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Recent trends in international tourist climate preferences: a revised picture for climatic change scenarios

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Abstract This paper investigates how the role of climate in tourist destination choice has changed over the last 15 years. To this end, a demand model for international tourism is estimated, including the main classic determinants but allowing a time-varying climatic sensitivity of tourists. Moreover, a complete database considering international tourism movement between 178 countries for the period 1995 to 2010 is used. Results show how turning point temperatures in origin and destination countries have changed over the period of analysis, evidencing a loss of competitiveness for traditional warm destinations. Additionally, using data for the projected growth of Gross Domestic Product per capita and climatic conditions within A2, B1 and B2 scenarios, an updated vision of their expected impact on international tourism flows is assessed, evaluating how climate change would imply a greater loss of attractiveness for traditional warm destinations around the world but would increase attractiveness for high latitude countries.

1 Introduction

International mass tourism began during the fifties, fuelled mainly by the economic development and progress of civil aviation after the Second World War Since then, according to the United Nations World Tourism Organization the number of international tourists has grown from 25 million international arrivals in 1950 to a record 1 billion in 2012, corresponding to an average annual growth rate of 6.1 %. The relevance of climate in tourist destination choice is observed through both the typical seasonality pattern in the most popular destinations and especially the latitude of the most popular tourist destinations around the world. However, considering that tourism represents 9.1 % of the total world Gross Domestic Product (WTTC 2012), the relatively little attention this sector has attracted within climate change literature is surprising, when compared with other activities of far less economic importance like, for instance, agriculture - estimated at 6 % of the World GDP (CIA 2012).

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Whatever the reason, whether through the direct effects of climate change - such as temperature and precipitation - or through secondary effects - such as vegetation, stream flows, reservoir levels, wildlife populations and miles of beaches - it can be expected that the spatial and temporal pattern of outdoor recreation activities will adjust. Despite the uncertainties related to projecting social phenomena in the long run, different pioneering quantitative studies have analyzed the economic effect climate change may have on the recreational use of outdoor environments. In this sense, it is possible to distinguish between microeconomic decision-making and general equilibrium (Shaw and Loomis 2008). For the specific case of tourism flows, two main approaches have dominated the literature.

The first one focuses on measuring the tourist attractiveness of a destination country from a physical point of view. A clear example of this first approach is represented by studies related to winter-tourism and snow cover (Scott et al. 2003, 2007), although it can also be applied to beach tourism (Moreno and Amelung 2009) or to the general physical conditions for tourism (Amelung et al. 2007). Within this perspective, and mainly for beach or general tourism, individual preferences are collected using satisfaction surveys and computing tourism-climatic indexes. Then, future climatic conditions are projected showing the loss or gain of tourism competitiveness in terms of climatic conditions. This approach allows a greater set of climate variables to be considered and to show differences between seasons. However, through this first approach it is not possible to estimate the effect of climate change on tourism demand, which remains subjective.

The second approach is characterized by the definition of statistical models of tourist behavior as a function of climate attributes. Within this perspective, Maddison (2001) and Lise and Tol (2002) estimate the relationship between the destination country's climate and the distribution of tourist flows from a particular origin, finding that tourists prefer a temperature of between 21 and 31 °C. Once the effects of climate on the distribution of international tourism movements have been estimated, a projected distribution under different climate scenarios can be obtained. This perspective is generalized in Hamilton et al. (2005a, b) and Hamilton and Tol (2007), where international tourism arrivals/departures to/from all the countries around the world for a particular year are evaluated through a demand model including economic wealth, population and climate attributes for both origins and destinations. This global model makes it possible to evaluate the consequences of population and economic growth and rise in temperatures on the distribution of international tourists worldwide. By doing this, it can be shown how climate change would alter the international tourist flows at a global level, for the first time.

Although the results of these models are currently used as a reference for tourist projections under the climatic change context, the presence of different drawbacks related, among other issues, to the poor quality of tourist databases, uncertainty in projecting other non-climate explanatory variables or the impossibility of knowing how climate preferences of tourists will change is acknowledged.[1] Thus, the inexistence of a homogeneous database related to domestic tourism prevents the analysis of substitutability between domestic and international tourism. This issue has been undertaken using a more restrictive dataset (Bigano et al. 2006b) or through the use of microdata (Bujosa and Rosselló 2013; Eugenio-Martin and Campos-Soria 2010), but with these methods a global view cannot be achieved.

Tol and Walsh (2012) extend previous works by introducing a wider array of countries along with a time dimension. By doing this, these authors show how bilateral determinants (i.e.

[1] See Gössling and Hall (2006) and the reply by Bigano et al. (2006a) for a more detailed discussion. Furthermore, Scott et al. (2012) present a more detailed discussion regarding the suitability of aggregated models for the evaluation of climate change impacts on tourism demand.

distance) are key factors in determining international tourism flows and how the parameters related to temperature reveal distinctive results for different years. Although their results should only have confirmed what other studies had previously found about tourism preferences on climate conditions, they opened the door to the introduction of a new methodology for modeling international tourism flows which considers both the bilateral nature of international tourism flows and the dynamic nature of data.

