Quantitative Models Evaluating the Effect Climate Change Effects on Tourism
State of the Art

Jaume Rosselló
Departament d'Economia Aplicada, Universitat de les Illes Balears, Carretera Valldemossa km 7.5, Palma de Mallorca, Spain

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Abstract: In a context of climate change, many destinations are considering what effects can be predicted on the tourist demand and how they should be tackled. This work analyses the most relevant perspectives presented in the literature evaluating the effect of climate change on tourism. A review is made by showing the results that rise from a triple point of view: the consideration of physical changes, the analysis of the tourist attractiveness through climatic indexes and modeling tourism demand. The review suggests that, although some methodologies are on a primary stage of development, results from the different perspectives agree in presenting a similar map of the main affected areas (positively and negatively) in terms of tourism demand and/or tourism attractiveness.

1 INTRODUCTION

Climate science is very certain that the Earth's climate will change at an unprecedented rate over the 21st century. Whether through the direct effects of climate change, such as increased temperature, or through ancillary effects such as sea-level rise, loss of snow cover or impact on landscapes, the spatial and temporal pattern of tourism demand can be expected to adjust. Despite the apparent overwhelming dependence of tourism on climatic factors, it is surprising that, in spite of the economic significance of the Travel and Tourism Industry (9.1% of the Gross domestic product worldwide according to the WTTC, 2012), the literature on the sectorial implications of climate change has been dominated by other sectors such as agriculture - with a lower weight in economic terms (6.1% of the Gross Domestic Product according to CIA, 2012) - while tourism has been pushed into the background. This circumstance is evidenced in the successive reports of the Intergovernmental Panel on Climate Change where tourism only recently appeared with some strength during the last AR4 Report (IPCC, 2007).

An initial justification of the relative neglect of tourism can be found in the uncertainties and complexity of expected tourism demand responses. In a recent study, Gössling et al. (2012) highlight the complexity of understanding tourist perceptions and reactions to the impacts of climate change in order to anticipate the decline or increase of specific tourism markets and seasonal shifts in tourism demand. They argue that tourism is characterized by a large adaptive capacity that has to be combined with other uncertainties concerning the implementation of future mitigation policies and its impacts on transportation systems, the wide range of climate change impacts on destinations, as well as broader impacts on society and economic development.

However, the industry needs to anticipate today the consequences of climate change on future demand in order to plan new infrastructures strategically and to detect business opportunities efficiently. Despite the controversy over the weaknesses of statistical models in predicting tourist flows under scenarios of climate change (Gössling and Hall, 2006; Bigano et al., 2006), results from this literature should be contextualized under the ceteris paribus clause entailing that all the determinants of tourism demand remain constant, except the climate, whose influence one wishes to study. One of the problems arising from the application of the clause is related to the interpretation of results. Thus, while in the short run the estimation of a tourism demand model and the

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evaluation of one single shock can produce direct forecasts of the tourism demand variable (Papatheodorou, et al., 2010) when long run determinants – such as climate – are evaluated, forecasts have a different interpretation and have to be taken as general projections rather than real forecasts.

Hence, for instance, regarding the specific market segment of winter tourism, although it is almost impossible to provide information regarding the change in preferences of potential tourists visiting mountain resorts during next 50 years, it is feasible to evaluate the physical consequences of loss of snow coverage originated by climate change. Extrapolation can be carried out through the quantification of expected snowfall which implicitly determines the availability of winter tourism conditions. Otherwise, optimal conditions for tourism can also be evaluated by assuming that a certain level of favorable climate conditions is required for main tourism activities. In this case, an assessment of what tourists consider optimal conditions have to be evaluated previously, in which case the assessment of these future climatic conditions is what later determines the loss or gain of tourism attractiveness in terms of climate conditions. Evidently, again, changes in climatic preferences by people are difficult to anticipate and only actual optimal climatic conditions can be projected.

Within the tourism demand modeling context, although tourism demand models had traditionally disregarded the consideration of climatic determinants in tourism demand modeling exercises (Goh, 2012), since the turn of the century the inclusion of climate variables (such as temperature, precipitation and wind) within tourism demand models have become more frequent. The evaluation of climate on tourism demand is often taken as a short-run determinant in the context of time series models or as a push/pull factor of the destination choice when both discrete choice models and aggregated tourism models are considered. The ceteris paribus clause here is clear since estimation techniques usually entail the isolation of each of the determinants possible in order to make simulations concerning the effect of climatic conditions while the rest of variables remain constant.

