

# Climate change and international tourism: An evaluation for different scenarios<sup>1</sup>

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**Abstract:** The current pattern of international tourist flows evidences how climate is one of the main factors in the destination choice of tourists. Climate scientists are very certain that the Earth's climate will change at an unprecedented rate over the 21st century, anticipating global warming. This paper investigates the role of climate and other determining variables in destination choice for international tourist flows. A model for international tourist arrivals is estimated by using bilateral tourism movements between 178 countries from 1995 to 2010, allowing the estimation of a time-varying climatic sensitivity of tourists. Using data for the projected growth of Gross Domestic Product per capita and climatic conditions within the A2, B1 and B2 scenarios, the expected impact on international tourism flows is assessed, showing and evaluating how climate change would imply a loss of attractiveness for traditional warmer destinations around the world but would increase attractiveness for high latitude countries.

**Keywords:** International tourism flows, Climate Change, Gravity model.

JEL CODES: L83, Q54, F64

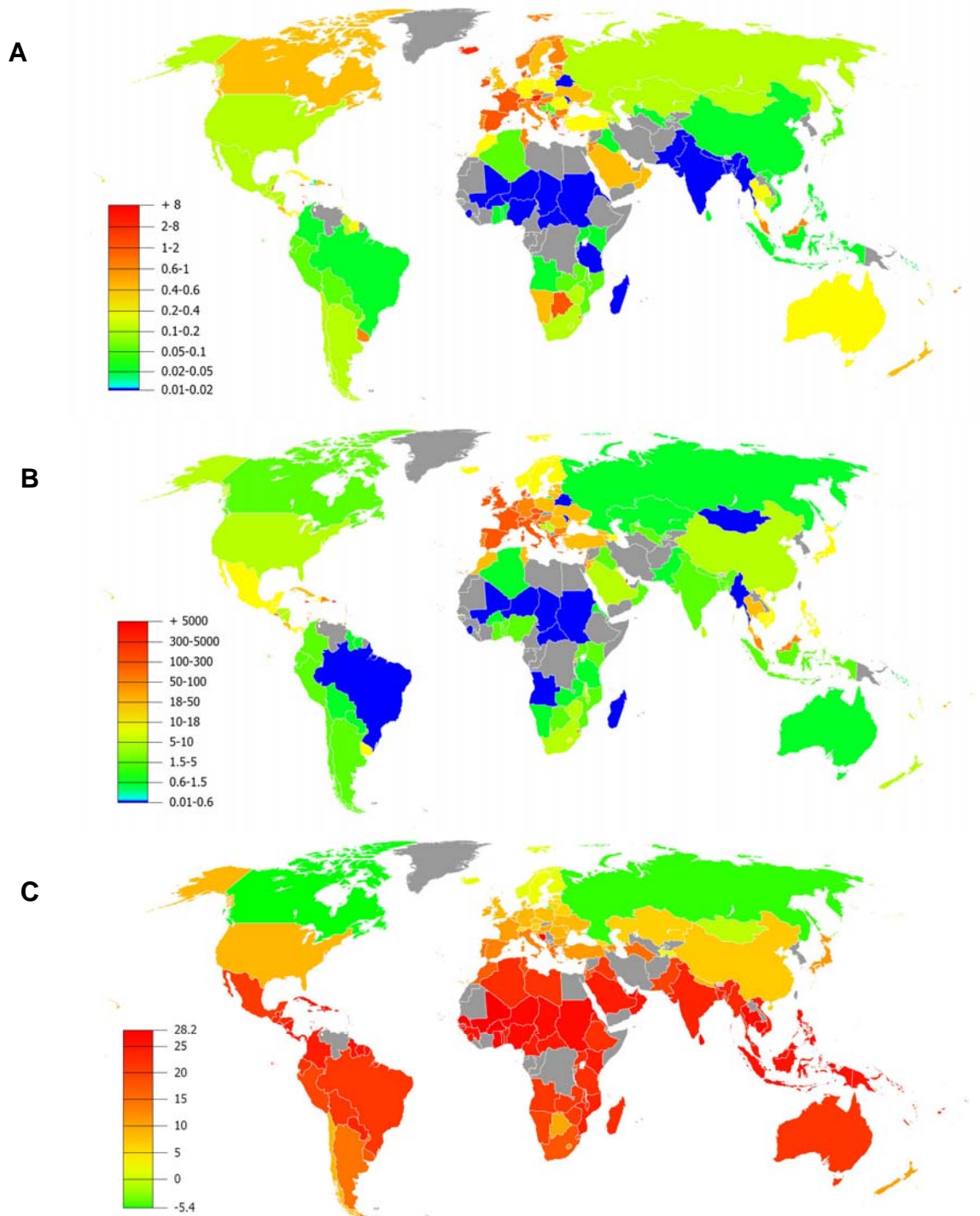
## 1. Introduction

It is agreed that international mass tourism began during the fifties, fuelled mainly by the development of civil aviation after the Second World War. Since then, according to the United Nations World Tourism Organization (UN-WTO) the figure of international tourists has grown from 25 million international arrivals in 1950 to an expected record of 1 billion in 2012, corresponding to an average annual growth rate of 6.1%. Actually, the relevance of climate in tourism choices is observed both through the typical seasonality pattern in the most popular

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destinations and especially by the latitude of the most popular tourists destinations around the world (Figure 1).



