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Climate change and international tourism: A simulation study

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Abstract

The literature on tourism and climate change lacks an analysis of the global changes in tourism demand. Here, a simulation model of international tourism is presented that fills that gap. The current pattern of international tourist flows is modelled using 1995 data on departures and arrivals for 207 countries. Using this basic model the impact on arrivals and departures through changes in population, per capita income and climate change are analysed. In the medium to long term, tourism will grow, however, the change from climate change is smaller than from population and income changes.

JEL classification: L83; Q25

Keywords: Tourism demand; Climate change; Global model

1. Introduction

Tourism is one of the largest and fastest growing economic sectors. Tourism is obviously related to climate. It is therefore surprising that the tourism literature pays little attention to climate and climatic change (e.g., Witt and Witt, 1995). It is equally surprising that the climate change impact literature pays little attention to tourism (Smith et al., 2001).

The situation is now slowly changing. Three branches of literature have started to grow. Firstly, there are a few studies (e.g., Maddison, 2001) that build statistical models of the behaviour of certain groups of tourists as a function of weather and climate. Secondly, there are a few studies (e.g., Abegg, 1996) that relate the fates of particular tourist destinations to climate. Thirdly, there are studies (e.g., Matzarakis, 2002) that try to define indicators of the attractiveness to tourists of certain weather conditions. These three strands in the literature share a common deficit, namely the lack of a larger, global assessment of push and pull factors of international tourism. This study is an attempt to fill that gap.

If one wants to estimate the implications of climate change for a particular tourist destination, then one would not only want to know how the attractiveness of that place is changing—as is done in the second strand of literature defined above. Rather, one would need to know how climate change affects the attractiveness of that place *relative to its competitors*. If, for instance, Switzerland loses half of its snow, but other European skiing destinations lose all—then Switzerland's position may well be strengthened as the only place in Europe with natural snow. Similarly, one would need the change in behaviour of all tourists, and not just of those from Germany, the Netherlands and the UK—as the first strand of literature does. This paper combines the first

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and second strands of literature to overcome these drawbacks. Like the third strand of literature, it uses attractiveness indicators, albeit ones that are based on observed behaviour. In combining these three elements, we obviously had to simplify. The novelty of this paper lies in the interactions of push and pull factors at a global scale, not in the details.

Section 2 reviews the literature on tourism, climate, and climate change. Section 3 presents the model, its calibration and the base results. Section 4 discusses the sensitivity of the model. Section 5 concludes.

2. Climate and tourism: a literature survey

2.1. Tourism demand

Tourism demand forecasting has been given considerable coverage in the literature. Witt and Witt (1995) review the various methods used in tourism demand forecasting and compare the explanatory variables used in econometric models, gravity models and time series analyses. Using Meta-Analysis, Crouch (1995) examines the results of 80 studies on international tourism demand. Sixty of the 110 studies reviewed by Lim (1995) included qualitative variables in the model specification. The number of studies that include destination attractiveness as a variable or what aspects of destination attractiveness were used was not specified. Lim concludes that the majority of studies focus on economic factors in estimating demand.

Demand systems provide the opportunity to examine the pattern of flows to different destination countries. Several recent studies have used the almost ideal demand system framework (AIDS). For example, Lyssiotou (2000) examined the demand of the British for international tourism using tourism expenditure data. More recently, Divisekera (2003) applied this method to examine the flows between New Zealand, UK, the US and Japan. In this case four independent systems are estimated and not a matrix of all flows. Lanza et al. (2003) applied this method to 13 OECD countries with the aim of examining the impact of specialisation in tourism. None of these studies included any natural resource characteristics in the demand functions.

Morley (1992) suggests an approach that includes destination characteristics. He shows that for different destinations different levels of utility will be attainable depending on the attributes of the destinations. Further, utility will be dependent on the time spent at the destination. Morley (1992) criticises the majority of tourism demand analyses on the grounds that they lack a basis in theory and do not consider utility in the decision making process. He suggests a discrete choice analysis based on Lancaster's product characteristics utility theory. He notes that climate and landscape attributes should be included in the characteristics set. According to Papatheodorou (2001), most empirical work on tourism demand neglects the characteristics of the tourism product. However, to predict changes in flows, whether spatially or temporally, he argues that an approach that includes destination characteristics is more appropriate. Seddighi and Theocharous' (2002) work follows on from that of Papatheodorou and Morley using a Logit analysis and focussing on the importance of political stability as a destination characteristic. Climate and landscape features were not included in their characteristics set.

