru, Philippines, Sierra Leone, South Korea, Sri Lanka, Tanzania, Thailand, Togo, Tunisia, Uruguay, Venezuela, and Vietnam. The 48 countries are selected based on the availability of data on the variables described below.

3.2.1. Sea-level rise data

The six impacted variables are the main factors used for investigating the effects of SLR on tourism performance—namely, the mediated effects. Data on the six impacted variables are obtained from Dasgupta et al. (2006), and the main research report referred to is Dasgupta et al. (2007). Dasgupta et al. (2007) applied Geographic Information System software to overlay the critical elements (the six impacted variables) in inundation zones projected for SLR of up to 5 m. Dasgupta et al. (2006, 2007) used spatially-disaggregated data that are available from seven public sources: the Center for Environmental Systems Research; the Center for International Earth Science Information Network; the International Centre for Tropical Agriculture (CIAT); the International Food Policy Research Institute; the National Aeronautics and Space Administration; the National Oceanographic and Atmospheric Administration; and the World Bank. Dasgupta et al. (2007) followed several steps in developing the country exposure database. First, they subset polygons based on the World Vector Shoreline (polygon) of the National Geospatial Intelligence Agency, with a 1:250,000 nominal scale. Second, coastal terrain models were developed using version-2 data from the CIAT Shuttle Radar Topographic Mission's 90-m digital elevation model. Third, the coastal terrain model was used to determine the inundation zones, where the value of pixels was set to 1 for different scenarios of different SLR. The fourth step was to calculate the exposure indicators. The inundation zone was overlaid with the appropriate surface exposure database, which includes agricultural decline, GDP, land area, population, urban expansion, and wetland. Due to differences in measurement units, the pixel values for GDP and population are in millions of USD and number of people, respectively, whereas the other four exposure indicators are in square kilometers. The fifth step adjusted the absolute exposure indicators to the country totals. The formula involved multiplying the ratio of country total, obtained via statistics, to country total calculated from the exposure grid surface, with the exposed value calculated from exposure grid surfaces. The last step is about assurance and control of data quality, the main purpose being to conduct adjustments for errors caused by overlying grid surfaces with different resolutions.

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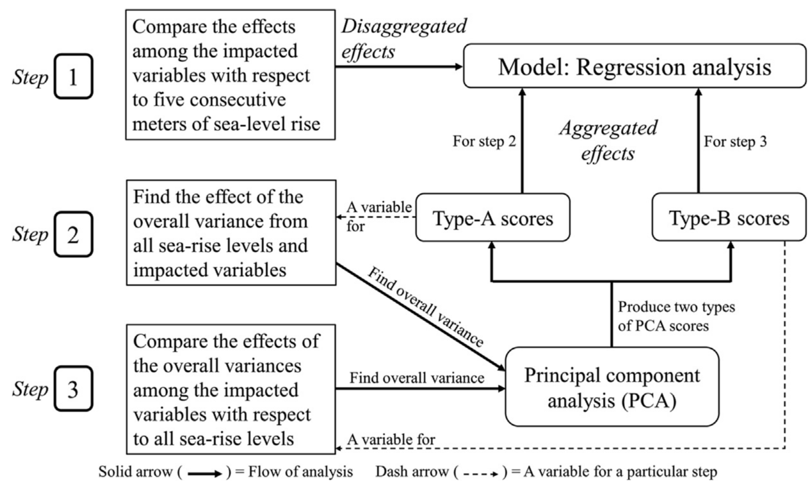

Fig. 2. Empirical procedure.