**Fig. 1.** Intensity of international tourist arrivals around the World in 2009. (A) Tourist arrivals/Population at destination. (B) Tourist arrivals/Area in square km at destination. (C) Annual temperatures by countries (average 1961-1990). Source: UN-WTO and Tyndall Centre for Climate Change Research. (Grey color means no data)

Considering that tourism represents 9.1% of the total world Gross Domestic Product (WTTC, 2012), it is surprising the relatively little attention it has attracted within climate change literature when compared with other activities of far less economic importance like, for instance, agriculture, estimated at 6% of the World GDP (CIA, 2012). Whatever the reason, whether through the direct effects of climate change, such as increased temperature, or through secondary effects, such as other environmental changes, GDP growth and population changes, etc., it can be expected that the spatial and temporal pattern of tourism demand will adjust. Consequently, different pioneering quantitative studies on the effect that climate change will have on tourism have recently appeared, it being possible to distinguish two main approaches.

The first one focuses on measuring the tourist attractiveness of a destination from a physical point of view. A clear example in this first approach is represented by studies relating winter-tourism and snow coverage (Scott et al., 2003 and 2007). This perspective can also be applied to beach tourism (Moreno and Amelung, 2009), or to the general physical conditions for tourism (Ameling et al., 2007). In this case, as an initial step, tourism-climatic indexes are built using tourism satisfaction surveys and, as a second step, the extrapolation of future climatic conditions are projected showing the loss or gain of tourism competitiveness in terms of climatic conditions. However, through this first approach it is not possible to obtain a quantification of the effects of climate change on tourism demand, and the impact on tourism demand remains subjective. The second approach is characterized by the construction of statistical models of tourist behavior as a function of weather and climate. Within this perspective, it is possible to evidence the relationship between climate and tourists movements when the geographic distribution of tourist flows from a particular origin has to be explained (Maddison, 2007; Lise and Tol, 2002). This perspective can be generalized by using aggregated tourism arrivals and aggregated tourism departures from all the countries around the world for a particular year (Hamilton et al., 2005; 2007a and 2007b), allowing the evaluation of the consequences of population and economic changes and rise in temperatures on the distribution of international tourists worldwide. However, the use of total arrivals and total departures in the initial estimation prevented the use of some relevant variables related to bilateral flows (such as distance, cultural affinity...) that are behind the choice of a tourist destination, and hence could bias the temperature effect in the event of a relationship between these omitted variables.

In the present study, we introduce a 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, ...) that have been previously found to be significant in the tourist literature. By considering the dynamic nature of the data, changes in climatic preferences of tourists are tested and used to project international tourism flows worldwide within A2, B1 and B2 scenarios, thus including climatic, population and economic projected data.

## **2. Determinants of International Tourism Flows**

The theoretical model that support international tourism demand applied in this paper is based largely on Morley (1992) and assumes that the individual utility derives from the visits to different international destinations as well as from the consumption of a vector of other goods. Then, the individual's utility function can be written as:

$$U_{ijt} = f(N_{ijt}, Q_{it}, ZO_{it}, ZD_{jt}) \quad (1)$$

where  $U_{ijt}$  is the utility that an individual from the origin  $i$  visiting a destination  $j$  at time  $t$  receives (note how  $i \neq j$  when only international trips are considered);  $N_{ijt}$  are the number of visits from origin  $i$  to destination  $j$  at time  $t$ ;  $Q_{it}$  is a vector of consumption of other goods; and  $ZO_{it}$  and  $ZD_{jt}$  are vectors of site qualities referred to the origin and destination, respectively. The constraint attached to the choices of a particular destination can be expressed as follows:

$$\pi_{ijt} N_{ijt} + p_{it} Q_{it} \leq M_{it} \quad (2)$$

where  $\pi_{ijt}$  is the cost of visiting destination  $j$  from origin  $i$  at time  $t$ ;  $p_{it}$  is the price vector of the consumption goods; and  $M_{it}$  is the personal income of the individual. The constrained maximization of the utility can be solved to find optimum levels of consumption of the other goods and number of trips between any specific origin to any specific destination. Analytically, the problem can be written as:

$$\begin{aligned} \text{Max}_{Q_{it}, N_{ijt}} U_{ijt} &= f(N_{ijt}, Q_{it}, ZO_{it}, ZD_{jt}) \\ \text{subj. to} \quad \pi_{ijt} N_{ijt} + p_{it} Q_{it} &= M_{it} \\ N_{ijt} &\geq 0, \quad Q_{it} \geq 0 \end{aligned} \quad (3)$$