Therefore, a significant number of quantitative studies have attempted to evaluate climate change consequences on tourism over the last fifteen years. So far, however, no attempt has been made to comprehensively integrate these findings to reveal a regular pattern, the establishment of which will constitute general principles and cumulative knowledge. Due to the multiple methodological alternatives that have appeared during the last years assessing the consequences of climate change on tourism quantitatively, this papers aims to evaluate them, showing how despite the different approaches used in tackling the problem, significant agreements in results can be found. What is more, as the distinct alternatives are analyzed jointly for the first time, it is possible to highlight some of the main advantages and limitations for each one.

2 EVALUATION THROUGH PHYSICAL CHANGES

One of the most direct consequences of climate change is frequently illustrated by the losing of snow-cover depth. Mountain resorts depend heavily on tourism and snow-reliability is one of the key elements of the offers made by winter tourism. The financial viability of winter tourism, however, depends on sufficient snow conditions. If climate change occurs, the level of snow-reliability will rise to higher altitudes over the next few decades. Although today, adaptation strategies are predominant in this tourism segment (e.g. artificial snow production), to anticipate the consequences of climate change on snow-cover depth becomes a key element when adaptation strategies have to be adopted. In this context, Breiling and Charamza (1999) analyze, for all districts in Austria, the impact of a 2°C change in temperature on seasonal snow-cover depth. They estimate that these changes will reduce ski season length and the usability of ski facilities. Warming will have strong impact on low altitude resorts, which the authors expect will disappear first and the remaining resorts will become more expensive. Similar studies have been carried out for winter sports tourism in Scotland (Harrison et al., 1999), Switzerland (Elsasser and Messerli, 2001), and Canada (Scott et al., 2006).

The methodological background of all these studies remains in estimating accurately the amount of precipitation that falls as snow and rain, the snow accumulation, and the snowmelt. Historical precipitation data can be analyzed for each alpine resort to determine the temperatures that best predict historical snowfall amounts. Then, using temperature and precipitation projected data from the different climate change scenarios (or assuming some trend in temperatures and precipitations) it is possible to estimate the amount of snow precipitation that in the meantime determines snow accumulation. Breiling and Charamza (1999), Harrison et al. (1999) Elsasser and Messerli, (2001), Scott et al., (2006) and other similar studies find a general decline in natural skiing conditions, although this will be less of a problem at high altitude sites. At this point it should be mentioned how the use of snow making machines, should be considered in the final evaluation, even though this partial solution is also temperature dependent.

At any rate, although the specific segment of winter tourism may be of special interest for certain regions, within the physical evaluation perspective it is possible to be more generalist and consider other physical consequences which, under climate change, could affect other segments including summer & beach tourism. Then , in the same way that winter tourism depends on snow, summer tourism in some destinations rely on other physical conditions necessary for the development of tourism activities. Although the models under this wide perspective are at a lower stage of development, the rise in sea level and its consequences on beach coverage (Nicholls et al., 2011), coral reef health (Hoegh-Guldberg, et al. 2007), proliferation of jellyfish (Purcell, 2012) and algal blooms (Englebert et al., 2008) would be on the agenda of future quantifications of the effects of climate change on tourism.

In this context it is important to highlight that although some exploratory studies have shown the relative irrelevance of tourism opinions when faced with a marginal loss of environmental quality (Gössling, et al. 2006), a certain threshold level - defined sometimes by visibility, abundance and variety of species, occurrence of algae or physically disappeared beaches- would exist (Gössling, et al. 2007), evidencing how tourists might respond to climate changes in a non-linear way. Then, although a marginal effect on environmental quality can not be detected through simple techniques, it is suggested that ecosystem responses to pressures are characterized by discontinuities and thresholds effects, resulting in difficulties for the accurate estimation of the tourism consequences.