3.2.2. Socioeconomic data

Data on the following variables are obtained from the World Development Indicators database of the World Bank (2020). Following the elements depicted in Fig. 1, tourism prosperity, as a dependent variable, is approximated by the number of international tourist arrivals to a country. This refers to the number of overnight visitors, spending no more than 12 months for non-remunerating activities. This indicator of tourism is chosen following two aspects of consideration. Regarding the first aspect, international but not domestic data are used for two reasons. First, data on international tourists are more convenient to obtain for the 48 countries. Second, as a country's tourism prosperity is due to the international market, it is best captured by the number of international tourists. The second aspect is that this indicator is the number of tourist arrivals rather than tourists' expenditure. Although tourism expenditure is often used to understand tourism behavior, the number of international arrivals is deemed more suitable for this study for two reasons. First, in addition to being important for the formulation of management policy, this indicator guides decision-making in both private and public sectors (Hoti et al., 2007; Chang et al., 2012). Notably, according to the assertion made by Hoti et al. (2007), natural disasters cause dramatic changes in international tourist arrivals to developing island economies. This reflects information about behavioral patterns of tourist arrivals that are particularly important to aid in the management of local tourism businesses (Ye et al., 2018) and for marketing purposes (Shareef and McAleer, 2005). Second, the number of international tourist arrivals is also deemed more appropriate for the current investigation because the core focus is on the SLR problem in the growth-led tourism hypothesis, where growth is associated with income. For instance, the number of tourist arrivals is known to be influenced by income, whereas tourism expenditure is determined by the exchange rate (Song et al., 2010; Martins et al., 2017).

Development activities that are expected to lead to global warming and SLR are controlled as a means of determining the effects of the six impacted variables. Thus, ten control variables, representing development activities and energy, are included: total greenhouse gases in kilotons of carbon dioxide equivalent; consumption of renewable energy in percent of total final energy consumption; GDP per capita in 2010 constant USD; trade in percent of GDP; density of population in people in 1 km^2 of land area; total labor force; total unemployment in percent of total labor force; gross domestic savings in percent of GDP; expenditures on final consumption in percent of GDP; and gross capital formation in percent of GDP. Greenhouse gases and renewable energy are chosen as controls in order to capture the extent of global warming, whereas the other controls are indicators of socioeconomic development activities. The control variables (possible confounders) supposedly relate to information on relative awareness and destruction throughout the 12-year period (2001−2012). The relative degree of awareness and destruction in those 12 years is assumed to repeat over the century, but with possible cumulative effects applying by the end of 2100, as captured by the projected data for SLR developed by Dasgupta et al. (2006).

4. Results and discussion

4.1. Rising sea levels and tourism performance

Figure 3 reports on the estimated effects from six projected impacts of SLR at five levels on tourism performance, indicated by the number of international tourist arrivals. According to the theoretical conceptualization outlined above, the effects are expected to be mediated by six aspects of SLR inundation, as shown by the six vertical bars on each meter of SLR in the column chart. The results are obtained by estimating random-effect regressions for each of the 5 m of SLR. In the first step in the procedure of empirical analysis, as depicted in Fig. 2, our initial focus is on individual meters of SLR, as indicated in Fig. 3, which shows a projection over the 21st century by Dasgupta et al. (2006, 2007). A further analysis is implemented in the following subsection to shed light on the aggregate effects of SLR based on PCA. The control variables are important, as these are based on the 2001–2012 period, because they capture relative awareness and destructive behaviors with respect to environmental quality. However, the results for the control variables are not presented here, so as to provide a more focused presentation of the main findings.

The random effects are checked using the Breusch–Pagan Lagrangian multiplier test. Under the null hypothesis, variances across panels are zero, and the ordinary least squares estimation is deemed appropriate because there is no panel effect. The test for each regression rejects the null hypothesis at 1% significance level, suggesting that panel effects are present. The test statistics for the five regressions (from 1 to 5 m of SLR) are 2429.84, 2305.25, 2316.25, 2140.37, and 2089.64, respectively, with probability values below 0.01. However, a limitation here is the absence of the Hausman specification test to identify possible fixed effects because the data on the impacted variables are constant over time, hence no fixed-effect regression is estimated. Robust standard errors are estimated because serial correlations are detected using Wooldridge's serial correlation test (Wooldridge, 2002; Drukker, 2003); the null hypothesis of no first-order autocorrelation is rejected (the F-statistic is 144.394 in each regression, and the probability value is below the 1% significance level).