The solution of the problem can be found through the maximization of the *Lagrangian equation* ( $\ell$ ) that in this case it could be written as:

$$\text{Max}_{Q_{it}, N_{ijt}} \ell = f(Q_{it}, N_{ijt}, ZO_{it}, ZD_{jt}) + \lambda (p_{it} Q_{it} + \pi_{ijt} N_{ijt} - M_{it}) \quad (4)$$

where  $\lambda$  is the *Lagrange multiplier*. The first order conditions of this problem give the following set of equations:

$$\begin{aligned} \frac{\partial \ell}{\partial N_{12t}} &= 0; \frac{\partial \ell}{\partial N_{13t}} = 0; \dots; \frac{\partial \ell}{\partial N_{1Kt}} = 0 \\ \frac{\partial \ell}{\partial N_{21t}} &= 0; \quad \frac{\partial \ell}{\partial N_{23t}} = 0; \dots; \frac{\partial \ell}{\partial N_{2Kt}} = 0 \\ \frac{\partial \ell}{\partial N_{31t}} &= 0; \frac{\partial \ell}{\partial N_{32t}} = 0; \quad ; \dots; \frac{\partial \ell}{\partial N_{2Kt}} = 0 \\ &\vdots \\ \frac{\partial \ell}{\partial N_{K1t}} &= 0; \frac{\partial \ell}{\partial N_{K2t}} = 0; \frac{\partial \ell}{\partial N_{K3t}} = 0; \dots; \\ \frac{\partial \ell}{\partial Q_{it}} &= 0; \frac{\partial \ell}{\partial \lambda} = 0 \end{aligned} \quad (5)$$

The solution of this set of equations gives the optimum levels of consumption of the other goods ( $Q^*$ ) and number of trips between any specific origin to any specific destination ( $N^*$ ):

$$\begin{aligned}
N_{12t}^* &= n(p_{12}, \pi_{12t}, M_{1t}, ZO_{1t}, ZD_{2t}) \\
N_{13t}^* &= n(p_{13}, \pi_{13t}, M_{1t}, ZO_{1t}, ZD_{3t}) \\
&\vdots \\
N_{K(K-1)t}^* &= n(p_{Kt}, \pi_{K(K-1)t}, M_{Kt}, ZO_{Kt}, ZD_{(K-1)t}) \\
Q_{it}^* &= q(p_{it}, \pi_{ijt}, M_{it}, ZO_{it}, ZD_{jt})
\end{aligned} \tag{6}$$

Once the individual demands have been determined, the aggregated demand can be obtained through the consideration of all the residents of a particular origin  $I$  visiting a particular destination  $J$ . Then:

$$N_{Ijt} = \sum_{i \in I / j \in J} N_{ijt}^* \tag{7}$$

According to previous assumptions about the determination of the number of trips for an individual, it can be assumed that:

$$N_{Ijt} = F(p_{It}, \pi_{Ijt}, M_{It}, ZO_{It}, ZD_{Jt}) \tag{8}$$

What is a generalization of the classical expression often used in traditional tourism demand modelling (Song and Li., 2008) that needs to be parameterized in order to find the best mathematical function  $F$  that describes the data and that could be estimated econometrically. The linear assumption is often combined through the use of logarithms and, thus, assuming constant elasticities between variables, although no consensus is found in the literature, and different alternatives are often tested simultaneously. Thus, if the multiplicative function is assumed between the number of trips ( $N$ ), the costs, the prices and the Income, Equation (8) can be formulated as:

$$N_{Ijt} = (p_{It})^{\beta_a} (\pi_{Ijt})^{\beta_b} (M_{It})^{\beta_c} f(ZO_{It}, ZD_{Jt}) \tag{9}$$

Where  $\beta_a$ ,  $\beta_b$  and  $\beta_c$  are parameters to be estimated and  $f$  is the function of the rest of the variables that is often assumed additive or multiplicative.