The travel cost method was originally developed in the 1960s to estimate recreation demand. However, developments have extended the original model to include characteristics of destinations and it has been applied to international tourism destinations. Maddison (2001) adapted the travel cost method to the demand for countries and included climate variables and beach length in the statistical estimation of demand. Maddison (2001) examined the demand patterns of British tourists and subsequent studies have been carried out for Dutch and German tourists (Lise and Tol, 2002; Hamilton, 2003). However, Freeman (1993) argues that the absence of substitute site qualities and prices in such travel cost models make it impossible to examine the effect of changes in destination characteristics at more than one site. Climate change will not affect one single country, rendering the travel cost method unsuitable for a complete analysis of the effect on the patterns of demand. Nevertheless, Maddison (2001) estimated the demand function of British tourists and then used it to examine changes in the number of tourists as well as changes in welfare, using projected changes in temperature and precipitation under a "business as usual" greenhouse gas emissions scenario.

2.2. Tourism and climate

Pike (2002) carried out a review of 142 destination image papers, which were published in the period 1973–2000. Only one of these specifically dealt with weather. This was a study by Lohmann and Kaim (1999), who note that there is a lack of empirical evidence on the importance of weather/climate on destination choice decision-making. Using a representative survey of German citizens the importance of certain destination characteristics were assessed. Landscape was found to be the most important even before price considerations. Weather and bio-climate were ranked third and eighth, respectively, for all destinations. They found that although weather is an important factor, destinations are also chosen in spite of the likely bad weather. Measuring the importance of destination characteristics is the focus of a study by Hu and Ritchie

(1993). They review several studies from the 1970s and found that "natural beauty and climate" were of universal importance in defining destinations attractiveness. A good climate and the possibility to sunbathe were included in Shoemaker's (1994) list of destination attributes.

The "Push–Pull" framework has been utilised by a number of studies to assess the range of attributes that motivate the desire to go on holiday and the destination choice. Push factors are social–psychological factors that motivate the individual to travel and the pull factors are qualities of destinations that attract the tourist such as infrastructure or cultural attractions. Of the ten "Push–Pull" studies reviewed by Klenosky (2002), none explicitly included origin climate or destination climate as push and pull factors, respectively. Nevertheless, in his study, "warm climate" appears as a pull factor and was found to be important for those interested in relaxing and in getting a suntan. However, climate did not make it into the seven most important factors from a group of 53 pull factors selected using factor analysis by Yuan and MacDonald (1990).

de Freitas (2001) classifies climate according to its aesthetic, physical and thermal aspects. The thermal aspect is argued to be a composite of temperature, wind, humidity and radiation. There is growing evidence, however, that climate has significant neurological and psychological effects (Parker, 2000), which may also have some influence on the choice of holiday destination. Many numerical indices have been developed to measure the thermal aspect of climate and to allow comparison of the suitability of different destinations for different tourism activities. de Freitas (1990) found that the relationship between HEBIDEX, a body–atmosphere energy budget index, and the subjective rating of the weather by beach users was highly correlated. Furthermore, he found that the optimal thermal conditions for beach users were not at the minimum heat stress level but at a point of mild heat stress. Matzarakis (2002) uses an index of thermal comfort to identify areas of Greece where there is a high likelihood of the conditions of heat stress occurring. The author states that climate change scenarios are not suitable to use with such indices because of their coarse resolution. Moreover, de Freitas (2001) criticises many of the existing indices because they are subjective.