The results are interpreted here by generalizing the relative awareness and destruction over the century, which is also assumed to be the baseline, whereby sea level rises to 5 m. As for the projected SLR that impacts land area, lower levels, such as 1 and 2 m, do not seem to show any apparent effects on tourism performance, although both estimates are negative. The effect starts to become more noticeable as sea level reaches 3 m. The effect of the 5-m SLR is more significant, statistically and economically, than 4 m and below. For instance, at the 5-m SLR, there is approximately a 0.5% reduction in tourism performance per 1% increase of the 5-m sea level, as the land area is adversely affected. Impacted urban expansion is also found to have a significant negative effect on tourism performance, although the effect only becomes apparent when SLR is at 4 m. The effects of the fourth and fifth levels are economically close, with both effects being equally significant. Comparing the effects between impacted land area and impacted urban expansion, we ascertain a greater effect of 0.6% by the latter. By standard-deviation commensurable changes, a 1 standard-deviation increase in impacted urban expansion leads to a 0.71 standard-deviation decrease in tourism performance, compared to a drop of 0.42 standard deviation from a 1 standard-deviation increase in impacted land area. These findings seem to make sense

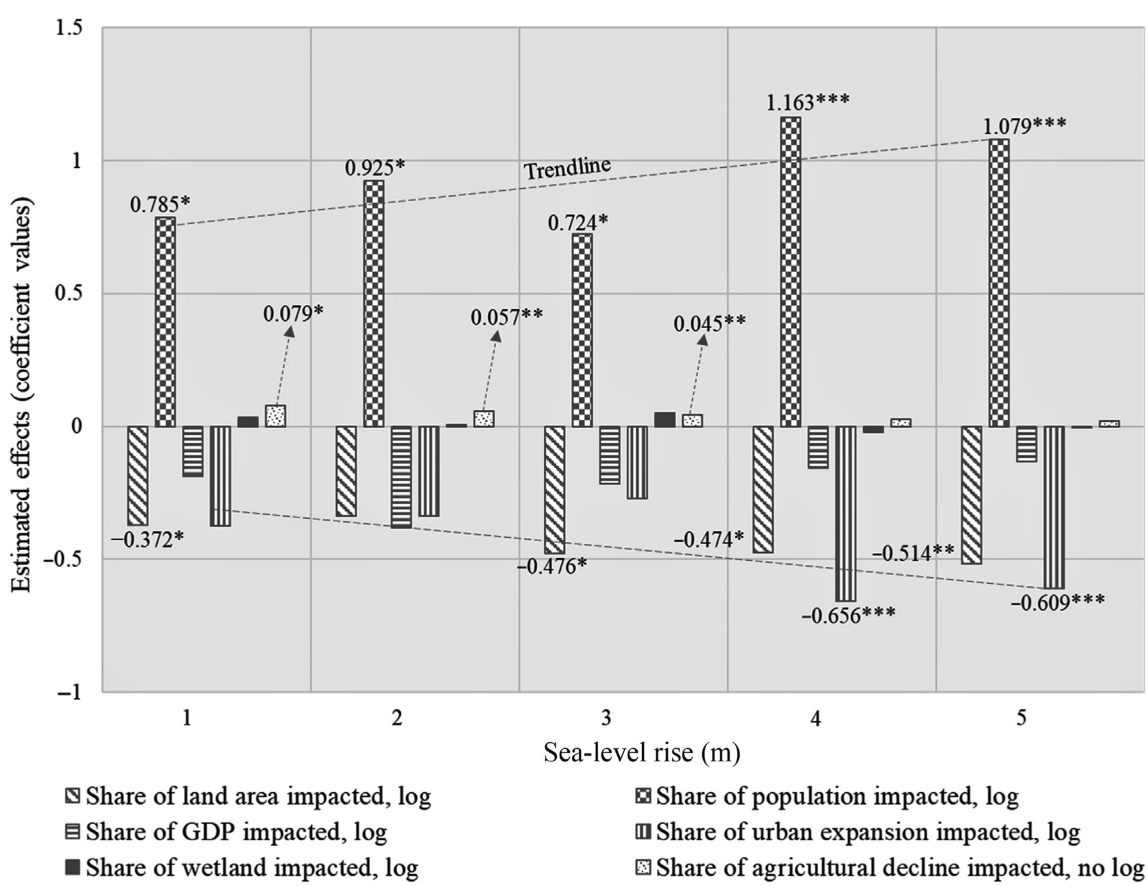

Fig. 3. Effects of six impacted variables for 1–5 m of sea-level rise on tourism prosperity (Values were estimated using random-effect generalized least squares regressions with robust standard errors; *, **, and *** indicate statistically significant at 10%, 5%, and 1% level, respectively).

because tourism activities tend to concentrate in urban areas, where there is a diversity of hotels, entertainment, and restaurants. Venice, for example, has been under stress due to rising sea levels that could unfavorably affect the tourism sector, as risk-averse tourists develop a fear of potential flood when the rainy season is predicted. In particular, one of the impacts linked to rising sea levels is storm surge (Nicholls et al., 1999), which could worsen tourists' expected experience when on vacation, thereby reducing the number of international tourist arrivals.

As climate change intensifies, the world population is expected to reduce and control environmentally-degrading activities, particularly those relating to heat, pollution, and deforestation. When will such awareness come about? A projected 1-m of SLR inundation is significant enough to create such an awareness in people because it adversely affects the population in the inundated areas. The positive coefficient suggests that such awareness urges the population to reduce activities that will contribute negatively to global warming. The adoption of environmentally-constructive attitudes will contribute to clean, fresh, and healthy environments for tourism activities that are environmentally oriented. Such awareness is expected to become