3 CLIMATIC INDEXES

A Climatic index refers to a set of climate variables that are combined through a mathematical formula in order to capture human comfort preferences. More precisely, a tourism climatic index (TCI) can be understood as a tool that "has evolved from more general knowledge about the influence of climatic conditions on the physical wellbeing of humans" (Amelung and Viner, 2006; p.351). The potential changes in human comfort levels suggested by combination of the TCI with scenarios of climate change could have profound implications for the tourism industry. Whereas some locations are likely to experience substantial increases in attractiveness due to improvements in their weather conditions, others may become significantly less appealing to tourists, leading to shifts in the temporal patterns of visitation and/or actual declines in the number of visits

Mieczkowski (1985) was among the first to apply the results of climate indices for tourism-related activities by developing a TCI. Although 12 climate variables were initially identified from the literature as pertinent to be included in the TCI, meteorological data limitations reduced the number of climate variables integrated into the TCI to seven which were combined in five sub-indices that comprised the most popular TCI. A standardized rating system, ranging from 5 (optional) to -1 (extremely unfavorable), was devised to provide a common basis of measurement for each of the sub-indices. Then, analytically the TCI can be derived from the following equation:

$$\mathrm{TCI}=2(4Cid+Cia+2\cdot Sun+2\cdot Prec+Wind) \quad (1)$$

Where, *Cid* is the daytime thermal comfort index; *Cia* is the daily thermal comfort index; *Sun* is an index of the amount of sunshine; *Prec* is an index of the amount of precipitation; and *Wind* is the index of the appreciation of wind. Bearing in mind that TCI scores range from -20 to 100, Mieczkowski proposed a classification of TCI scores, with values in excess of 60 corresponding to 'good' conditions, scores exceeding 70 expressing 'very good' climatic conditions, levels of over 80 corresponding to 'excellent' conditions, and scores of 90 or more standing for 'ideal' circumstances.

Although the Mieczkowski index was not originally devised to explore the impacts of climate change on tourism, since climatologists can provide future data about the five sub-indices it is possible to evaluate the climatic attractiveness of regions under different climate change scenarios and to compare them with the current situation. This has been carried out for Europe (Rotmans, et al. 1994), European beaches (Moreno and Amelung, 2009), Mediterranean countries (Amelung and Viner, 2006), North America (Scott et al., 2004) and even on a worldwide scale (Amelung et al., 2007). It should be noted how maps depicting TCI show a strong correlation with currently popular destinations, suggesting that the index performs quite well as a predictor of tourist arrivals.

Weights used in Equation (1) give the highest weight to the daytime comfort index to reflect the fact that tourists are generally most active during the day. The amount of sunshine and the amount of precipitation are given the second-highest weights, followed by daily thermal comfort and wind speed. Although these weights are ultimately subjective, they are founded on scientific knowledge owing to the fact that they are based on the declared preferences of tourists collected through questionnaires. Consequently they can be adapted for different tourist market segments. This is the case of Morgan, Gatell, Junyent, Micallef, Özhan and Williams (2009) who devised a specific climate index for beach tourism that contained the same elements as Mieczkowski's (1985) TCI except for the daily thermal component. The main difference between the two indices is in the rating and weighting schemes. While Mieczkowski (1985) based his schemes heavily on expert judgment, Morgan et al., (2000) based theirs on the stated preferences of actual beach users. These preferences were elicited from 1,354 questionnaires, filled out by a total of north European beach users while spending their holidays in Wales, Malta, and Turkey in 1994 and 1995.

One of the main goals of the use of climatic indexes can be found in the analysis of seasonality. Hence, as sub-indices composing TCI are referred to monthly data, implications of projected climate change on tourism seasonality can be revealed. In this way, Amelung et al. (2007) shows how countries in northern Europe may experience substantial improvements in summer climatic conditions while countries in the northern Mediterranean that currently attract the traditional "sun and sand" summer vacationer are likely to become too hot for comfort in the current summer season, which would contrast with the improvement of climatic conditions during the non-summer period. Thus, while northern countries are expected to improve their tourism attractiveness under climate change, the consequences for actual warmer destinations remain uncertain owing to the final balance between a loss of attractiveness during the summer and a gain of attractiveness during the rest of the year.

The Physiologically Equivalent Temperature has recently emerged as alternative to the TCI. Originally developed to assess human comfort in general (Matzarakis et al., 1999), it has been applied to tourism comfort by Lin and Matzarakis (2011) who depict seasonal distribution maps of the physiologically equivalent temperature showing that Taiwan and Eastern China are perceived as comfortable during spring and autumn for those residing in temperate regions, while only the southern region during spring and the northern region during summer are perceived as comfortable for those residing in sub-tropical regions.