2.3. Tourism and climate change

Qualitative impact studies of climate change have been carried out for the Mediterranean (Nicholls and Hoozemans, 1996; Perry, 2000), the Caribbean (Gable, 1997), wetland areas in Canada (Wall, 1998) and the German coast (Krupp, 1997; Lohmann, 2001). These studies vary in their focus and techniques. The latter used surveys, scenarios and consulted both tourist and tourist industry discussion groups in their analysis. Viner and Agnew (1999) examine the current climate and market situation for the most popular tourist destinations of the British. The consequences for demand for these destinations under a changed climate are discussed. According to Witt and Witt (1995), few studies have been published which use qualitative forecasting techniques such as the Delphi method and scenario projection. Currently, however, a Delphi study is being carried out with the aim of summarising expert opinion on the impacts of hazards, such as climate change, on the development of tourism in tropical coastal areas (Cunliffe, 2002).

While these studies provide information about vulnerabilities and the likely direction of change, they do not provide estimates of changes in demand. Three groups of quantitative studies exist: changes to the supply of tourism services, travel cost models of demand and time series models. Abegg (1996) analysed the impact of changes in temperature on snow depth and coverage and the consequences of these changes on ski season length and the usability of ski facilities. Similar studies were carried out for winter sports tourism in Scotland, Switzerland, alpine Austria and Canada (Harrison et al., 1999; Kromp-Kolb and Formayer, 2001; Elsasser and Bürki, 2002; Scott et al., 2001). These studies rely on the assessment of physical conditions that make tourism possible in these areas for a certain activity, that is, the supply of tourism services for a specific market segment. Scott and McBoyle (2001) apply the tourism index approach to the impact of climate change on city tourism in several North American cities. Cities are ranked according to their climatic appropriateness for tourism and then this ranking is examined under a scenario of climate change. The authors predict an increase in revenue from tourist accommodation for Canadian cities. In the above studies, changes in the relative market position of these destinations are neglected, as well as the change in climate relative to the origin climate of tourists. Such limitations can also be found in the studies carried out using the "Pooled Travel Cost Model" (PTCM) for tourists from the UK, the Netherlands and Germany (Maddison, 2001; Lise and Tol, 2002; Hamilton, 2003). Nevertheless, they have estimated the relationship between demand and certain climate variables. The possibility of taking a vacation in the origin country was included in the study by Hamilton. Domestic tourism and international inbound and outbound tourism were modelled by Agnew and Palutikof (2001) using a time series of tourism and weather data.

From this review of tourism demand forecasting and climate and tourism literature the following gaps are evident. Firstly, the possibility of substitution between destinations has been neglected in all studies. Secondly, the studies have focussed on particular areas or particular origin nationalities; the global picture has yet to be filled in. Thirdly, in the forecasting literature, environmental characteristics are assumed to be fixed and only economic variables are seen as varying over time. Climate as a ''push'' factor has also been largely overlooked. A global study of flows from origin countries to destination countries that includes the climate of countries as a factor in both the estimation of demand to travel as well as the demand for a particular destination would fill this gap, as well as allowing an examination of the substitution process.

3. The model and basic results

3.1. Model structure

We constructed a model of international tourist flows from 207 countries to 207 countries. The purpose of the model is not to understand the current pattern of international tourism; for that, we need more detailed information than was available to us. Rather, the purpose of the model is to analyse how the current pattern may change under not-implausible scenarios of future population growth, economic growth and, particularly, climate change. The inputs to the patterns and their changes are the empirical regularities reported in Section 2. The exact details are given below.

The basis of the model is the matrix of bilateral tourism flows. This matrix is perturbed with scenarios of population growth, economic growth and climate change. The perturbations on the supply side are perturbations on the *relative attractiveness* of holiday destinations. The perturbations on the demand side are perturbations on the *number of tourists* from origin countries. For these perturbations, we used the same relationships as we used to construct the bilateral tourism flow matrix.

Note that data on international tourism are available only at a national level. This implies a distortion of reality, particularly for large and diverse countries for which we have to assume a representative climate, income and so on. This is obviously problematic for the USA, but also for France, the most popular destination, where tourism is concentrated in Paris and the south. Similarly, data are reported per year. Seasonal tourism flows are not accounted for.

