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How to evaluate the effects of climate change on tourism

Jaume Rosselló-Nadal*

Departament d'Economia Aplicada (UIB), Campus UIB, Edifici Jovellanos Cra, Valldemossa, Km 7, 07122 Palma Mallorca, Spain

HIGHLIGHTS

- Statistical models evaluating the effect of climate change on tourism are investigated.
- Climate change would lead to a gradual shift of tourists' towards higher latitudes.
- Global warming would increase domestic trips, especially in colder countries.
- Global warming is good news for seasonality.
- Different perspectives show a non-linear relationship between tourism and temperature.

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ABSTRACT

The aim of this study is to assess the most relevant quantitative approaches to evaluating the effects of climate change on tourism. In recent years, numerous empirical studies have conducted evaluations of this kind, based on different methodologies and perspectives. This review shows that the effects of climate change can first be assessed through changes in physical conditions essential to tourism; secondly, by using climate indexes to measure the attractiveness of tourist destinations; and, thirdly, by modelling tourism demand with the inclusion of climate determinants. The review suggests that, although some methodologies are in the early stages of development, different approaches result in a similar map of those areas mainly affected by the problem.

1. Introduction

Climate science shows that, in the 21st century, changes in the Earth's climate will take place at an unprecedented rate (Solomon et al., 2007). The spatial and temporal pattern of tourism demand can be expected to adjust to this, either as a result of the direct effects of climate change, such as rising temperatures, or due to secondary effects, such as rising sea levels, a loss of snow cover or impacts on the landscape. Despite the economic significance of the Travel and Tourism Industry, estimated as accounting for 9.1% of the Gross Domestic Product worldwide (WTTC, 2012), and tourism's apparent overwhelming dependence on climatic factors, literature on the economic implications of climate change has been dominated by other sectors such as agriculture – with a lower weight in economic terms, estimated as representing 6.1% of the Gross Domestic Product (CIA, 2012) –, while tourism has been pushed into the background. This is reflected in successive reports by the *Intergovernmental Panel on Climate Change*, in which tourism only featured more prominently in the last AR4 Report (IPCC, 2007).

The relative extent to which tourism has been overlooked in literature on climate change could be explained by the uncertainty and complexity of expected tourism demand reactions. In a recent study, Gössling, Scott, Hall, Ceron, and Dubois (2012) highlight the complexity of understanding tourist perceptions and reactions to the impacts of climate change as a means of anticipating the decline or increase of specific tourism markets and seasonal shifts in tourism demand. They argue that tourism stands out for its substantial adaptive capacity, which must be combined with other uncertainties concerning the implementation of future mitigation policies and their impacts on transportation systems, together with the wide range of climate change impacts on destinations and broader impacts on society and economic development.

However, the tourism industry today needs to anticipate the consequences of climate change on future demand. Despite controversies regarding the weaknesses of statistical models in predicting tourist flows under scenarios of climate change (Bigano, Hamilton, Maddison & Tol, 2006; Gössling & Hall, 2006), strategic planning is now needed by the tourism industry in terms of new infrastructures and the detection of mid and long-run business opportunities. The results of literature on tourism and climate change should be contextualized, implying that all the determinants of tourism demand – except for climate, whose

* Tel.: +34 971 172459; fax: +34 971 172389.
E-mail address: jrossello@uib.es.

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influence is being analysed – should be held constant. Consequently it must be assumed that a high level of uncertainty will remain, given the difficulties involved in forecasting social phenomena in the medium and long run. For instance, with the winter tourism market segment, although it is almost impossible to provide information on the changing preferences of potential tourists visiting mountain resorts during the next 50 years, it is feasible to evaluate the physical consequences of a loss of snow cover brought about by climate change. An idea of future snow cover can then be forecast by quantifying expected snowfalls, which in turn will implicitly determine the availability of winter tourism conditions.