more intense as the projected SLR inundation increases, as shown by the more statistically-significant effect of the 4 and 5 m of SLR. Furthermore, as the current sample is based on developing countries, agriculture is relatively important, although this sector is also particularly vulnerable to SLR-related inundation. Hence, destruction of agricultural area also creates an awareness in people to adopt environmentally-constructive attitudes, which, in turn, benefits the tourism sector. Whereas the estimates for the 4-m and 5-m of SLR are insignificant, higher levels might be more generally captured by the impacted population variable. This awareness may be perceived in terms of the Kuznets curve phenomenon observed by Kuznets (1955), where income inequality increases in GDP per capita, and then decreases thereafter (i.e., an inverted U-shape). A variant of the Kuznets curve—the EKC—has attracted debate in the literature (e.g., Dasgupta et al., 2002; Stern, 2004, 2017). The EKC theory predicts that environmental degradation initially increases following economic development, but eventually that decreases, forming an inverted U-shape. In the current study, we attribute this pattern to the point at which awareness outweighs destructive tendency, as represented by the two hypotheses in the theoretical framework. From this analysis of the economic impacts on tourism development, the results carry the implication of the EKC theory—a population takes environmental quality more seriously following the stress caused by SLR inundation, as global warming, brought about by the acceleration of economic development, is worsening. Nevertheless, in the current study, we do not expect to observe the inverted U-shape pattern of the EKC, and the theory is adopted here rather to explain how logical the positive and negative effects in Fig. 3 might be. The combination of negative and positive results likely mirrors a small portion of the curve, and not the entire curve.

The results in Fig. 3 indicate that SLR could affect tourism performance by one mechanism. As sea level burgeons, the tourism sector is negatively affected, as the inundating impacts continue to expand. However, these effects are expected to raise awareness to avoid further global warming and SLR. We view this possibility of awareness as statistically significant (e.g., the impacted population and agricultural decline variables show positive effects), likely suggesting that some groups of people are aware of the consequences of SLR and have already been taking preventive steps. However, the results in Fig. 3 do not indicate whether the overall effect of SLR on tourism performance supports either one of the two hypotheses outlined in the theoretical framework. In other words, it is still unclear, following the impacts of SLR, whether environmental awareness that benefits tourism performance is stronger than the destructive effects, or vice versa. The current study clarifies this matter in the following subsection by adding two types of PCA scores, as shown in the second step in Fig. 2.