3.2. Baseline

The model is calibrated against the international arrivals and departures data of 1995 contained in the World Resources Databases (WRI, 2000).[1] There are three major problems with this dataset. Firstly, for some countries, the reported data are arrivals and departures for tourism only. For other countries, the data are arrivals and departures for all purposes. Unfortunately, it is impossible to correct for this.[2] Secondly, the data are total arrivals and total departures; there are no data on the origin of the arrivals or the destination of the departures. We therefore need to construct a database on bilateral tourism flows for all pairs of countries. Thirdly, there are missing observations, particularly with regard to departures.

For arrivals, 181 countries have data but 26 do not. We filled the missing observations with a statistical model, viz.

$$\begin{aligned} \ln A_i = {} & \underset{0.97}{5.97} + \underset{0.96}{2.05} \times 10^{-7}\, Area_i + \underset{0.07}{0.22}\, T_i \\ & - \underset{2.21}{7.91} \times 10^{-3}\, T_i^2 + \underset{3.03}{7.15} \cdot 10^{-5}\, Coast \\ & + \underset{0.09}{0.80} \ln Y_i, \\ N = 139;\ & R^2_{adj} = 0.54, \end{aligned} \tag{1}$$

where A denotes total arrivals, *Area* is land area (in square kilometres); T is annual average temperature for 1961–990 (in degrees Celsius) averaged over the country, *Coast* is length of coastline (in kilometres), and Y is per capita income; i indexes destination country. This model is the best fit [3] to the observations for the countries for which we do have data.[4] The total number of tourists increases from 55.2 million (observed) to 56.5 million (observed + modelled). The 26 missing observations constitute only 2% of the international tourism market.

For departures, the data problem is more serious: 107 countries report but 99 do not;[5] 46.5 million departures are reported, against 56.5 million arrivals, so that 18% of all international tourists have an unknown

[1]The reported departures from the Czech Republic were divided by 10; comparison to earlier and later years shows that the 1995 data have a typographical error.

[2]However, we did correct the Polish departure data. According to Statistic Poland, only 12% of the reported international departures are tourists (Central Statistical Office Poland, 2002, http://www.stat.gov.pl/english/serwis/polska/rocznik11/turyst.htm).

[3]The estimation procedure started with a large number of explanatory variables, including precipitation, number of world heritage sites, political stability and a range of other indicators. Explanatory variables that are individually and jointly insignificant were eliminated. The specification results are shown. We experimented with different representations of temperature (e.g., temperature of the hottest month); the annual average temperature describes the data best.

[4]The data on per capita income were taken from WRI (2000), supplemented with data from CIA (2002); the data on area and the length of international borders are from CIA (2002); the data on temperature from New et al. (1999). All data can be found at http://www.uni-hamburg.de/Wiss/FB/15/Sustainability.

[5]These are mostly African countries and small dependencies; however, data from Pakistan and Taiwan are also missing. Luxemburg is the only OECD country without departures data.

origin. We filled the missing observations with a statistical model, viz.

$$\ln \frac{D_i}{Pop_i} = \underset{17.05}{1.51} - \underset{0.17}{0.18}\ T_i + \underset{16.82}{4.83} \times 10^{-3}\ T_i^2 - \underset{4.22}{5.56} \times 10^{-2}\ Border + \underset{0.09}{0.86}\ \ln\ Y_i - \underset{0.13}{0.23}\ \ln\ Area_i,$$
$$N = 99;\ R^2_{adj} = 0.66, \quad (2)$$

where D denotes departures (in number), Pop denotes population (in thousands) and $Border$ is the number of countries with shared land borders; i indexes the country of origin. Again, this model is the best fit [6] to the observations for the countries for which we do have data,[7] but although the fit is better than for arrivals, the uncertainty about the parameters is larger. This leads to a total number of departures of 48.2 million, so we scaled up *all* departures [8] by 17% so that the total number of observed and modelled departures equals the total number of observed and modelled arrivals.

Note that most results below are given relative to 1995 or relative to the base scenario, which itself is relative to 1995. The fact that we had to adjust the data should not distort the qualitative results.