In the present study, we use a large database of international tourism flows considering 178 origin-destination countries around the world for the period 1995–2010 and a set of determining variables for bilateral tourism flows such as geographical distance, economic size, historical and cultural relationships and other geographical attributes of the country which have previously been found to be relevant in tourism literature. Although the limitation of not introducing domestic tourist data is not overcome because of data availability, by considering the dynamic nature of the data changes in climate, preferences of tourists can be tested for the first time. Moreover, international tourism flows worldwide are simulated within A2, B1 and B2 scenarios, including climatic, population and economic projected data, thus an update of the effects of climate change on international tourism flows on a worldwide scale is provided.

2 Determinants of international tourism flows

Although the theoretical background of aggregated tourism models arises from the individual utility theory (Morley 1992), the most popular approach has been the construction of regression models exploring the correlation between tourism flows (origin-destination) and a set of determinants, mainly income and prices. At this point it is important to highlight how, although climate is considered a key factor in determining tourism, climate variables have not usually been considered in tourism demand models since the turn of the century (Goh 2012). This apparent contradiction can be justified through the interest of researchers and planners in the relationship between income and/or price and tourism, in order to forecast tourism demand in an accurate way - a key issue for service industries management - or, alternatively, in order to assess the consequences of taxes or exchange rate policies. This would explain 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 for a short-time model and, additionally, is not correlated with the income and price determining variable, so no bias in estimated relationships is expected.

Whatever the reason, the general theoretical background in determining aggregated tourism flows can be expressed as:

$$N_{IJt} = f(p_{IJt}, M_{It}, ZO_{It}, ZD_{Jt}) \tag{1}$$

Where N_{IJt} are the number of visits from origin country I to destination country J at period t; p_{IJt} is a price variable representing the cost of travelling from I to J; M_{It} is a variable representing the personal income of a resident in the country of origin; and ZO_{It} and ZD_{Jt} are vectors of site qualities related to the origin and destination, respectively. Although no consensus is found in the literature as to the suitable mathematical function f, the multiplicative assumption between number of trips, price (or cost of transport), and income have been the most widely used. Reasoning for the use of the multiplicative function (which implies the consideration of the natural logarithms of the original variables) is often found (i) in the practical argument that it is the best in describing data or (ii) in a way of reducing heteroscedasticity and/or (iii) in the theoretical assumption of constant elasticities between the variables. Thus, if the multiplicative function is assumed between the number of trips, cost, price and income, Eq. (1) can be written as:

$$N_{IJt} = (p_{It})^{\beta_a}(M_{It})^{\beta_c} f^{+}(ZO_{It}ZD_{Jt}) \tag{2}$$

Where β_a, β_b and β_c are parameters to be estimated and f^+ is the function of the rest of the variables which, again, is often assumed to be additive or multiplicative. At this point it is important to note how, Eq. 2 can be interpreted as a tourism demand equation and a gravity equation (see supplementary material S1 for a discussion). Then, when bilateral flows are analyzed and distance is used as determining variable literature refers frequently to this model as 'gravity equation' and has had a long tradition in the analysis of international trade (Anderson 1979; Kimura and Lee 2006; Bergstrand and Egger 2007; Head and Ries 2008). The gravity model is used extensively in empirical exercises due to its goodness of fit, since international flows of goods, migrations or foreign direct investment are expected to increase with the economic size of countries (national income) and decrease as the distance between them increases (cost of transport).

Since tourism is a special type of trade in services, and because of the interest in analyzing structural determinants of tourism flows, the terminology of gravity equation has been recovered recently in the context of analyzing tourism flows. In this line (Gil-Pareja et al. 2006, 2007) uses a gravity equation to analyze the effect embassies and exchange rates in international tourism flows in different European Union countries. Fourie and Santana (2011) investigated the impact of mega-events on international tourism flows. Vietze (2012) analyzed the role of religion affiliation on tourism trips to USA. Then, the main advantage of using bilateral flows and introducing distance as explanatory variable (so using a gravity equation) is found in the possibility to avoid bias in the estimations of parameters of determining variables in the event of a potential relationship between distance and the rest of determining variables. Thus, in the context of climate change and tourism, if distant destinations are also the ones that are characterized by a different climate, an error in the estimation of climate effects arises and, consequently, projections of the distribution of tourists under different climatic change scenarios could be biased. Until now studies using the gravity equation in modeling international tourism flows have not included climatic variables in determining international tourism flows, despite the intuitive relationship between tourism and climate.