An advantage of thermal indices is that they are rooted in the long tradition of physiological research; a major drawback is that they disregard important non-thermal aspects of weather and climate. For a proper assessment of the suitability of climate and weather conditions for tourism purposes, the use of composite measures is to be preferred (Moreno and Amelung, 2009). At any rate, the main drawback of the use of TCIs is the inability to provide a quantitative measure of tourism impact in economic terms or in tourism arrivals. This explains why Amelung and Moreno (2012) recently included the TCI as an independent variable in a tourism demand model estimating the number of bed nights for European countries. However, this perspective, based on revealed preferences, brings us to the following section.

4 TOURISM DEMAND MODELS

The neglect of tourism within the literature on climate change came with the omission of climate variables within tourism demand models since the turn of the century (Goh, 2012). In the revision of Crouch (1994), only few papers had included climate or weather variables as determining variables, and, on many occasions, with limited success. A feasible explanation for this omission would be related to the interest of researchers and planners in income elasticities and/or price elasticities in order to forecast tourism demand in an accurate way - a key issue for service industries with relatively high fixed costs – or, alternatively, in order to evaluate the consequences of taxes or exchange rate policies. This explains why tourism demand literature has been dominated by time series models and frequently linked to forecasting issues (Song and Li, 2008). Thus, as climate is a relatively stable variable, the climate factor does not have the required variability and, additionally, is not correlated with the determining variable, so no bias in estimated elasticities is expected.

However, with increasing interest in climate issues and, more precisely, in evaluating the consequences of climate change on tourism, part of the literature on tourism demand modeling has been reoriented in order to integrate climate and weather factors in the estimation of tourism demand. Hence, consumers are assumed to be revealing their climate preferences through purchasing habits. Knowing their climate preferences and, ceteris paribus, it is possible to project future tendencies through projected climatic conditions. Note how within this framework the focus of the analysis is the tourists not the physical conditions. Within the tourism demand framework, three main perspectives have been adopted: time series analysis, discrete choice models, and aggregated tourism models.

4.1 Time Series Analysis

In the context of time series analysis, it is preferable to talk about weather (the short term atmospheric conditions) rather than climate (the mean atmospheric conditions of a region) because under this perspective the most popular proposal is to attempt to capture some kind of short term relationship between tourism demand and an extreme weather event. Thus, Subak, et al. (2000) assess impacts on tourism of the anomalously hot summer of 1995 and the warm period from November 1994 through October 1995 in the U.K finding how the tourism sector showed clear differences in its response to winter and summer warm anomalies. Agnew and Palutikof (2006) look into the sensitivity of UK tourism to weather conditions using monthly data for domestic tourism and annual data for trips abroad, showing that outbound flows of tourists are responsive to weather variability of the preceding year, whereas domestic tourism is responsive to variability within the year of the trip. Using the anomalously warm year of 1995 in the UK, the potential impact of climate change is evaluated suggesting that the generally warmer and drier conditions of 1995 benefited the UK domestic tourist industry but wetter and duller-than-average conditions in the previous year seemed to encourage more trips abroad.

In a more general framework, it is proposed that, using a monthly time series model, on the one hand, the cyclical-trend component can be captured through an ARIMA model (Rosselló et al., 2011) or even including prices, and other economic determining variables (Álvarez and Rosselló, 2010; Rosselló, 2011). On the other hand, because meteorological variables can present a high variability and are not present in the long-run, it is hypothesized that affect the short run of the time series and consequently can not be captured though ARIMA or Economic factors, and remain in the error term. Then, the hypothesis to be tested is whether short term extreme weather episodes are related to this residual term. Analytically, the problem can be summarized in terms of a Transfer Function Model:

$$\phi_p(L)Y_t = \theta_p(L)a_t + \varphi_b(L)d_t \qquad (2)$$

where Y_t is the number of tourism flows a month t; a_t is the innovation or moving average term; d_t is a weather variable (or a set of weather variables) that could influence the number of tourism flows; $\phi_p(L)$ and $\theta_p(L)$ are the lag operator polynomials for both Y_t and a_t, respectively capturing the cyclical-trend component (the long-term component) of Y_t as is common practice in ARIMA modeling; and $\varphi_b(L)$ are the lag operator polynomial (or transfer function) for the weather determining variables, thus assuming that some lag between the observation of weather variables and tourist flow data occurs.