Bilateral tourism flows were derived as follows: In keeping with the model described below, we constructed a *general attractiveness index* for each country.[9] The tourists of each country are allocated to other countries according to a *country-of-origin-specific attractiveness index* that is equal to the *general attractiveness index* times *the distance* between the two capital cities raised to the power -1.7×10^{-4}.[10] That is, tourists are allocated to destinations based on the general attractiveness of the destinations and the distance to these destinations. In this manner, the model reproduces the 1995 pattern of total departures and arrivals (see Figs. 1 and 2). As a comparison of the two maps shows, the model is well calibrated. However, the fact that the total pattern is simulated well does not imply that all bilateral flows are simulated well. Fig. 3 shows the observed and modelled destination preferences of German tourists. Although the overall pattern is similar, details may be quite different.

Qualitatively, the model works as follows: The number of tourists going on an international holiday is determined by the income and the climate in the country of origin. Richer people travel more. People from very hot or very cold places travel more. Other reasons to travel are assumed to be constant (area, land borders) or omitted. After deciding to take a holiday abroad, the destination is chosen. Poor countries, hot countries, and cold countries are not attractive. Other features that attract tourists are assumed to be constant (area, coastline) or omitted. With different climates, incomes, and populations, different travel patterns arise. The model is admittedly simple, but captures the essentials (cf. Figs. 1 and 2) while richer representations of arrivals and departures do not describe the data better.

3.3. Population and economic growth

Scenarios of population and economic growth are taken from the 17-region IMAGE 2.2 implementation (IMAGE Team, 2001) of the SRES scenarios (Nakicenovic and Swart, 2001). Note that the SRES *scenarios* on populations, economies and emissions are associated to SRES *storylines* with qualitative descriptions of wider social and political change. We only use the quantified scenarios.

There is only weak empirical support that tourists are attracted to places with low or high population densities. Population growth is therefore assumed to affect international tourism as a proportional increase in departures. As population growth is not uniform over the globe and tourism is partly determined by distance, this simple assumption already creates a shift in the pattern of international tourism (see Tables 1–3).

Economic growth is assumed to affect tourism according to Eqs. (1) and (2). That is, a country becomes more attractive as it grows richer, with an elasticity of 0.80. A country generates more tourists as it become richer, with an elasticity of 0.86. The population and economic scenarios together produce a marked shift of international tourism towards Asia (see Tables 1–3).

As stated, international tourism demand has an income elasticity of 0.86, which is smaller than unity, that is, international tourism demand is a necessary good, not a luxury good. This is counterintuitive, but the best fit to the international cross-section of data. The data, unfortunately, do not allow us to estimate an income elasticity that falls with income, or with the number of international trips. Although one would expect tourism demand to saturate, if only because of time limitations, we do not observe this in the data.

[6]The estimation procedure started with a large number of explanatory variables. Explanatory variables that are individually and jointly insignificant were eliminated.

[7]The data on population were taken from WRI (2000), the data on the number of land borders were taken from CIA (2002).

[8]Scaling up only the interpolated departures leads to distortions, as many small countries do not report departures data. Besides, countries have less of an interest in counting departures than in counting arrivals, so departures are probably underreported even if there are data available. Note that by equating total arrivals and total departures numbers, we assume that tourists visit one country per trip only.

[9]The general attractiveness index was adjusted in an iterative calibration. In the first iteration, the attractiveness index equals the market share of each country in world tourism. The ratio between predicted and observed tourist arrivals was used to adjust the attractiveness index. Changes in the attractiveness index follow Eq. (1).

[10]Lise and Tol (2002) analyse tourism flows from selected OECD countries to selected OECD countries. This allows them to estimate a distance elasticity. The number reported here is the average of their estimates.