At this point it is important to note how, although Equation (9) has been derived from the utility theory, it would be possible to present this equation from the gravity models methodology, used frequently in the analysis of international trade. Although the theoretical underpinning of the gravity model is often criticised for their poor theoretical background it is used extensively in empirical exercises due to its goodness of fit, since it is expected that international flows, i.e. trade, tourism, migrations or foreign direct investment (FDI), increase with the economic size of countries and decrease as the distance between them increases. Thus, gravity models have been used to estimate the effects of economic and non-economic events on international flows of goods (Fратиanni 2007), migrants (Karemera et al. 2000; Gil-Pareja et al. 2006) and FDI (Bergstrand and Egger 2007; Eichengreen and Tong 2007; Head and Ries 2008). Moreover, since tourism is a special type of trade in services, traditional gravity equation for international trade has been also used to estimate tourism flows. In fact, Kimura and Lee (2006) show that trade in service is better predicted by gravity equations than trade in goods

A gravity equation has been previously defined in the literature to study the main determinants of tourism volume (Eilat and Einav, 2004, Gil-Pareja et al., 2007 and Fourie and Santana 2012). Indeed, this type of equations has been commonly used to investigate a number of empirical regularities in tourism such as the common currency effect (Gil-Pareja et al 2006; Santana et al 2010 and 2012), mega-events (Fourie and Santana 2011;) or cultural effects (Vietze, 2012). For this reason, the gravity equation for tourism demand presented in Equation 9 seems to be a suitable estimation method for the purposes of the present study.

### 3. The World Tourism Model

Estimation of Equation 9 requires the compilation of a database which includes information on international tourism flows and all their potential determinants. In our case, this collection has been done considering the aim of the study with reference to projecting international tourism flows for different climate change scenarios. According to the United Nations World Tourism Organization (UN-WTO) 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).

Tourism data for each country is obtained from the Tourism Factbook Database (UN-WTO, 2012), including 178 countries as origin/destination for the period 1995-2010. Cost of travelling is considered through four different variables: the great-circle distance between capital cities of countries ( $Dist_{it}$ ); the cultural affinity expressed in terms of sharing a common language ( $Language_{it}$ ) and having or having had a colonial relationship ( $Colony_{it}$ ); and sharing a common land border ( $Border_{it}$ ). 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 ( $Area_{it}$ ), length of its coastline in kilometers ( $Coast_{it}$ ) and a set of climatic variables including annual mean temperature ( $Temp_{it}$ ) precipitation ( $Prec_{it}$ ) and cloud cover (although this variable was not significant when considered jointly with temperature and precipitation). 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. 2005, 2007a and 2007b) so squared temperatures are also considered. 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* published by the *World Bank*. 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 and precipitation, were collected from the Tyndall Centre for Climate Change Research (TYN CY 1.1) dataset.<sup>2</sup> These variables take the mean average of the weather in the recent past (1961-1990), thus they remain constant throughout the whole 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:

$$\begin{aligned} \ln N_{IJt} = & \beta_0 + \beta_1 \ln \text{Dist}_{IJ} + \beta_2 \ln \text{GDPpc}_{it} + \beta_3 \ln \text{GDPpc}_{jt} + \beta_4 \text{Colony}_{IJ} + \beta_5 \text{Language}_{IJ} + \\ & + \beta_6 \text{Border}_{IJ} + \beta_7 \text{Area}_I + \beta_8 \text{Area}_J + \beta_9 \text{Coast}_I + \beta_{10} \text{Coast}_J + \beta_{11} \text{Temp}_I + \beta_{12} \text{Temp}_I^2 + \\ & + \beta_{13} \text{Prec}_I + \beta_{14} \text{Temp}_J + \beta_{15} \text{Temp}_J^2 + \beta_{16} \text{Prec}_J + \gamma_I + \delta_J + \lambda_t + u_{IJt} \end{aligned} \quad [3]$$

Where  $\ln$  denotes natural logs; sub-index  $I$  and  $J$  refer to the origin and destination country, respectively;  $\beta_1, \dots, \beta_{16}$  are parameters to be estimated;  $\gamma_I$ ,  $\delta_J$  and  $\lambda$  are origin, destination, and year fixed effects, respectively and  $u_{IJt}$  is a well-behaved disturbance term.

Classical panel estimation by fixed effects cannot be applied since climate variables remain time-invariant and would be dropped from the estimate. Then, 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, panel data enable the estimation of a time-varying parameter for some specific variables by including a time trend ( $t$ ) and a squared time trend to the variables of interest (Brun et al. 2005). In this sense, the change in tourism preferences in reference to the climate conditions can be tested though the following extension:

$$\begin{aligned} \ln N_{IJt} = & \beta_0 + \beta_1 \ln \text{Dist}_{IJ} + \beta_2 \ln \text{GDPpc}_{it} + \beta_3 \ln \text{GDPpc}_{jt} + \beta_4 \text{Colony}_{IJ} + \beta_5 \text{Language}_{IJ} + \\ & + \beta_6 \text{Border}_{IJ} + \beta_7 \text{Area}_I + \beta_8 \text{Area}_J + \beta_9 \text{Coast}_I + \beta_{10} \text{Coast}_J + t + \beta_{11} \text{Temp}_I + \alpha_1 t \text{Temp}_I + \\ & \alpha_2 t^2 \text{Temp}_I + \beta_{12} \text{Temp}_I^2 + \alpha_3 t \text{Temp}_I^2 + \alpha_4 t^2 \text{Temp}_I^2 + \beta_{13} \text{Prec}_I + \beta_{13} \text{Temp}_J + \alpha_5 t \text{Temp}_J + \\ & \alpha_6 t^2 \text{Temp}_J + \beta_{14} \text{Temp}_J^2 + \alpha_7 t \text{Temp}_J^2 + \alpha_8 t^2 \text{Temp}_J^2 + \beta_{16} \text{Prec}_J + \gamma_I + \delta_J + \lambda_t + u_{IJt} \end{aligned} \quad [4]$$

Where  $\alpha_1, \dots, \alpha_8$  are the new parameters to be estimated. Estimated equations 1 and 2 are shown in Table 1. By checking goodness of fit through the R-squared measure, 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, meaning that national economic mass has a positive influence on tourism. In other words, the richer the countries are, the greater the international tourism flows between them. The distance variable is consistently negative and significant. This result is also confirmed by the large and significantly positive effect of the common border dummy variable. Sharing a common language and colonial links reveals significant, positive coefficients in the estimates, suggesting that historical and cultural linkages are strong determinants of tourism. The surface area of both origin and destination country presents positive, significant coefficients. As expected, the length of coastline in the destination country has a positive effect on the number of tourist arrivals.

<sup>2</sup> [http://www.cru.uea.ac.uk/~timm/cty/scen/TYN\\_CY\\_3\\_0\\_var-table.html](http://www.cru.uea.ac.uk/~timm/cty/scen/TYN_CY_3_0_var-table.html) (accessed 20 October 2012)

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

**Table 1.** Effect of climate on tourist arrivals. Panel data estimate

Variable	Equation 3			Equation 4		
	Coef.		t-stat	Coef.		t-stat
<i>LnDist</i>	-1.585	*	-264.04	-1.585	*	-264.04
<i>LnGDPpc<sub>I</sub></i>	0.399	*	18.51	0.380	*	17.48
<i>LnGDPpc<sub>J</sub></i>	0.548	*	27.23	0.562	*	27.02
<i>Colony<sub>IJ</sub></i>	0.740	*	24.20	0.740	*	24.22
<i>Language<sub>IJ</sub></i>	1.249	*	93.75	1.249*	*	93.72
<i>Border<sub>IJ</sub></i>	1.253	*	42.05	1.254	*	42.10
<i>Area<sub>I</sub></i>	1.3E-07	*	14.54	1.3E-07	*	14.88
<i>Area<sub>J</sub></i>	4.5E-07	*	35.21	4.4E-07	*	34.67
<i>Coast<sub>I</sub></i>	6.2E-06	*	10.87	6.6E-06	*	11.35
<i>Coast<sub>J</sub></i>	1.6E-05	*	21.52	1.5E-05	*	21.31
<i>Temp<sub>I</sub></i>	-0.350	*	-16.01	-0.347	*	-15.12
<i>t·Temp<sub>I</sub></i>				0.001		0.83
<i>t<sup>2</sup>·Temp<sub>I</sub></i>				-2.5E-05		-0.27
<i>Temp<sub>I</sub><sup>2</sup></i>	0.012	*	14.41	0.012	*	13.96
<i>t·Temp<sub>I</sub><sup>2</sup></i>				0.0001	***	-1.62
<i>t<sup>2</sup>·Temp<sub>I</sub><sup>2</sup></i>				2.2E-06		0.72
<i>Prec<sub>I</sub></i>	-0.001	*	-9.26	-0.001	*	-8.92
<i>Temp<sub>J</sub></i>	0.521	*	19.65	0.493	*	17.90
<i>t·Temp<sub>J</sub></i>				0.004	**	2.06
<i>t<sup>2</sup>·Temp<sub>J</sub></i>				-0.0001		-0.92
<i>Temp<sub>J</sub><sup>2</sup></i>	-0.017	*	-18.09	-0.015	*	-16.15
<i>t·Temp<sub>J</sub><sup>2</sup></i>				-0.0002	*	-3.78
<i>t<sup>2</sup>·Temp<sub>J</sub><sup>2</sup></i>				8.5E-06	*	2.67
<i>Prec<sub>J</sub></i>	-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			0.83		
F-stat	2152			2047		
Prob > F	0.0000			0.0000		

Origin, destination 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.