The estimation of equation (2) makes the prediction of within-sample values possible, which can be compared with simulated predictions using scenarios of climate change thus affecting the d_t variables. For instance, Rosselló et al. (2011) using the transfer function methodology found a significant relationship between British tourists abroad and different British weather variables such as temperature, heat waves, air frost days and sunshine duration. Using different simulations in the context of average temperature warming they found that an additional 1°C to the UK average temperature will provoke an annual decrease of 1.73% of British outbound flows, a percentage that is not homogeneous throughout the year because of the expected higher impact during the winter time. This result suggests, again, the presence of non-linear relationships between temperatures and tourist flows.

The use of more complex structures has dominated the most recent literature. Then, Kulendran and Dwyer (2012) use the Autoregressive Conditional Heteroskedasticity modeling approach for identifying the relationship between climate variables such as maximum temperature, relative humidity, and hours of sunshine and seasonal variation, defined as the repetitive and predictable movement around the trend line in holiday tourism demand in the context of seasonal variation in holiday tourism demand to Australia from the US, UK, Japan, and New Zealand. Otero-Giráldez et al. (2012) found also a significant positive connection between the North Atlantic Oscillation –as a meteorological indicator- and tourism demand in Galicia (Spain) using autoregressive distributed lag model. Goh (2012) built an error correction tourism model for tourism demand which also looks into the presence of structural changes in the estimations using the TCI as a determining variable, showing how the climatic index is found to have a significant and positive relationship for all the tourism demand series analyzed.

Summarizing, the analysis of the relationship between climate (or weather) and tourism through time series models has evidenced a current, real relationship between tourism and climatology. Like TCI, one of the main goals of the use of time series can be found in the analysis of seasonality. However, it should be noted how, within this framework, only short term relationships are suitable to be captured despite climate change issues belong to the long term.

4.2 Discrete Choice Modeling

Within the framework of revealed preferences, a second perspective is the use of Discrete Choice Models. In this context the relevant question is why people choose a particular destination, and the theoretical background is found in Lancaster (1966) where the source of utility is proposed to be the characteristics of the commodities and services not the commodities or services by themselves. Then, taking the utility theory into account within the context of tourism decisions, as formally described for the first time in Morley (1992), a new framework is introduced that allows different perspectives of tourism decisions and a larger set of explanatory variables to be considered. Analytically, the utility U_{ni} that a tourist n derives from choosing to visit destination i is assumed to take the following form:

$$U_{ni} = \beta_n^{'} x_{ni} + \varepsilon_{ni} \quad (3)$$

where $\beta_n{'}x_{ni}$ is the deterministic portion of the utility received if destination i is visited. Therefore, x_{ni} are the observed attributes characterizing the alternatives available to tourists and β_n is the vector of estimated coefficients for tourist n representing his/her tastes. Finally, the error term ε_{ni} captures the variation in preferences between tourists in the population. As the individual is assumed to visit the destination yielding the greatest utility, the probability π_{ni} of him choosing the *i-th* alternative is:

$$\pi_{ni} = \Pr\left(\beta_n^{'} x_{ni} + \varepsilon_{ni} > \beta_n^{'} x_{nj} + \varepsilon_{nj}\right) \; \forall j \neq i \quad (4)$$

Thus, individuals or households with exactly the same socioeconomic and demographic characteristics might choose very different destinations. However, over and above the consideration of the utility theory, through the use of random utility models it is generally recognized that tourists have different tastes and that choosing a final destination is not an independent decision, but the final decision of a set of choices. In this sense, it is argued that once tourists have decided to go on holiday and have established a budget and mode of transport, they choose a destination conditional upon their preferences and the attributes characterizing the alternatives in the choice set (Eugenio-Martin, 2003).

This framework for modeling tourism demand from a microeconomic perspective has become of interest to different tourism stakeholders, such as tourism marketing analysts, because of the high potential for identifying the determinants of destination choice decisions. It is important to highlight that choosing a destination is considered to be one of the most complex stages in the decision process by tourists, with a wide number of variables (dependent on the aim of the study) that are likely to influence such decisions (Marcussen, 2011).

In the context of climate change and tourism, Eugenio-Martín and Campos-Soria (2010), using a Discrete Choice Model for European households, focus their analysis on the relationship between climate in the home area and the choice of taking holidays in the region of origin or abroad, showing that the climate in the region of residence is a strong determinant of holiday destination choice. They show that residents in regions with better climate indices have a higher probability of travelling domestically and a lower probability of travelling abroad while colder regions trend to travel abroad with a higher frequency than warmer ones.