3 The world tourism model

Estimation of Eq. 2 requires the compilation of a database including information on international tourism flows and all their potential determinants. In our case, this collection has been carried out by considering the aim of the study with reference to projecting international tourism flows for different climatic change scenarios. According to the United Nations World Tourism Organization, a visitor is "any person travelling to a place other than that of his/her usual environment for less than 12 consecutive months and whose main purpose of the trip is other than the exercise of an activity remunerated from within the place visited". Additionally, a tourist is "a visitor who stays at least one night in a collective or private accommodation in the place visited" (UN-WTO 1995). Thus, tourism data for each country is taken from the United Nations World Tourism Organization, specifically from the Tourism Factbook Database (UN-WTO 2012), including 178 countries as origin/destination for the period 1995–2010. Thus, it is possible for the first time to analyze bilateral flows (not only aggregated data for destination or origin countries) and investigate recent trends in this data.

Cost of travelling is considered through four different variables: the great-circle distance between capital cities of countries ($Dist_{IJ}$); cultural affinity expressed in terms of sharing a common language ($Language_{IJ}$) and having or having had a colonial relationship ($Colony_{IJ}$); and sharing a common border ($Border_{IJ}$). It should be noted how these last three variables are binary variables which are: unity if they share a common language and zero otherwise; unity if one country ever colonized the other and zero otherwise; and unity if they share a common land border and zero otherwise. Personal income of the residents in the country of origin is captured through the inclusion of the Gross Domestic Product per capita in the origin country converted to real terms by using the US GDP deflator ($GDPpc_{It}$).

The vector of site qualities referred to the origin country (ZO_{It}) includes surface area (in square kilometers) of the country ($Area_I$), length of its coastline in kilometers ($Coast_I$) and a set of climatic variables that includes annual mean temperature ($Temp_I$) and precipitation ($Prec_I$).[2] As previous literature has found, a non-linear relationship between tourism flows and temperature is expected (Maddison 2001; Lise and Tol 2002; Hamilton et al. 2005a, b; Hamilton and Tol 2007), so squared temperatures are also included in the model. Therefore, it is assumed that the historical climatic conditions remain constant over the sample period, while it is hypothesized that tourist sensitivity could change. The vector of site qualities referred to the destination (ZD_{Jt}) includes the same spatial and climatic variables as the ones included for the origin plus the Gross Domestic Product per capita in the destination country ($GDPpc_{Jt}$) as a way to capture the development of the society and the tourism industry in the destination.

GDPpc and land area were obtained from the *World Development Indicators*. In the event of missing data, these were completed with data from the *UNCTAD Handbook of Statistics*. The distance variable, common language, common border and colonial ties were collected from the *Centre d'Etudes Prospectives et d'Informations Internationales* (CEPII 2012) dataset, while country coastline was taken from the CIA World Factbook (CIA 2012). Data for the climate variables, which are temperature, precipitation and cloud cover, were collected from the Tyndall Centre for Climate Change Research (TYN CY 1.1) dataset.[3] These variables take the mean average of the weather in the recent past (1961–1990), thus they remain constant throughout the sample period since the objective of the analysis is to study the effect of expected climate on tourist destination choice.

Thus, the initial model to be estimated can be written as:

$$\begin{aligned} Ln\,N_{IJt} = {} & \beta_0 + \beta_1 LnDist_{IJ} + \beta_2 LnGDPpc_{It} + \beta_3 LnGDPpc_{Jt} + \beta_4 Colony_{IJ} + \\ & + \beta_5 Language_{IJ} + \beta_6 Border_{IJ} + \beta_7 Area_I + \beta_8 Area_J + \beta_9 Coast_I + \beta_{10} Coast_J + \beta_{11} Temp_I + \\ & + \beta_{12} Temp^2{}_I + + \beta_{13} Prec_I + \beta_{14} Temp_J + \beta_{15} Temp^2{}_J + \beta_{16} Prec_J + \gamma_I + \delta_J + \lambda_t + u_{IJt} \end{aligned} \tag{3}$$

Where *Ln* denotes natural logs; sub-index *I* and *J* refer to the origin and destination country, respectively; $\beta_1,\ldots,\beta_{16}$ are parameters to be estimated; γ_I, δ_J and λ are origin, destination, and year fixed effects, respectively and u_{IJt} is a well-behaved disturbance term. It should be noted how the multiplicative function (and the use of natural logarithms) has been considered in the case of the dependent variable (*N*), distance between capital cities of countries (*Dist*) and the Gross Domestic Product per capita (*GDPpc*). For the *Area*, *Coast*, *Temp* and *Prec* variables the linear form produced the best results (although they were very similar to the multiplicative assumption). Finally for *Language*, *Colony* and *Border*, the linear form was directly applied because of the binary nature of these variables.

[2] Cloud coverage was initially considered, but it turned out to be non-significant when temperature and precipitation were considered, so it was dropped from the final model

[3] http://www.cru.uea.ac.uk/~timm/cty/scen/TYN_CY_3_0_var-table.htm(accessed 20 October 2012)

Classic fixed effects panel estimation cannot be applied since climate variables remain time-invariant and would be dropped from the estimate. Hence, the model is estimated by Ordinary Least Squares but introducing individual destination and origin country fixed-effects, as a way of controlling unobserved heterogeneity (Kandogan 2008; Anderson and van Wincoop 2003). Moreover, year fixed effects are added to include time in the model and to control for year-specific events.