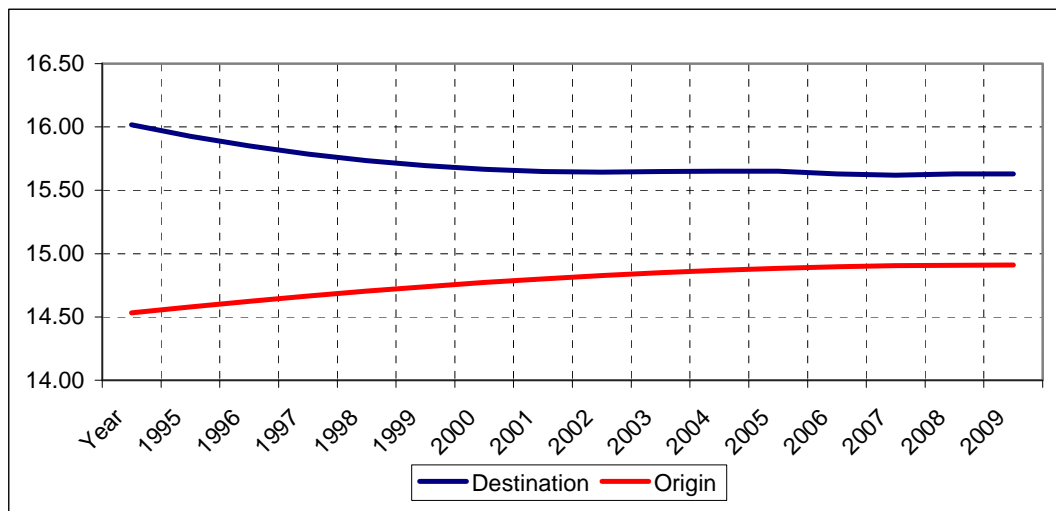
Regarding the variables of interest, which are the climate variables, all of them are significant and present the expected sign. On the one hand, for the destination country the coefficients of the linear and quadratic temperature terms are positive and negative, respectively. This result suggests that there exists an optimal temperature in the destination country, estimated at 15.72°C on average from Equation 3<sup>3</sup>. Moreover, precipitation in the destination country presents the

<sup>3</sup> The optimal temperature for the destination country is calculated as:  $T^{op} = -\frac{\beta_{11}}{2\beta_{12}}$ . Similarly for the optimal temperature for the origin country.



expected negative sign, implying that tourists prefer sunny, dry destinations. 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 Equation 3 are negative and positive, respectively, suggesting that there also exists an optimal temperature in the origin country. That is, *ceteris paribus*, people from very hot or very cold countries travel more, thus implying the existence of an optimum yearly mean temperature for remaining in the host country. This optimal temperature for tourist departures is 14.69°C on average.

**Fig. 2.** Time varying temperature effect estimated from Equation 4. Optimal temperatures at destination for tourism arrivals and optimal temperatures at origin for departures.



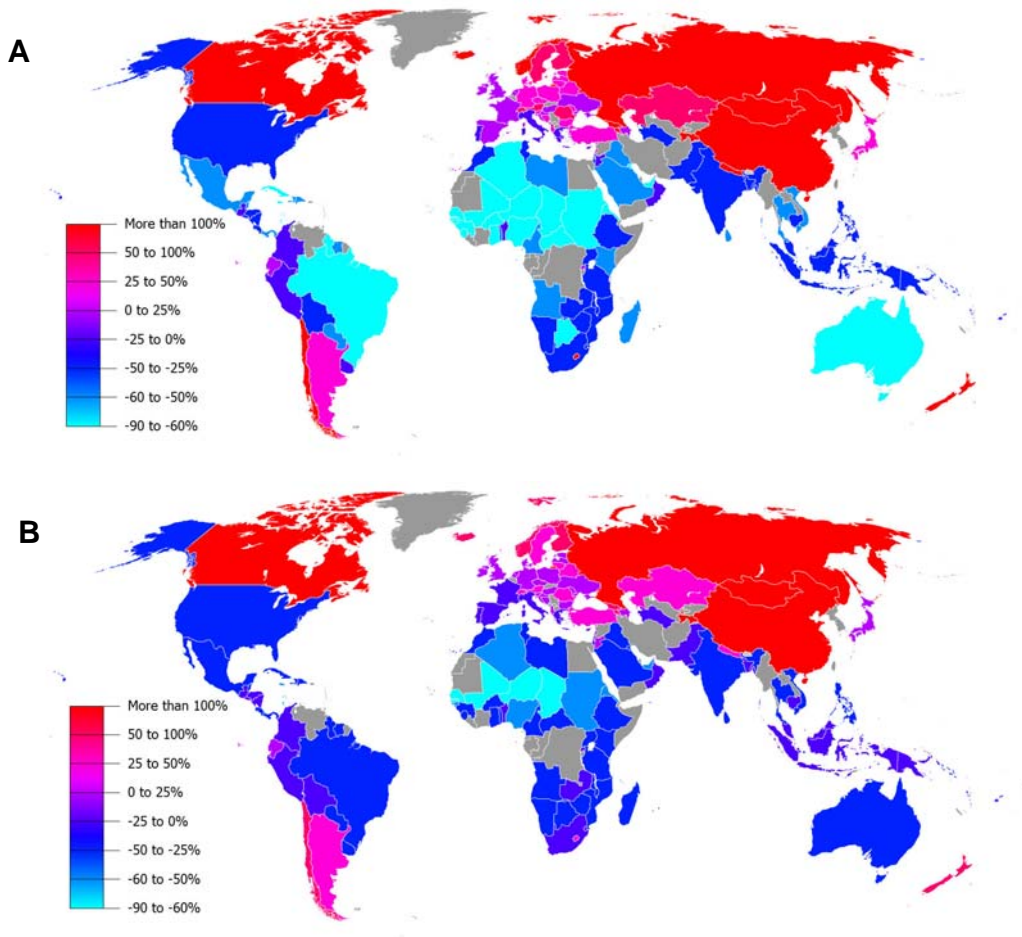
However, the significance of some temperature parameters including  $t$  in Equation 4 suggests that both optimal temperatures at origin and destination have changed over the period of analysis (1995-2010) (Figure 2)<sup>4</sup>. Although this change could be interpreted as the result of real warming 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 Mediterranean countries. Thus, a high level of competitiveness is expected for these destinations as colder countries are 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.