Similarly, optimal tourism conditions can also be evaluated by assuming that some tourism activities require a certain level of favourable climate conditions. For instance, visits to nature reserves, cycling, golf tourism, beach tourism, nautical tourism or city tourism can require certain weather conditions. In this case, an assessment is needed of what tourists perceive to be optimal conditions, and a subsequent evaluation of future climate conditions will then determine a destination's diminished or improved attractiveness for tourists. Evidently, changes in climatic preferences are hard to anticipate and only optimal climate conditions can be projected.

Although the inclusion of climatic determinants in modelling exercises in the field of tourism demand has traditionally been disregarded, since the turn of the century the incorporation of climatic variables (such as temperature, precipitation and wind) in tourism demand models has become more common (Goh, 2012). The effect of climate on tourism demand is taken as a short-run determinant in the context of time series and as a push and pull structural determinant when both discrete choice models and aggregate tourism models are considered. Since estimation techniques usually entail the isolation of each of the determinants, it is possible to evaluate the marginal contribution of climatic factors to tourism demand while the rest of the variables are held constant.

As a result, over the last fifteen years numerous quantitative studies have attempted to evaluate the consequences of climate change on tourism. So far, however, no attempt has been made to compile these findings to any great extent in order to try and identify a regular pattern as means of building up knowledge and establishing certain general principles. Due to the recent emergence of multiple quantitative methodologies for assessing the consequences of climate change on tourism, this paper aims to evaluate these different alternatives, demonstrating that despite the different approaches used to tackle the problem, the results show a significant consistency. What is more, because a pioneering joint analysis is made of the different alternatives, it is possible to highlight some of the main advantages and limitations of each one.

2. Evaluations through physical changes

A change in the depth of snow cover is the most direct consequence of climate change, and winter tourism is heavily dependent on the reliability of snow cover at mountain resorts. As a result, the financial viability of winter tourism depends on favourable snow conditions. However, reliable snow cover will rise to higher altitudes over the coming years if climate change occurs (Elsasser & Bürki, 2002). Adaptational strategies play an important role in the winter tourism segment (e.g. artificial snow production), and anticipating the consequences of climate change on the depth of snow cover has become a key factor in management and strategic decision-making. Breiling and Charamza (1999) analysed the impact of a 2 °C temperature change on seasonal snow cover depth for all areas of Austria, finding that it leads to a reduction in the length of the ski season and usability of ski facilities. Warming will have a strong impact on low altitude resorts, which are expected to disappear first by the authors, while the remaining resorts will become more expensive due to the reduced supply. Further studies have been made of winter sports tourism in Scotland (Harrison, Winterbottom, & Shephard, 1999), Switzerland (Elsasser & Messerli, 2001), Canada (Scott, McBoyle, Minogue, & Mills, 2006), the Alps (Rixen et al., 2011; Soboll & Dingeldey, 2012) and Australia (Pickering, 2011).

Methodologically, all these studies seek to estimate the amount of precipitation that falls as snow and rain, snow accumulation, and snowmelt. Historical precipitation data can be analysed for each mountain resort in order to determine the temperatures that best predict historical snowfall amounts. Then, by using projected temperature and precipitation data for different climate change scenarios (or by assuming the existence of a certain trend in temperatures and precipitation), it is possible to estimate the amount of snow precipitation that determines snow accumulation. Breiling and Charamza (1999), Harrison et al. (1999) Elsasser and Messerli (2001), Scott et al. (2006), Rixen et al. (2011) and Soboll and Dingeldey (2012) 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 is important to note that the use of snowmaking machines should be taken into consideration in the final evaluation, even though this partial solution is also temperature dependent.