Panel data estimation implies to use bilateral tourism flows (from an origin country to a destination one) during different years. Thus, a three dimension panel is considered allowing some parameters to change along time. For instance, *GDP* per capita varies across the sample period while other variables like distance or temperatures remains constant but not their effect on tourist arrivals. In particular, the key point for the aim of this study is measuring if the tourists' sensitivity to climate change varies over the sample period of the analysis. To that end, the methodology proposed by Brun et al (2005) is used by including a linear time trend t (which takes values from 1 to 16 for each year in the sample) and a squared time trend t^2, in order to test and establish the existence of a turning point. Then, interactions between t, t^2 and the parameter of the temperature are defined, as presented in Eq. 4.

$$\begin{gathered} LnN_{IJt} = \beta_0 + \beta_1 LnDist_{IJ} + \beta_2 LnGDPpc_{It} + \beta_3 LnGDPpc_{Jt} + \beta_4 Colony_{IJ} + \beta_5 Language_{IJ} + \\ + \beta_6 Border_{IJ} + \beta_7 Area_I + \beta_8 Area_J + \beta_9 Coast_I + \beta_{10} Coast_J + t + \beta_{11} Temp_I + \alpha_1 t\, Temp_I + \\ \alpha_2 t^2 Temp_I + \beta_{12} Temp^2{}_I + \alpha_3 tTemp^2{}_I + \alpha_4 t^2 Temp^2{}_I + \beta_{13} Prec_I + \beta_{14} Temp_J + \alpha_5 t\, Temp_J + \\ \alpha_6 t^2 Temp_J + \beta_{15} Temp^2{}_J + \alpha_7 tTemp^2{}_J + \alpha_8 t^2 Temp^2{}_J + \beta_{16} Prec_J + \gamma_I + \delta_J + \lambda_t + u_{IJt} \end{gathered} \tag{4}$$

Where $\alpha_1,\ldots,\alpha_8$ are the new parameters to be estimated. The significance of the α-parameters can be interpreted through two different ways. The first one would consider how climate change really affects tourist destination choices. The second one would consider that during the period of analysis (1995–2010), tourists have changed their climate preferences (for instance, people do not want to endure extreme temperatures nowadays, but 15 years ago they were willing to do so). Although the two contexts are plausible, we assume the second interpretation on the basis that international tourist choices are determined by the expectations of climate in the destination country. In this sense, although some changes could have been reported regarding global warming during the last 15 years, expectations as to climate in the different destinations around the world may remain unaffected. In fact, we are interested in the tourists' "climate expectations", so a baseline of climatic variables that remain constant throughout the sample period are used, instead of a set of time-changing climate variables.

Estimates from Eqs. 3 and 4 are shown in Table 1. By checking the goodness of fit through the R^2 measure, we can conclude that the estimated equation explains approximately 83 % of the variation in international tourist arrivals. In general, the estimated parameters yield the expected signs and sizes, suggesting that the model is correctly specified. GDP per capita of both the destination and origin countries are positive and significant, suggesting that national economic mass has a positive influence on tourism. In other words, the richer the countries are, the greater the international tourism flow between them. The distance variable is consistently negative and significant. This result is also confirmed by the large, significantly positive effect of the common border dummy variable. Sharing a common language and colonial links reveals significant, positive coefficients in the estimates. These historical and cultural linkages are strong determinants of tourism. The surface area of both origin and destination country shows positive, significant coefficients. As expected, the length of coastline in the destination country has a positive effect on the number of tourist arrivals. More

Table 1 Equations 3 and 4 estimation results

Variable	Equation 3		Equation 4	
	Coef.	t-stat	Coef.	t-stat
LnDist	−1.585*	−264.04	−1.585*	−264.04
$LnGDPpc_I$	0.399*	18.51	0.380*	17.48
$LnGDPpc_J$	0.548*	27.23	0.562*	27.02
$Colony_{IJ}$	0.740*	24.20	0.740*	24.22
$Language_{IJ}$	1.249*	93.75	1.249**	93.72
$Border_{IJ}$	1.253*	42.05	1.254*	42.10
$Area_I$	1.3E-07*	14.54	1.3E-07*	14.88
$Area_J$	4.5E-07*	35.21	4.4E-07*	34.67
$Coast_I$	6.2E-06*	10.87	6.6E-06*	11.35
$Coast_J$	1.6E-05*	21.52	1.5E-05*	21.31
t			−.0014	−0.30
$Temp_I$	−0.350*	−16.01	−0.347*	−15.12
$t \cdot Temp_I$			0.001	0.83
$t^2 \cdot Temp_I$			−2.5E-05	−0.27
$Temp^2_I$	0.012*	14.41	0.012*	13.96
$t \cdot Temp^2_I$			0.0001***	−1.62
$t^2 \cdot Temp^2_I$			2.2E-06	0.72
$Prec_I$	−0.001*	−9.26	−0.001*	−8.92
$Temp_J$	0.521*	19.65	0.493*	17.90
$t \cdot Temp_J$			0.004**	2.06
$t^2 \cdot Temp_J$			−0.0001	−0.92
$Temp^2_J$	−0.017*	−18.09	−0.015*	−16.15
$t \cdot Temp^2_J$			−0.0002*	−3.78
$t^2 \cdot Temp^2_J$			8.5E-06*	2.67
$Prec_J$	−0.0004*	−6.53	−0.0004*	−6.83
Constant	6.794*	27.75	6.749*	29.35
Number of obs	130,114		130,114	
R-squared	0.830		0.830	
F-stat	2152		2047	
Prob > F	0.0000		0.0000	