4.2. Principal component analysis

The PCA is performed on the 35 variables of SLR based on the original data sourced from Dasgupta et al. (2006, 2007). Because the SLR data are interval observations, measured in commensurable units, a linear combination is suggested with PCA. Furthermore, Bartlett's tests show no evidence in favor of the null hypothesis that the variables are not intercorrelated; each test is significant at the 1% critical level. In particular, the values of KMO are all above the acceptable level according to the guideline determined by Kaiser (1974), indicating sampling adequacy; therefore, there is no evidence of unacceptable sampling adequacy. In accordance with the conducive results of the statistical tests, PCA is deemed to be feasible for the following analyses.

To save space, the upper part of Table 1 reports only the first six eigenvalues of the total 30 components. The first four components capture 96% of the variance; we benchmark 95% of variance captured as sufficient. The first component has all positive values, whereas the other three components distinguish the impacted variables of SLR with negative and positive values. Four datasets of principal component (type-A) scores are generated from the four components. The generated scores are tested in regression analysis to find the overall effect of SLR on tourism performance. In addition, the PCA is also implemented to find the principal component scores combining all SLR meters for each impacted variable. The PCA eigenvalues for the six impacted variables are shown in the lower part of Table 1, wherein the first eigenvalue of each variable captures more than 95% of variance. In this case, we obtain the (type-B) scores from the first component for each impacted variable across all SLR meters. We also test the principal component scores using regression analysis. The results based on the principal component scores for each impacted variable are expected to reveal further insights into the negative and positive effects on tourism performance. The scores are used with the third step of the empirical analysis (see procedure in Fig. 2), and the regression analysis is discussed in the following subsection.

4.3. Regression analysis using principal component scores

The overall effect of SLR on tourism performance is negative. As shown in Table 2, in the type-A score column, one of the four principal component scores (component 2) is statistically significant with a negative coefficient sign. We learn that tourism prosperity is incurring a negative hit by SLR impacts over the century. In standard-deviation units, this effect is a 0.13 reduction in tourism performance from a 1 standard-deviation increase in the score of component 2 capturing the effects of the six impacted variables of SLR. That said, if destruction beyond the 2001−2012 period is worsened rather than reduced, the adverse effect on tourism performance is likely to become greater toward the end of 2100. From 2013 until 2100, there are 88 years, which means that there are 7.3 cycles of a 12-year period until 2100. As the predicted effect from the 12-year period (2001−2012) is 0.13, we predict that this effect could grow to 0.95 by the end of this century. The implication is that, although we generalize the relative degree of awareness and destruction for the 7.3 cycles over the entire century, the effect in one cycle accumulates with the effect in the next cycle, in which case a multiplier effect occurs. This interpretation is consistent with the knowledge that the world is already committed to further SLR and global warming, even if the greenhouse gas concentrations in the atmosphere become stable (e.g., Meehl et al., 2005).

However, the negative effect is also embedded with deeper information between awareness of environmental quality and destructive behaviors with respect to SLR. This is demonstrated by the results from the other regression in Table 2, as shown in the type-B score column. The current study tests component-1 scores of the six impacted variables, wherein each component captures over 95% of the variance of the SLR impacts. The impacted population shows a positive effect on tourism performance (a 0.630 standard-deviation decrease in tourism performance for a 1 standard-deviation increase in this component), whereas the impacted GDP shows a negative effect (a 0.288 standard-deviation decrease in tourism performance for a 1 standard-deviation increase in this component). We initially learned, from the results in Fig. 3, that land area and urban expansion are negatively impacted by SLR and that this negatively affects tourism performance in developing countries. In contrast, the significant effect in Table 2 is found for the impacted GDP variable. As land and urban production are adversely impacted, the effects may

Table 1
Principle component analysis of overall versus specific inundation impacts of sea-level rise.