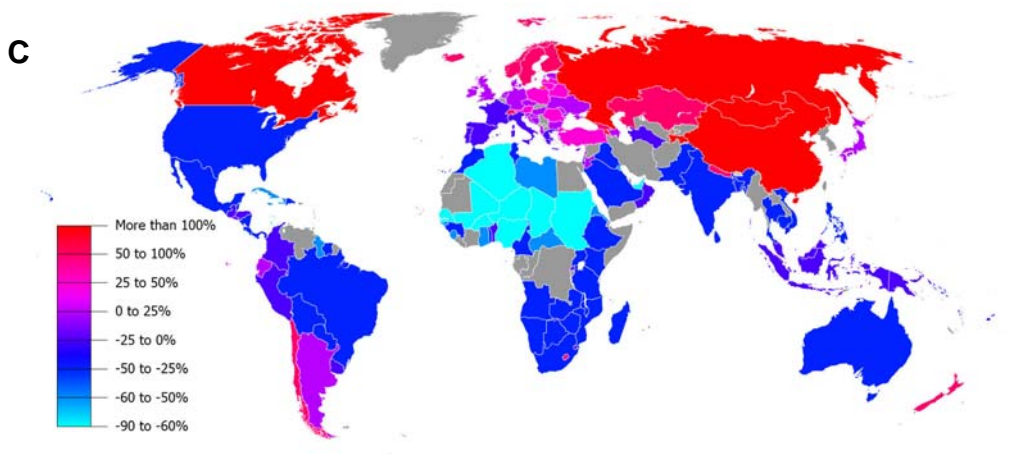
<sup>4</sup> The variation of the optimal temperature of the destination country is calculated as:  $T_t^{op} = -\frac{\beta_{11} + \alpha_1 t + \alpha_2 t^2}{2(\beta_{12} + \alpha_3 t + \alpha_4 t^2)}$ . The evolution of the optimal temperature for the origin country is obtained in the same way.

#### 4. Simulation

In order to project future maps of 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 richer the 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.