Origin (I), destination (J) and year fixed effect are not reported

Huber-White estimator is computed to obtain robust standard errors. Significance at 1 % (*), 5 % (**) and 10 % (***) level, respectively

surprising is the result that the kilometers of coastline in the origin country also has a positive impact on promoting tourist departures.[4]

[4] It is true that it seems to be implausible for tourists from origin countries with a large coastline to travel more; however as expected, the impact of the magnitude of the coastline in the destination country is larger than the magnitude in the origin one. Moreover, this result indicates that a large coastline per se does not imply more tourism, but rather that good weather is also required. Hence, warm countries with long coastlines are the most preferred tourist destinations.

Regarding the variables of interest, which are the climate ones; all of them are significant and reveal the expected sign. Precipitation in the destination country reports the expected negative sign, implying that tourists prefer sunny, dry destinations. In reference to temperature, on the one hand, for the destination country the coefficients of the linear and quadratic temperature terms are positive and negative, respectively, a result that was also found in Hamilton et al. (2005a, b; Hamilton and Tol 2007). This result suggests that there exists a turning point temperature in the destination country that can be interpreted in the context that the maximum likelihood of a given destination to be visited in reference to temperature is obtained at 15.7ºC for international tourists. Using data for 1995, Hamilton and Tol (2007); Hamilton et al. (2005a, b) found this turning point at 13.9ºC. This difference can be explained by both the difference in the reference period and a possible bias because of not including bilateral variables between countries in the tourism demand model.

On the other hand, for the origin countries the sign of the coefficients is the opposite. The coefficients of the linear and quadratic temperature terms in Eq. 1 are negative and positive, respectively, suggesting that there also exists a minimum annual temperature in the origin country to travel abroad. That is, ceteris paribus, people from very hot or very cold countries are more likely to travel abroad, thus implying the existence of an optimum yearly mean temperature for not travelling abroad (or travelling domestically). As observed, the turning point temperature for tourist departures is significantly lower than the turning point temperature in the destination country. In particular, the estimated turning point temperature in the origin is 14.7ºC on average (Eq. 3). Using data for 1995, Hamilton et al. (2005a, b); Hamilton and Tol (2007) also found a minimum temperature of 18.6ºC. Again, this gap can be explained by the different reference period used in the estimations and a possible bias for not including bilateral variables the model estimation.

Estimates from Eq. 4 take into account the dynamic nature of tourism data, and changes in tourist sensitiveness toward climate conditions are addressed. As can be observed in Figure 1, both turning point temperatures at origin and destination countries have changed over the period of analysis (1995–2010). Although this change could be interpreted as the result of real warming taking place during this period, it could also be a consequence of a change in climate preferences shown by tourists.

Whatever the reason, what seems clear is that the negative trend for the countries considered as destinations and the positive one when considered as origins show how colder countries (as destinations) have increased their tourist attractiveness while the warmer the origin country, the greater amount of international departures is expected. These tendencies imply, on the one hand, a loss of competitiveness for traditional warm destinations such as

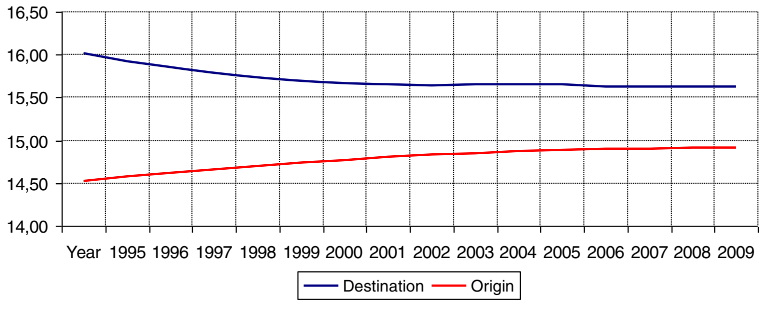

Fig. 1 Time varying temperature effect estimated from Eq. 4. Turning point temperatures at destination for tourism arrivals and turning point temperatures at origin for departures

Mediterranean countries. Thus, a high number of competitors are expected for these destinations as colder countries become more preferred by tourists. On the other hand, the increase in tourism numbers, ceteris paribus, is related to higher temperatures, so it is not expected that the traditional North-South flow in the Northern Hemisphere will lead to an increase in tourism numbers under a scenario of global warming.