All impacted variables and sea levels	Bartlett's test of sphericity: Chi-square = 97,179.768 [0.000]			
	KMO: 0.818			
	Component	Eigenvalue	Variance explained (%)	Above 95% of total variance explained
	1	19.991	66.6	66.6
	2	4.217	14.1	80.7
	3	2.412	8.0	88.7
	4	2.192	7.3	96.0
	5	0.567	1.9	
	6	0.313	1.0	
	⋮	⋮	⋮	
	Total = 30			
All sea levels, specific impacted variables	Component	Bartlett's test of sphericity, KMO	Eigenvalue[a]	Above 95% of total variance explained
	Share of land area impacted	15,113.597 [0.000], 0.569	4.945	98.9
	Share of population impacted	10,010.742 [0.000], 0.712	4.785	95.6
	Share of GDP impacted	8813.094 [0.000], 0.797	4.749	95.0
	Share of urban expansion impacted	10,773.487 [0.000], 0.725	4.830	96.6
	Share of wetland impacted	12,209.875 [0.000], 0.645	4.780	95.6
	Share of agricultural decline impacted	13,684.034 [0.000], 0.585	4.803	96.1

Notes:
[a]Eigenvalues of the first component out of five are shown.
Values in brackets indicate probability values.
Values of KMO according to Kaiser (1974): 0.90−1 = marvelous, 0.80−0.89 = meritorious, 0.70−0.79 = middling, 0.60−0.69 = mediocre, 0.50−0.59 = miserable, and 0−0.49 = unacceptable.

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Table 2
Regression analysis using principal component (type-A and type-B) scores: Random-effect generalized least squares regression results with robust standard errors.

	Dependent variable: number of international tourist arrivals	Type-A scores All impacted variables and sea levels		Type-B scores All sea levels, specific impacted variables	
Impacted variables: principal component scores	Component 1	0.031	(0.029)		
	Component 2	−0.102*	(0.055)		
	Component 3	−0.045	(0.046)		
	Component 4	0.087	(0.086)		
	Share of land area impacted, component 1			−0.061	(0.081)
	Share of population impacted, component 1			0.459*	(0.277)
	Share of GDP impacted, component 1			−0.211*	(0.124)
	Share of urban expansion impacted, component 1			−0.140	(0.189)
	Share of wetland impacted, component 1			0.006	(0.077)
	Share of agricultural decline impacted, component 1			0.008	(0.071)
Control variables	Greenhouse gases, log	−0.022	(0.055)	−0.021	(0.055)
	Renewable energy, log	−0.012	(0.076)	−0.011	(0.076)
	GDP per capita, log	1.237***	(0.130)	1.227***	(0.132)
	Trade openness, log	0.233**	(0.109)	0.238**	(0.109)
	Population density, log	0.610***	(0.210)	0.550***	(0.210)
	Total labor force, log	0.595***	(0.116)	0.654***	(0.122)
	Unemployment, log	−0.086	(0.083)	−0.090	(0.084)
	Domestic savings	−0.002	(0.013)	−0.002	(0.013)
	Final consumption, log	0.097	(0.984)	0.091	(0.977)
	Capital formation, log	0.043	(0.086)	0.043	(0.086)
	Intercept	−8.778*	(5.020)	−9.378*	(5.012)
Specification	Number of observations	576		576	
	R-squared	0.642		0.644	
	Breusch−Pagan Lagrangian multiplier test for random effects	2464.60 [0.000]		2285.94 [0.000]	

Notes:
***, **, * indicate significance at 1%, 5%, 10% critical levels.
Values in parentheses indicate standard errors. Values in brackets indicate probability values.
Descriptions of each control variable are given in the section of empirical methods and data.
Type-A and type-B scores are two principal component category scores, as described in Fig. 2.

translate into a lower GDP performance. This represents a more comprehensive impact of SLR that negatively affects tourism performance across the developing countries, which responds to hypothesis 1 in the conceptual framework. The positive effect of the impacted population variable suggests people's awareness, as previously elaborated. Impacted populations raise concerns over environmental quality, which promotes tourism development because more people endeavor to develop shared values and appreciation. This can improve the quality of living standards amid environmental degradation.