Despite winter tourism's special interest appeal, the importance of sun and sand tourism cannot be ignored because it is also affected by climate change. Just as winter tourism depends on snow, summer tourism at some destinations relies on other physical conditions that are required for tourism activities. Although the development of models for this broad area (sun and sand tourism) is in the initial stage, the rise in sea level and its consequences on beach coverage (Nicholls et al., 2011), coral reef health (Hoegh-Guldberg et al., 2007), the proliferation of jellyfish (Purcell, 2012) and algal blooms (Englebert, McDermott, & Kleinheinz, 2008) should be on the agenda of future quantification of the effects of climate change on tourism. These quantified assessments could be considered at both a global and regional level. It should be possible to characterize the extension of beaches, coral reef coverage, jellyfish and other tourism-related environmental attributes sensitive to climate change at a global level. If all these characteristics are projected in the context of climate change, then the link with tourism can be established. On the other hand, at a local level, if a particular region is popular because of its natural environment, the role of each of the natural characteristics in attracting tourism can be estimated. Consequently, future tourism demand can be projected once the environmental attributes altered by climate change have been pinpointed.

In this context, it is important to note that although some exploratory studies have demonstrated the relative irrelevance of tourism opinions when faced with a marginal loss of environmental quality (Gössling, Bredberg, Randow, Sandström, & Svensson, 2006), a certain threshold level – defined sometimes by visibility, the abundance and variety of different species, the occurrence of algae or the physical disappearance of beaches – seems to exist (Gössling, Lindén, Helmersson, Liljenberg, & Quarm, 2007), showing that tourists might respond to climate changes in a non-linear way. Although a slight change in environmental quality cannot be detected through simple techniques, it is suggested that ecosystem responses to pressures are characterized by discontinuities and threshold effects, hindering accurate estimations of the consequences on tourism.

3. Climate indexes

A climate index is a set of climate variables combined through a mathematical formula to capture human comfort preferences. The potential changes in human comfort levels suggested by a combination of a climate index and scenarios of climate change could have profound implications for the tourism industry. Mieczkowski (1985) was among the first to apply the results of climate indexes for tourism-related activities by developing a tourism climate index (TCI). Initially, Mieczkowski (1985) identified 12 climate variables from relevant literature to be included in the TCI. However, due to meteorological data constraints, the number of climate variables included in the TCI was reduced to seven, combined in five sub-indexes to form the most popular TCI. A standardized rating system, ranging from 5 (optional) to −1 (extremely unfavourable), was devised to provide a common measurement procedure for each of the sub-indexes. Analytically, the TCI can be derived from the following equation:

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

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 (1985) 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 for the five sub-indexes, 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, Hulme, & Downing, 1994), European beaches (Moreno & Amelung, 2009), Mediterranean countries (Amelung & Viner, 2006), North America (Scott, McBoyle, & Schwartzentruber, 2004) and even on a worldwide scale (Amelung, Nicholls, & Viner, 2007). It should be noted that maps depicting the TCI show a strong correlation with currently popular destinations, suggesting that the index performs quite well as a predictor of tourist arrivals.

The weights used in Equation (1) give the highest weight to the daytime comfort index, reflecting the fact that tourists are generally most active during the day. The amount of sunshine and amount of precipitation are given the second highest weights, followed by daily thermal comfort and wind speed. Although these weights are ultimately subjective because they are founded on expert judgements, more recent versions of the TCI have been based on declared tourist preferences, gathered through questionnaires. Morgan et al. (2000) collected the preferences of 1354 beach users on holiday at different destinations, thus adapting the index to different tourist market segments through the use of different weights.

One of the main goals of climate indexes is to seek simplicity in analyses of seasonal patterns. Because the TCI's sub-indexes are based on monthly data, the implications of projected climate change on the seasonality of tourism can be revealed. In this way, Amelung et al. (2007) show that countries in northern Europe may experience substantial improvements in summer climate conditions while northern Mediterranean countries that currently attract traditional "sun and sand" summer holidaymakers are likely to become too hot for comfort in the current summer season, contrasting with improved climate conditions during the non-summer period. Thus, while northern countries are expected to become more attractive to tourists with 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 in attractiveness during the rest of the year.

However, it should be pointed out that sometimes perceptions of climate differ from objective climate measurements, with the former being a determinant of human behaviour. Within this framework, the Physiologically Equivalent Temperature index recently emerged as an alternative to the TCI, which was originally developed to assess human comfort in general (Matzarakis, Mayer, & Iziomon, 1999). It has also been applied to tourism comfort by Lin and Matzarakis (2011), who create PET seasonal distribution maps, showing that Taiwan and Eastern China are perceived to be 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 regarded as being comfortable for those residing in sub-tropical regions.