Thanks to the estimation of the β_n vector of equation (4) they project how individuals' choice changes when input climatic data from Europe change, evaluating the probability of travel abroad and/or domestically. Thus, under a scenario of climate change, a not very strong relationship is found when the evaluation of both travelling abroad and travelling domestically is considered. However, it seems that a rise in temperature increases the likelihood of traveling domestically only and lowers the likelihood of traveling abroad, a result that was also obtained within the time series framework.

Using the same methodology, Bujosa and Rosselló (2013) investigate the impact of climate change on destination choice decisions in the context of summer domestic coastal tourism in Spain. Once destinations are characterized in terms of travel cost and coastal 'attractors' (temperature and beach-related attributes) the observed pattern of interprovincial domestic trips is modeled, showing trade-offs between temperature and attractiveness in the likelihood of a particular destination being chosen. Using A1FI and B1 climate change scenarios they show how Spain's colder Northern provinces would benefit from rising temperatures while provinces in the south would experience a decrease in the frequency of trips. In this application it is important to highlight how a squared term for the temperature was used, thus providing an estimation of maximum or minimum comfort temperatures and evidencing the non-linear relationship between tourism and climate.

Although models evaluating the effects of climate change on tourism within the discrete choice modeling framework have just emerged, it should be noted how the assumptions about the utility function should be deeper investigated. Then, the use of additive sum of the individual utilities would be that the tourist is assumed to be risk-neutral, an assumption sometimes difficult to justify within the framework of tourism choices.

4.3 Aggregated Tourism Demand Models

Aggregated tourism demand modeling continues to be a popular issue in tourism literature. Reviews by Lim (1999), Li et al. (2005) and Song and Li (2008) show that tourism demand estimation mainly focuses on time series models, thus including variables with significant short term variability, such as prices and income, and neglecting structural determinants, such as climate, which are expected to be collected by the constant term. This practice can be justified by the interests of tourism planners, who have preferably been interested in income elasticities and/or price elasticities in order to forecast tourism demand in an accurate way (a key issue for service industries with relatively high fixed costs), or alternatively in order to evaluate the consequences of taxes or exchange rate policies.

However, with the growing interest of climate issues, a set of aggregated tourism demand models have emerged focusing their interest on climate variables. Hence, the pioneering study of Maddison (2001) sets out a cross-sectional model for chosen destinations of British tourists using classical price determinants of tourism demand and incorporating climate variables in terms of attractors. The estimation of the model permits the quantification of the trade-off between climate and holiday expenditure and, because of the introduction of non-linear effects (through a 4^{th} order polynomial) the identification of 'optimal' climate for British generating tourism. The findings are used to predict the impact of several climate change scenarios on different tourist destinations. In a similar way, Lise and Tol (2002), using aggregated data and regression analysis, find optimal temperatures at travel destinations for different tourists and tourist activities, showing that OECD tourists prefer an average of the hottest month of the year temperature of 21 ◦C indicating that, under a scenario of gradual warming, tourists will spend their holidays in different places than they currently do. With a global perspective, Hamilton et al. (2005a and 2005b) set out what is known as the Hamburg Tourism Model (HTM), consisting of the estimation of two equations for international tourist departures and arrivals for a specific year. Analytically:

$$\ln A_d = \alpha_0 + \alpha_1 G_d + \alpha_2 T_d + \alpha_3 T_d^2 + \alpha_4 C_d + \alpha_5 \ln Y_d \quad (5)$$

$$\ln \frac{D_o}{P_o} = \beta_0 + \beta_1 T_o + \beta_2 T_o^2 + \beta_3 B_o + \beta_4 Y_o + \beta_5 \ln G_o \quad (6)$$

where *A* refers to the total number of arrivals in a country *d*; *D* the total number of departures from s country *O*; *P* the population in thousands; *G* the area in squared kilometers; *T* the country's mean yearly temperature for the period 1961-1990 in degrees centigrade; *C* the length of the coastline in kilometers; *Y* the country's per-capita income; *B* the number of countries bordering a particular country; and α_i and β_j parameters to be estimated.