4 Simulation

In order to project and map future tourism flows, GDP, population, temperature and precipitation projections for 2080 within the A2, B1 and B2 climate change scenarios are considered IPCC (2001). Projections of GDP per capita for the three scenarios were collected from the "GGI Scenario Database", while projected population data were collected from the *World Population Prospect*. Predicted climate for 2080 was taken from the TYN CY 1.1 dataset mentioned above. The rest of the variables considered remain constant. It should be highlighted how economic growth is assumed to affect tourism in a double way. That is, a country becomes more attractive as it grows richer, as well as the fact that the richer a country is, the greater the tourist departures from this country. Furthermore, climate change is expected to have a profound impact on tourism. In general, sunny countries with high temperatures - up to a turning point - and low precipitations attract tourists while cold, cloudy, rainy weather is a push factor for tourist departures.

For simulation purposes, the estimates presented in Table 1 are used to generate predicted tourist arrivals for 2007 (the year with fewer missing values and so as not to take into consideration the global economic crisis which entailed a slowdown in international tourism flows) which is used as a reference year, in order to be compared with values obtained from the simulations of the three different scenarios for 2080. Predicted total tourist arrivals (calculated as the sum of arrivals from each origin country to a particular destination) for 2007 and 2080 under the three different scenarios are obtained using different simulation assumptions.

Thus, Figure 2 shows the results of the simulation analysis considering only the effect of climate change on tourist arrivals (no change in population or GDP are considered). The results show how tourism growth for directly climatic motivations will be heterogeneous around the world, implying growth for colder countries and a decline for warmer ones. Thus, climate change would lead to a gradual shift of tourist destinations towards higher latitudes. Climate change would imply that Western European tourists travelling to the Mediterranean region would stay closer to home, visiting neighboring countries or remaining in the origin countries. Meanwhile, colder countries such as Canada or Russia would become more attractive because of the increasing number of months with a suitable climate for tourism, and thus implying a tourism demand increase in relative terms.

However, climate change is expected to have impacts on population numbers and economic growth that will in turn determine tourism flows. Thus, Figure 3 shows the effect on tourist arrivals of climate change and economic development for the three different scenarios. In this case, the expected economic growth in the next 70 years moderates the negative impact of climate change. However, yet again, the United States and the countries from the southern hemisphere would be the losers in these prospective scenarios, whereas colder countries would benefit.

Finally, a more specific view of the consequences of climate change is presented in Table 2 where the ranking of the 15 most important countries nowadays with the highest number of