Overall, the main advantages of climate indexes are that they provide an easy, quick, objective view of the relationship between climate conditions and tourism attractiveness that can be applied both locally and globally. Additionally, they can be adapted to different market segments with specific climatic preferences. The main drawback of TCIs, nonetheless, is the inability to provide a quantitative measure of the impact on tourism in economic terms or from the perspective of tourism arrivals. This explains why Amelung and Moreno (2012), Goh (2012) and Eugenio-Martín and Campos-Soria (2010) recently included the TCI as an independent variable in a tourism demand model. However, this perspective, also based on revealed preferences, brings us to the following section.

4. Tourism demand models

The absence of literature on climate change to take into account the tourism sector has been associated with the omission of climate variables in tourism demand models since the turn of the century (Goh, 2012). In the review by Crouch (1994), only a limited number of papers were found to have included climate or weather variables as determinants and, on many occasions, with limited success (Barry & O'Hagan, 1972). A feasible explanation for this omission could be researchers and planners' interest in income elasticities and/or price elasticities as a means of achieving accurate tourism demand forecasts – a key issue for service industries with relatively high fixed costs – or, alternatively, as a means of evaluating 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 & Li, 2008). Thus, as climate is a relatively stable variable, the climate factor does not have the required variability and it is not correlated with the determining variable, so no bias in estimating elasticities is expected.

However, with increasing interest in climate issues and, more precisely, in evaluating the consequences of climate change on tourism, some literature on tourism demand modelling has integrated climate and weather factors into the estimation of tourism demand. Hence, consumers are assumed to reveal their climate preferences through their purchasing habits. Once their climate preferences are known and, assuming that the remaining variables are held constant, it is possible to project future trends through projected climate conditions. Note that, with this approach, the analysis focuses on the tourists rather than the physical conditions. Within the framework of tourism demand modelling, three main perspectives have been adopted: time series analysis, discrete choice models, and aggregate tourism models.

4.1. Time series analysis

Within the context of time series analysis, it is preferable to talk about weather (short-term atmospheric conditions) rather than climate (a region's mean atmospheric conditions) because, with time series, the most popular approach 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 the tourism impacts of the unusually hot summer of 1995 and the warm period from November 1994 through to October 1995 in the UK, showing that the tourism sector displayed clear differences in its response to hot summer and warm winter anomalies. Agnew and Palutikof (2006) explore the sensitivity of UK tourism to weather conditions using monthly data for domestic tourism and annual data for trips abroad, showing that outbound tourist flows are responsive to the previous year's weather variability, whereas domestic tourism is responsive to variability within the year of the trip. Using the unusually warm year of 1995 in the UK, the potential impact of climate change is evaluated, suggesting that the generally warmer drier conditions of 1995 benefited the UK domestic tourist industry although the previous year's wetter and cloudier-than-average conditions seemed to encourage more trips abroad.

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

$$\phi_p(L)Y_t = \theta_p(L)a_t + \varphi_b(L)d_t \tag{2}$$

where Y_t is the number of tourism flows per month t; a_t is the innovation or moving average term; d_t is the weather variable (or set of weather variables) that could influence the number of tourism flows; $\varphi_p(L)$ and$\varphi_p(L)$ 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 modelling; and $\theta_p(L)$ is the lag operator polynomial (or transfer function) for the variables determining the weather, thus assuming that some lag between the observation of the weather variables and tourist flow data occurs.

By estimating Equation (2), intra-sample values can be predicted and compared with simulated predictions of the d_t variables under different scenarios of climate change. For instance, using the transfer function methodology, Rosselló et al. (2011) 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 of average temperature warming, they found that a 1 °C rise in the UK's average temperature will lead to a 1.73% annual decrease in British outbound flows, a percentage that is not uniform throughout the year, given the expected stronger impact during the wintertime (2.1% in December versus 1.33% in May). Again, this result suggests the presence of non-linear relationships between temperature and tourist flows.