According to the conceptual framework, the second hypothesis argues that environmental awareness can foster positive actions, thereby bringing positive effects on tourism performance. Although awareness may not be the only influencing factor, it is deemed to be the primary factor underlying all positive actions amid climate change and SLR, which is also a major concern in the literature. For instance, Marshall et al. (2013) investigated environmental awareness for the primary sector in Australia and the study implies that other industries that plan to cope with climate change risk should consider investing in climate change awareness, as this will enhance their adaptive capacity. According to a case study in South Africa, Mandleni and Anim (2011) refer to this as a two-stage process; awareness followed by adaptive measures. As for other possible factors that are correlated with tourism performance and environmental awareness, the current study uses control variables to capture the confounding effects; the results are not presented in Fig. 3, but Table 2 shows the results for the same list of control variables used for the regressions presented in Fig. 3. As for the final results presented in Table 2, the relationship between awareness and tourism performance is not found to be economically weak at 0.459, although its statistical significance is only at the 10% critical level. In standard-deviation units, economically, this is equivalent to a 0.630 standard-deviation increase in tourism performance for a 1 standard-deviation increase in environmental awareness subsumed in the share of population impacted principal component. Overall, the findings of positive effects seem to be in line with the theoretical model and its practical implication elaborated in the conceptual framework section.

5. Conclusions and discussion

This study shows the empirical effects of SLR, captured by six growth-essential economic factors, on the future of tourism prosperity. Moving up each consecutive sea level from 1 m to 5 m, the impacted population shows relatively bigger effects than other factors, with the average effect of a 0.95 standard-deviation change for every 1 standard-deviation increase in SLR impact. In particular, the positive effect suggests that constructive behaviors (due to awareness) are embedded in the population in favor of preserving environmental quality. However, an increasing pattern of negative impacts is manifested in the impacted urban expansion of up to −0.609 at 5 m. This is accompanied by impacted land area, which has smaller negative effects than impacted urban expansion. The significant negative estimate stemming from the latter two growth-essential factors at 4 m is on par with the positive effect of the impacted population in terms of magnitude, whereas the negative effect outweighs the positive effect at 5 m. This implies a threshold at which the negative impact will become dominant when the increase in awareness within the population is insufficient. No significant effect is found from impacted wetland at each projected sea level. This could be the result of two factors. First, urban areas are the first destinations for most international tourist arrivals; hence it is only when the urban area has experienced SLR-related inundation that foreign tourist arrivals visiting wetland areas will be impacted. The implication is that the urban area will capture this effect. Second, because the impacted land area variable represents inundation across a broader range of tourist destinations, the effects on impacted wetland could be embedded in the impacted land area variable. Similar reasons seem to apply to the impacted agricultural decline. In contrast, agriculture represents a major source of food in most developing countries; hence, impacted agricultural decline can raise awareness of environmental preservation. The benefits of successful environmental preservation spill over into benefits of environmental attractions to the tourism sector. This impacted factor remains significant until the third meter of SLR inundation. Thereafter, these effects seem to be captured by a broader factor such as impacted population. Finally, impacted GDP, as a measure of economic performance, appears to be too broad to capture any significant impacts of SLR inundation on the tourism sector when the inundation is examined meter by meter. For instance, when the overall variance across sea levels on impacted GDP is examined, evidence of a negative effect on tourism prosperity is found.