**Fig. 3.** 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).





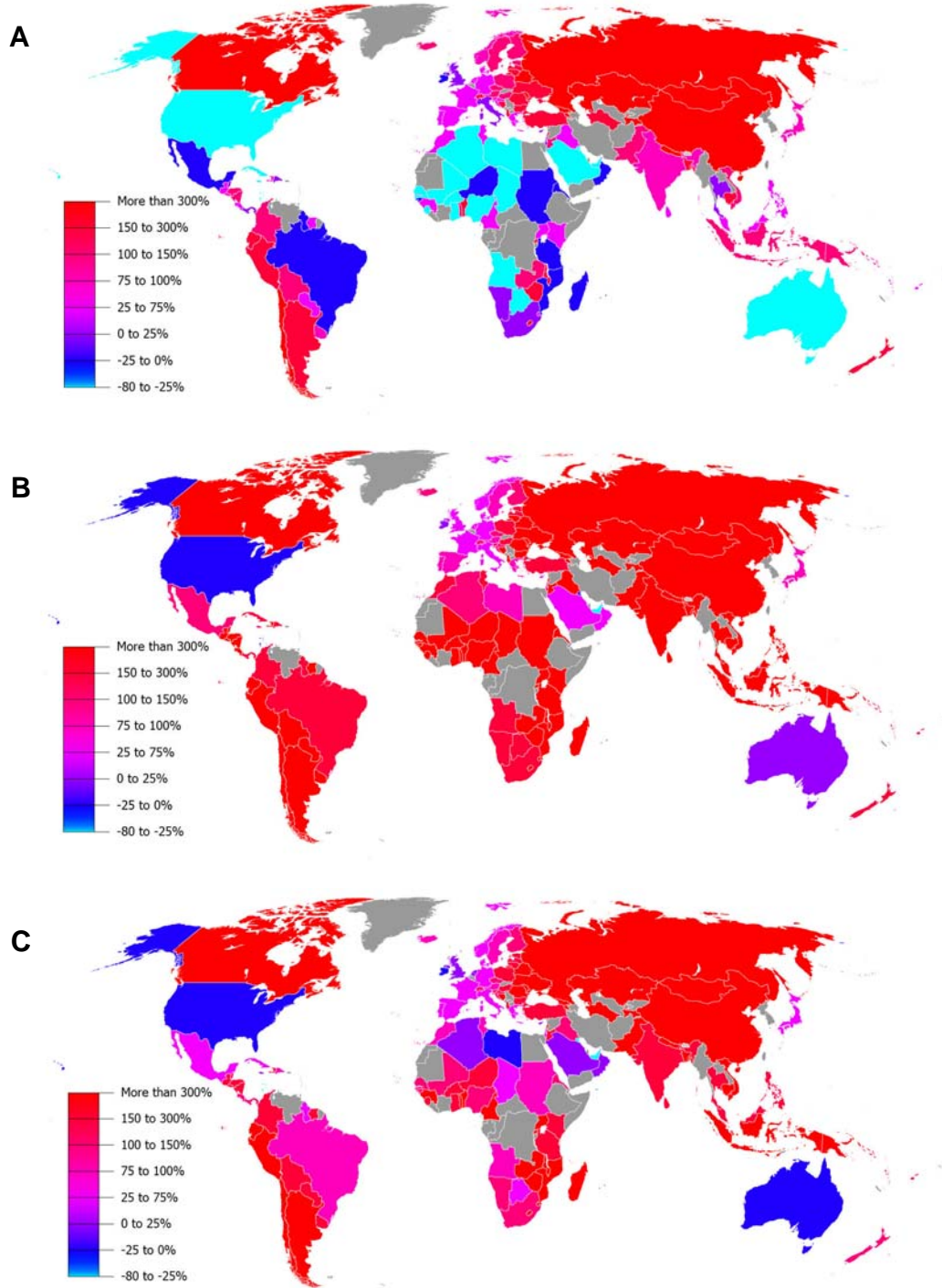
For simulation purposes, estimates presented in Table 1 are used to generate predicted tourist arrivals for 2007 which is used as a reference year, in order to be compared with values obtained from the simulations of the three different scenarios for 2080<sup>5</sup>. Predicted total tourist arrivals (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. Then, Figure 3 shows the results of the simulation analysis considering only the effect of climate change on tourist arrivals (Population and GDP remains constant as the same level as in 2007). The results show how tourism growth for directly climatic motivations will be heterogeneous around the world, implying a growth for colder countries and fall for warmer ones. Thus, climate change would lead to a gradual shift of tourist destinations towards higher latitudes. Climate change would imply that Western Europe tourists travelling to the Mediterranean region would stay closer to home, visiting neighboring countries or remaining in the host countries. Meanwhile, colder countries such as Canada or Russia could increase their attractiveness by enlarging the months with a suitable climate for tourism, thus implying a great 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 4 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, while colder countries would benefit.

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<sup>5</sup> 2007 is used as reference since is the year with fewer missing values in the dataset and not to taking into consideration the global economic crisis which entailed a slowdown in international tourism flows.

**Fig. 4.** 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).



Finally, a more specific view of the consequences of climate change is presented in Table 2 where the ranking of the 15 most important actual countries around with the highest number of international tourism arrivals are presented (see supplementary material for a complete table). From this table it should be highlighted how the actual warmer traditional destinations located in southern latitudes will be replaced by big countries located in the north such as China, Russia and Canada, thus inverting the tourist “gravity” force towards northern 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 countries. However, the nature of the database used and the estimation method have enabled a more powerful extrapolation of the estimates for an evaluation of the A2, B1 and B2 scenarios. Thus, global warming is, on the whole, bad news for warm destinations in terms of loss of competitiveness. Then, 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 optimum rises 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 at origin country and tourism demand is found, thus also revealing the existence of optimal climatic conditions for remaining at home. This optimum also falls during the period of analysis, showing an increase in the 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 marked segments to climate change? What will the induced effects of climate change be on biodiversity loss, dry episodes, beach transformations, etc.? The model operates at a national scale, with annual time and without considering domestic tourism. 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 behaviour. But this remains under the inherent uncertainty that social phenomena entail and are beyond the scope of this paper.

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