Recent literature has been dominated by the use of more complex structures. Kulendran and Dwyer (2012) use the Autoregressive Conditional Heteroskedasticity modelling approach to identify the relationship between climate variables such as maximum temperatures, relative humidity, sunshine hours and seasonal variations, defined as the repetitive and predictable movement around the trend line in holiday tourism demand within the context of seasonal variations in holiday tourism demand to Australia. Otero-Giráldez, Álvarez-Díaz, and González-Gómez (2012) also found there to be a significant positive connection between the North Atlantic Oscillation – as a meteorological indicator – and tourism demand in Galicia (Spain) using an Autoregressive Distributed Lag Model. Goh (2012) built an Error Correction Model for tourism demand which also explores the presence of structural changes in estimations using the TCI as a determining variable, showing that the climate index has a significant positive relationship for all the tourism demand series under analysis.

To summarize, analyses of the relationship between climate (or weather) and tourism, using time series models, have demonstrated a current, real relationship between tourism and climatology. Like the TCI, one of the main purposes of using time series is to analyse seasonality. However, it should be noted that, within this framework, only short-term relationships can be captured, despite long-term climate change issues.

4.2. Discrete choice modelling

Within the framework of revealed preferences, a second approach is to use Discrete Choice Models. In this context, the relevant question is why people choose a particular destination, and the theoretical background can be found in Lancaster (1966), where the proposed source of utility are the characteristics of commodities and services and not commodities or services in themselves. Tourism choices are considered to be a process of both quantitative and qualitative consumption. The quantitative unit of tourism consumption can be represented by the number of days' stay, the number of visits etc. The qualitative unit of tourism consumption is represented by the bundle of characteristics provided by destinations. Different destinations provide different bundles of characteristics in the form of heterogeneous tourism goods. Attractions are characteristics whose amount will depend on the destination's climate, natural and historical attributes, and on other features. 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 for the consideration of different perspectives of tourism decisions, together with a larger set of explanatory variables. Analytically, the utility U_{ni} that a tourist n derives from choosing to visit destination i is assumed to take the following form:

$$U_{ni} = \beta'_n x_{ni} + \varepsilon_{ni} \tag{3}$$

where $\beta'_n x_{ni}$ is the deterministic portion of the received utility if destination i is visited. Therefore x_{ni} are the observed attributes that characterize the alternatives open to tourists and β_n is the vector of estimated coefficients for tourist n, representing his/her tastes. Lastly, the error term ε_{ni} captures the variation in preferences among the population of tourists. As individuals are assumed to visit the destination yielding the greatest utility, the probability π_{ni} of them choosing the *i-th* alternative is:

$$\pi_{ni} = \Pr\left(\beta'_n x_{ni} + \varepsilon_{ni} > \beta'_n x_{nj} + \varepsilon_{nj}\right) \ \forall j \neq i \tag{4}$$

Thus individuals or households with exactly the same socio-economic 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-Martín, 2003).

This framework for modelling tourism demand from a microeconomic perspective has become of interest to different tourism stakeholders, such as tourism marketing analysts, because of its high potential for identifying the determinants of destination choice decisions. It is important to note 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).

Within the context of climate change and tourism, using a Discrete Choice Model for European households, Eugenio-Martín and Campos-Soria (2010) focus their analysis on the relationship between climate in the home area and the choice of taking a holiday in the tourist's home region or abroad, showing that the climate in the home region is a strong determinant of holiday destination choices. They show that residents in regions with better climate indexes have a higher probability of domestic travel and a lower probability of travelling abroad, while residents of colder regions tend to travel abroad more often than residents of warmer ones.

By estimating the β_n vector in Equation (4), they project how individuals' choices change when climatic input for Europe changes, evaluating the probability of foreign and/or domestic travel. Thus, under a scenario of climate change, a relatively weak relationship is found when an evaluation of both foreign and domestic travel is considered. However, it seems that a rise in temperature increases the likelihood of domestic travel and lowers the likelihood of foreign travel, a result that was also obtained with time series.