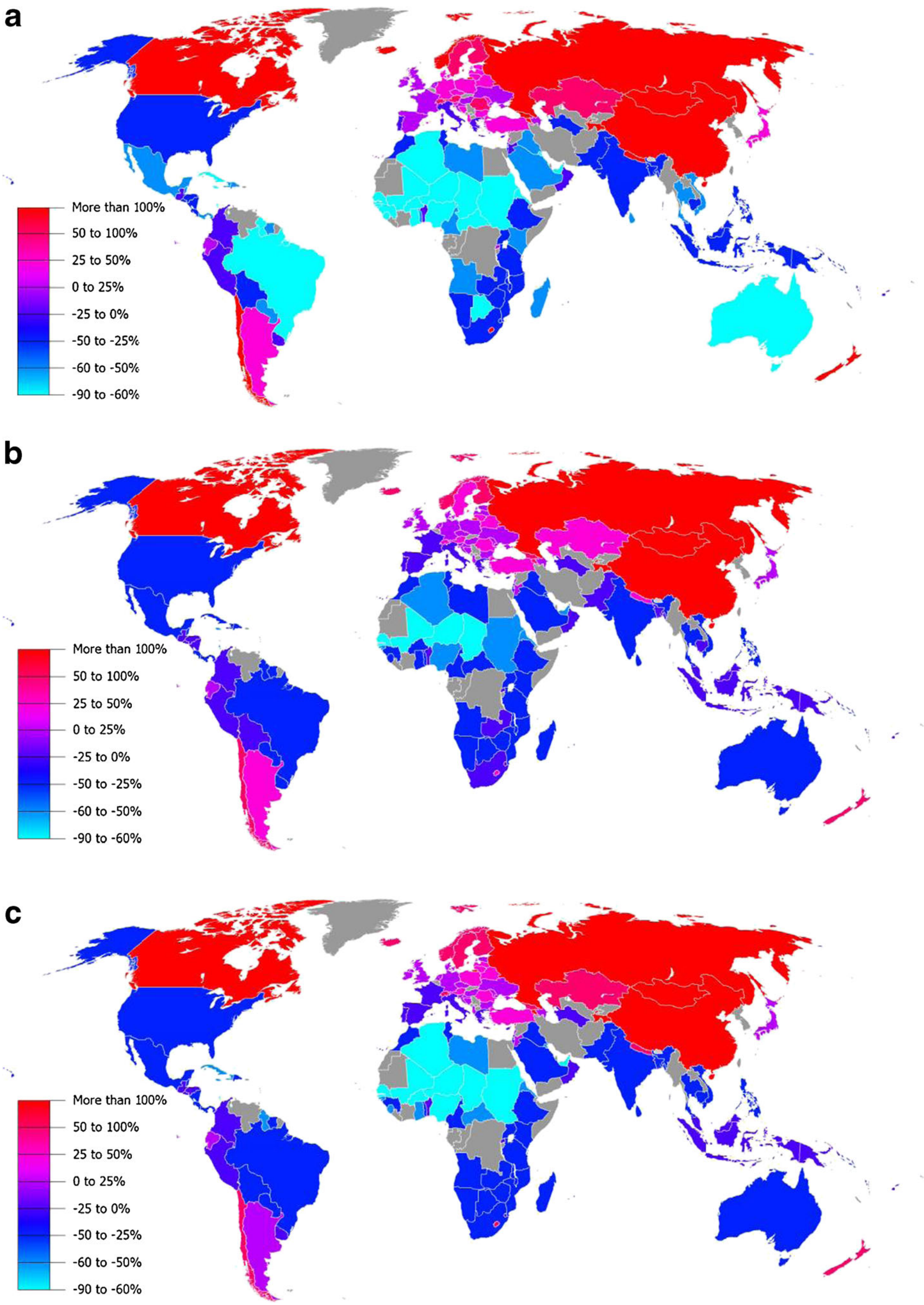

Fig. 2 Percentage variation in tourist arrivals caused by change in temperatures. Percentage change in tourist arrivals for 2080, compared to arrivals in 2007, considering only the effect of temperature for scenarios A2 (**a**), B1 (**b**), and B2 (**c**)

international tourism arrivals are presented (see supplementary material S2 for a complete table). From this table it should be highlighted how the current warmer traditional destinations