The effect of impacted population is robust regardless of overall or individual levels of sea rise, signaling an urgent circumstance in which people's awareness seems to grow stronger when economic activities are paused or interrupted by SLR. This positive outcome outweighs the overall negative effect captured by impacted GDP, which represents various economic activities directly or indirectly related to tourism performance. However, the combined effect of the six impacted variables is still negative, which is consistent with past predictions that we are already compelled to endure global warming. The new findings show that a 1 standard-deviation increase in the economic impact of sea-level rise can lead to a 0.95 standard-deviation decrease in tourism performance. Hence, we suggest that the inundation costs to a country's tourism sector are approximately equal to the inundation costs to its economic growth. This suggests that a further boost in awareness seems to be imminent. However, all countries must still pro-actively step forward and engage in worldwide cooperation to support tourism prosperity into the future.

A rising sea level brings the possibility of large-scale catastrophe, according to global SLR predictions. Its impact on the tourism industry is a fundamental question underlying the tourism−growth relationship. As Stern (2008) emphasizes, shared values will be very important in alleviating this disastrous phenomenon. Nevertheless, we are already obliged to accept SLR and further global climate change, even if the concentration of greenhouse gases in the atmosphere stabilizes (Meehl et al., 2005). Hence, adaptation measures are believed to be crucial (e.g., Winsemius et al., 2016). Because tourism is an environmentally-oriented activity, inundation owing to SLR is likely to reduce the prosperity of this industry. In line with the mitigating actions suggested in previous studies, this study's empirical findings on the economic mechanism involved underscore the importance of SLR awareness as a key component of the adaptation measures that must be substantively and substantially developed. This awareness, along with enhanced shared values and appreciation through international collaboration, will help us to avoid further climate change and human-induced accelerated land subsidence. Understanding the impacts of SLR on tourism benefits may be an essential step, particularly in developing countries in which economic development is aggressively targeted, often at the expense of environmental degradation. This is not limited to land-based tourism: understanding SLR impacts on marine ecosystems seems to be equally important, as the diversity of water tourism activities could have made a major effect on a country's tourism performance. In this study, nevertheless, tourism performance represents a broad consideration of all possible tourist activities, and we hope that future studies will shed light on the particular intricacies of marine ecosystems.

The empirical findings are based on future projections over the 21st century, in which—if the awareness levels of today persist—evidence suggests that the conservation of environmental quality is likely to remain low throughout the century, relative to the importance of boosting economic prosperity. From the results, although we observe some awareness of environmental quality, this is considered to be in the latent stage, as compared to the destruction that dominates in many developing societies. Tourism, as an emerging prosperous industry in many countries, is predicted to face the possibility that its growth will backfire, due to human development activities over this century. In addition to climate change, river deltas such as the Mekong, Ganges, and Nile, which serve as tourist attractions, are subject to geographical alteration, thereby triggering flood hazards. As another example, Venice has shown evidence of tidal flooding in the city following SLR and land subsidence, which has halted many tourism activities. In line with Butler's (1991) remark, when knowledge, responsibility, and long-run planning are relatively lacking, tourism and its related developments are neither culturally nor environmentally sympathetic.

Economic costs relating to SLR could be a fundamental trigger for awareness, given the losses that will occur. Hence, promoting a shared appreciation of the environment could be a crucial factor. For example, one study has demonstrated that 48 km^2 of roadway in Honolulu, Hawaii faces the risk of inundation following SLR (Habel et al., 2017), foreshadowing the potential burden of economic costs that other countries will risk incurring. It is also valuable to compare future economic wealth with future global damage in relation to SLR (e.g., river flood hazards), as demonstrated by Winsemius et al. (2016). Consequently, it is arguably the case that we need to further stimulate awareness via an understanding of the economic costs of SLR. The current study has shown this by estimating SLR-related costs for the tourism sector, mediated through several growth-essential factors, and by revealing new insights into the tourism-led growth phenomenon as far as environmental degradation is concerned.

Declaration of competing interest

The author declare no conflict of interest.

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