Using the same methodology, Bujosa and Rosselló (2013) investigate the impact of climate change on destination choice decisions within a context of domestic summer coastal tourism in Spain. Once the destinations have been characterized in terms of the travel cost and coastal 'attractors' (temperature and beach-related attributes), the observed pattern of interprovincial domestic trips is modelled, showing trade-offs between temperature and attractiveness in the likelihood of a particular destination being chosen. Using A1FI and B1 climate change scenarios (IPCC, 2000), they show that 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 emphasize the use of a squared term for temperature, thus providing an estimation of maximum or minimum comfort temperatures, and to highlight the non-linear relationship between tourism and climate.

The use of discrete choice models to evaluate the effects of climate change on tourism is a recent phenomenon and assumptions about the utility function should be more deeply investigated. For example, when the sum of individual utilities is used, tourists are assumed to be risk neutral, a hypothesis that can sometimes be hard to justify within the framework of tourism choices.

4.3. Aggregate tourism demand models

Aggregate tourism demand modelling continues to be a popular issue in tourism literature. Reviews by Lim (1999), Li, Song, and Witt (2005) and Song and Li (2008) show that tourism demand estimations mainly focus on time series models, thus including variables with significant short-term variability, such as prices and income, while neglecting structural determinants, such as climate, which are expected to be captured by the constant term.

However, with the growing interest in climate issues, a set of aggregate tourism demand models have emerged that focus on climate variables. Madison's pioneering study (2001) presents a cross-sectional model of destinations chosen by British tourists, using classic price determinants of tourism demand and incorporating climate variables in terms of attractors. The model's estimation allows the trade-off between climate and holiday expenditure to be quantified and, through the introduction of non-linear effects (through a 4th order polynomial), the 'optimal' climate for generating British tourism is identified. The findings are used to predict the impact of several climate change scenarios on different tourist destinations. In a similar way, using aggregate data and a regression analysis, Lise and Tol (2002) find optimal temperatures at travel destinations for different tourists and tourist activities, showing that OECD tourists prefer an average temperature for the hottest month of the year of 21 °C, indicating that, in a scenario of gradual warming, tourists will spend their holidays in different places than their current ones. Taking a global perspective, Hamilton, Maddison, and Tol (2005a, 2005b) present 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:

$$\ln A_d = \alpha_0 + \alpha_1 G_d + \alpha_2 T_d + \alpha_3 T_d^2 + \alpha_4 C_d + \alpha_5 \ln Y_d \tag{5}$$

$$\ln \frac{D_{OR}}{P_{OR}} = \beta_0 + \beta_1 T_{OR} + \beta_2 T_{OR}^2 + \beta_3 B_{OR} + \beta_4 Y_{OR} + \beta_5 \ln G_{OR} \tag{6}$$

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

Hamilton et al. (2005a, 2005b) use the HTM to analyse 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 that in the medium to long term tourism will grow in absolute terms although this increase will be smaller than population and income changes and it will not be homogeneously distributed, with a higher growth for colder countries and lower one for warmer ones. With climate change, the currently predominant group of international tourists – sun and sand lovers from Western Europe – would also stay closer to home, implying a relatively small drop in total international tourist numbers and the total distance travelled. However, the authors stress that changes induced by climate change are generally much smaller than those resulting from population and economic growth.

As an aggregate model, the HTM has been criticized and extended in many ways, although the methodology's improvement has often implied a loss of generalization. Bigano, Hamilton, & Tol (2006) extend the HTM by considering substitution between domestic and international tourism, while also analysing tourist expenditure. Nonetheless, taking into account these two issues implies limiting the sample countries included in the model due to data restrictions, and only 45 countries of origin travelling to 200 destination countries are considered. Hamilton and 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 behaviour 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's dynamics by testing changes in tourism preferences linked to climate conditions. Despite the relatively high level of complexity of the specification and estimation process, 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 and thus providing more evidence that climate change would imply a weakening of the currently predominant international tourism flow from North to South.