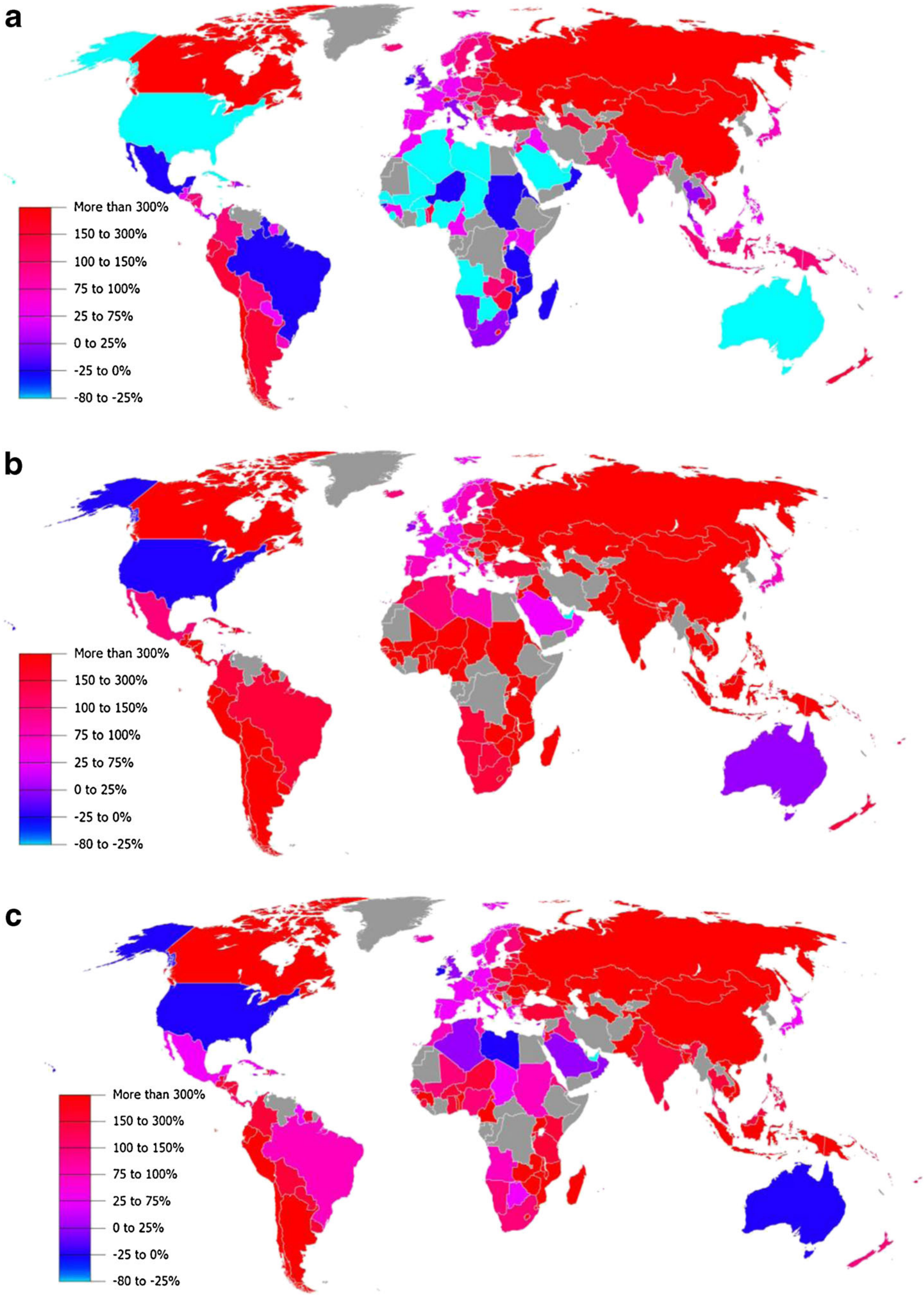

Fig. 3 Percentage variation in tourist arrivals caused by change in temperatures and GDPpc. Percentage change in tourist arrivals for 2080, compared to arrivals in 2007, considering scenarios A2 (**a**), B1 (**b**), and B2 (**c**)

located in lower latitudes will be replaced by big countries such as China, Russia and Canada, thus inverting the tourist "gravity" force towards higher latitudes.

Table 2 Top tourist countries in terms of international arrivals. Distributional effect of climate change on international tourism arrivals

Country	Real 2007 weigth	2080 Climate Change (Only Climate variables)			2080 Climate Change (Climate variables + GDPpc growth)		
		A2	B1	B2	A2	B1	B2
France	9,19	6,72	8,33	7,88	4,04	3,90	4,03
Spain	6,67	4,74	6,00	5,67	3,36	3,32	3,52
United States	6,37	2,31	3,69	3,65	1,56	1,65	1,87
China	6,22	14,84	11,77	12,82	24,21	20,67	20,26
Italy	4,96	2,75	3,81	3,48	1,96	1,93	2,15
United Kingdom	3,51	3,04	3,55	3,44	1,48	1,41	1,44
Germany	2,78	2,57	2,99	2,91	1,52	1,32	1,48
Ukraine	2,63	1,94	2,60	2,47	3,53	4,38	5,43
Russian Federation	2,60	14,46	6,10	7,63	17,51	6,96	10,42
Turkey	2,53	2,64	2,90	2,91	2,37	2,49	2,52
Mexico	2,43	0,75	1,41	1,20	0,62	1,48	1,12
Malaysia	2,38	1,23	1,85	1,70	1,17	3,02	2,84
Austria	2,36	2,70	2,82	2,82	1,68	1,32	1,55
Canada	2,04	10,16	5,57	6,48	6,96	2,47	3,32
Hong Kong	1,95	0,70	1,14	1,00	0,54	0,95	0,95

5 Conclusion

Many tourist destinations around the world are considering what kind of effects climate change could lead to, with the consequences on tourist demand as one of the most recurrent ones. Despite the uncertainties and complexity of evaluating expected tourism demand responses in a context of global warming, the literature has started to answer this question. The general results obtained in this paper are in line with intuition showing the preferences of tourists for warmer destinations and closer counties. However, the nature of the database used and the estimation method have enabled a more powerful extrapolation of the estimates for an evaluation of A2, B1 and B2 scenarios. Thus, global warming is, on the whole, bad news for warm destinations in terms of loss of competitiveness. Hence, it shows how the search for a more comfortable climate is found to be one of the main motivations in determining international global tourism flows and, as such, climate change would imply a loss of attractiveness for traditional winter resorts and traditional warmer destinations around the world. However, on the other hand, it seems that global warming would increase attractiveness for high latitude countries.

Another agreement that has been found with the previous literature is the non-linear relationship that exists between tourism flows and temperature. More precisely, an inverted u-shape in the relationship between temperature at destination and tourism demand is found, thus revealing the existence of optimal climatic conditions for the practice of tourism in the destination country. This turning point falls during the period of analysis, evidencing the loss of competitiveness of warmer destinations and showing an increase in climate sensitiveness by international tourism. Meanwhile, a u-shape in the relationship between temperature in the origin country and tourism demand is found, thus also revealing the existence of optimal climatic conditions for remaining at home. This turning point rises during the period of analysis, showing an increase in propensity to travel abroad from the warmest countries.

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 segments to climate change? What will the induced effects of climate change be on biodiversity loss, dry episodes, beach transformations, etc.?

The model presented in this paper operates on a national scale, with annual data and without considering domestic tourism, and, consequently, suffers from the same spatial-temporal limitations that have characterized previous econometric exercises. These limitations arise from the tourist databases that are collected around the world according to the recommendations of the United Nations World Tourism Organization (UN-WTO 1995). Additionally it should be noted how a single specification of the model is used, with sensitivity analyses on the parameters only. Particularly, the projection of international tourism demand is made through constant elasticities, ignoring possible saturation, an issue that would be plausible especially in reference to income elasticity. The model and projections neglect that changes in preferences, age structure, working hours and life styles would also affect tourist behavior. But these remain under the inherent uncertainty entailed in social phenomena, and are beyond the scope of this paper.

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