Hamilton et al. (2005a and 2005b) use the HTM to analyze how climate change alters the relative appeal of countries, studying the redistribution of tourist arrivals and departures due to changes in population, per-capita income and climate change. The results show how, in the medium to long term, tourism will grow in absolute terms but this increase will be smaller than population and income changes and not homogeneously distributed, with it being higher for colder countries and lower for warmer ones. Climate change would also imply that the currently dominant group of international tourists - sun and beach lovers from Western Europe - would stay closer to home, implying a relatively small fall in total international tourist numbers and total distance travelled. However, it should be noted how the authors highlight that changes induced by climate change are generally much smaller than those resulting from population and economic growth.

The HTM, as an aggregated model, has been criticized and extended in many ways, although the improvement of the methodology has often implied a loss of generalization. Thereby, Bigano et. al. (2006) extend the HTM by considering substitution between domestic and international tourism, while also analyzing tourist expenditure. However, the consideration of these two issues implies the limitation of the sample of countries to be included in the model due to data restrictions, and only 45 origin-countries travelling to 200 destination-countries are considered. Hamilton & Tol (2007) assess the impact of climate change on tourism from a regional perspective in Germany, the UK and Ireland, based on different scenarios of climate change for the regions under analysis. They suggest that non-uniform warming within countries might lead to tourist behavior patterns that are regionally different, pointing to the need to develop HTM methods on a lower scale than a national one.

Recent updates of the HTM can be found in Rosselló and Santana (2012) and Tol and Walsh

(2012), who use bilateral tourism flows and consider the nature of the data dynamics by testing the change in tourism preferences in reference to climate conditions. Despite the relatively high level of complexity in the specification and estimation, using specific projected climatic, population and economic data related to A2, B1 and B2 scenarios, Rosselló and Santana (2012) forecast tourist arrivals for 2080 finding similar results to previous works, thus providing more evidence that climate change would imply that the currently dominant international tourism flow from North to South would be weaker.

5 CONCLUSIONS

Many tourist destinations around the world are considering what kind of effects climate change would lead to, with the consequences on tourist demands as one of the most recurrent ones. Despite the uncertainties and complexity of evaluating expected tourism demand responses in a context of climate change the literature has just started to answer this question assuming the inability to control the complexity nature of tourism demand decisions by turning to the ceteris paribus clause. In this work, the most relevant methodologies presented in the literature quantitatively evaluating the effect of climate change on tourism and projecting this relationship to the future are summarized in three categories: the consideration of physical changes, the analysis of tourist attractiveness through climatic indexes, and tourism demand modeling based on revealed preferences.

One of the common results that the different methodologies show is that climate change is, on the whole, bad news for warm destinations whatever the methodology used. Then, the search for a more comfortable climate is found to be one of the main motivations determining global tourism flows and, as such, climate change will imply a loss of attractiveness for traditional winter resorts and traditional warmer destinations around the world. However, it seems that climate change, on the one hand, would increase domestic trips, especially in colder countries, and, on the other hand, could be good news for seasonality. This is what the revealed preference methods show us. What is more, this would be an opportunity for the industry to capture the increasing segment of short breaks during non-summer seasons. At any rate, further research in this respect is encouraged. Another agreement that is shown from the different perspectives is the non-linear relationship that apparently exists between tourism and climate. More precisely, an inverted u-shape in the relationship between temperature and tourism demand has been found using different perspectives, thus revealing the existence of optimal climatic conditions for the practice of tourism.

Nevertheless, some questions remain. Will some destinations be too hot? The inverted u-shape can be explained by both the existence of a turning point (destination will be too hot) or by the increase of competitors. What are the most sensitive marked segments to climate change? What will the induced effects of climate change be on biodiversity loss, dry episodes, beach transformations, etc.? Thus, it seems clear that more quantitative studies are needed

Given the aim of this paper, the integration of research findings is limited to studies that report quantitative evidence of the relationship between tourism and climate with the aim of extrapolate the relationship in the context of different climate change scenarios. Other non-empirical studies, however, may be applicable insofar as they provide relevant theories which can contribute to the knowledge of future reaction of tourism to climate change. This study does not attempt to integrate the findings of all the relevant empirical studies. For instance, there is bound to be a number of unpublished studies. Nevertheless, the set of studies examined is reasonably comprehensive and the resulting large set of findings is fairly representative.

The results provided in this article would be a useful guide for other researchers and practitioners interested in carrying out similar studies investigating the effects of climate change on tourism. The selection of the most suitable approach, however, will depend upon the circumstances and objectives of the study being planned. It would be wrong to blindly adopt any one approach without first judging its limitations and assumptions. In this regard, this work provides a convenient reference.

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