5. Conclusions

Many tourist destinations around the world are contemplating how they would be affected by climate change, with studies of tourism demand being one of the main focuses of attention. Despite the uncertainties and complexity of evaluating expected tourism demand responses as a result of climate change, research into this issue has just started to appear the scientific literature, recognising the complex nature of tourism demand decisions by isolating the effect of climate on tourism. This paper summarizes some of the methodologies used in tourism literature that seek to quantitatively evaluate the effect of climate change on tourism and to extrapolate this relationship into the future. The methodologies are grouped into three categories: studies based on a consideration of physical changes, the use of climate indexes to analyse tourism attractiveness, and tourism demand modelling based on revealed preferences.

Correlations can be made between current tourism demand patterns and both physical attributes and climate indexes, suggesting that climate performs well as a predictor of tourist arrivals. Nonetheless, in tourism demand models, the inclusion of temperature alone as a determining climatic variable has tended to prevail. Although many papers that use demand models have tried to include other variables as well as temperature, the results have shown that, due to a problem of multicollinearity (a correlation between temperature and other climatic variables) or the irrelevance of certain other climatic variables, temperature has been the most decisive influential climatic variable. Most recent studies have also tried to incorporate climate indexes into tourism demand models.

One of the common results of the different methodologies is that climate change is a negative outcome for warm destinations whatever the methodology that is used. 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 worldwide. Conversely, it seems that climate change will, increase domestic trips, especially in colder countries, and it could exert a positive influence on seasonality by increasing the attraction of certain destinations during winter months. This is what revealed preference methods show. What is more, this would be an opportunity for the industry to attract the growing short-break segment during non-summer months by taking advantage of better winter climate conditions. Whatever the case, further research is required. Another finding common to the different approaches is the non-linear relationship that apparently exists between tourism and climate. More precisely, an inverted u-shape has been found in the relationship between temperature and tourism demand using different methodological perspectives, thus revealing the existence of optimal climatic conditions for tourism.

Nevertheless, some questions remain. Will some destinations be too hot for visitors? The inverted u-shape can be explained by both the existence of a turning point (the destination will be too hot), an issue that is supported by tourism climate indexes, and simply by an increase in competitors, a result mainly supported by tourism demand models. Which tourist segments will be most sensitive to climate change? What will the induced effects of climate change be on biodiversity loss, dry episodes and changes to beaches ?

Given the aim of this paper, the research findings were limited to studies that report quantitative evidence of the relationship between tourism and climate in order to extrapolate this relationship to different climate change scenarios. Other non-empirical studies, however, may be applicable insofar as they provide relevant theories that can contribute to a broader knowledge of future tourism responses to climate change. This paper does not attempt to gather the findings of all relevant empirical studies, given certain constraints, such as the possible existence of a number of unpublished studies. Nevertheless, a reasonably comprehensive series of studies was analysed and the resulting extensive set of findings is fairly representative.

The results of this paper could be a useful guide for other researchers and practitioners interested in carrying out similar studies of how to assess the effects of climate change on tourism. The most suitable approach, however, will depend on the circumstances and objectives of the said study. It would be wrong to blindly adopt any one approach without first assessing its limitations and assumptions and, in this sense, this paper could serve as a good reference tool.

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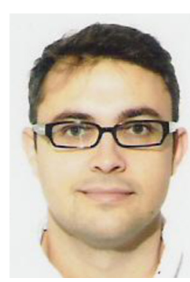

Jaume Rosselló is Associate Professor in the Department of Applied Economics at the Universitat de les Illes Balears (Spain) where he teaches Microeconomics, Tourism Economics and Tourism Demand Modeling. Because of their interest in tourism modeling he has taken part in different competitive research projects financed mainly by public administrations. Main results of his work have been published in academic Journals like Annals of Tourism Research, Tourism Management, Tourism Economics, Journal of Sustainable Tourism and Journal of Travel Research. He is currently Director of the Master in Tourism and Environmental Economics at the University of the Balearic Islands.