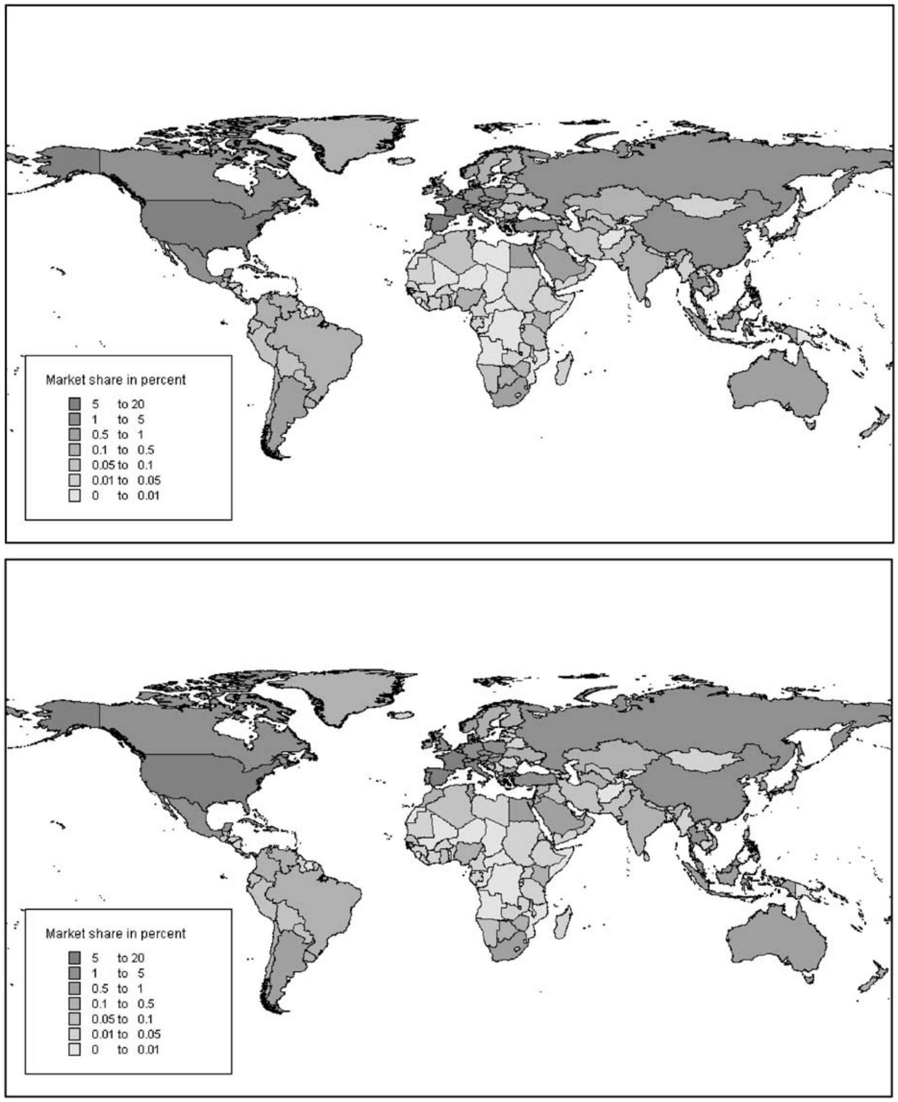

Fig. 1. The share of worldwide arrivals per country as observed (top) and modelled (bottom) in 1995.

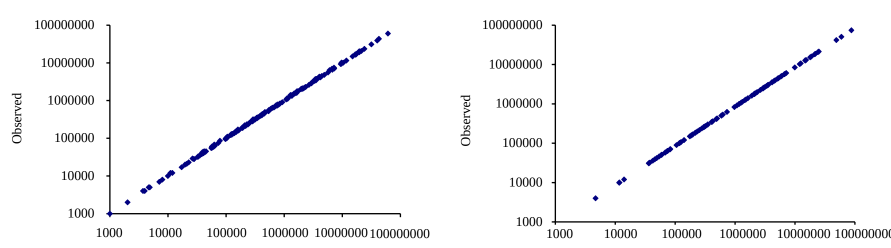

Fig. 2. Modelled versus observed arrivals (left panel) and departures (right panel) in 1995.

Bermudans travel most, on average 1.57 trips in 1995, which is far below a sensible point of saturation.[11] We report some sensitivity analyses below.

[11]For instance, each of the three authors of this paper travel substantially more than this (for what would be classified as pleasure).

3.4. Climate change

Climate change scenarios for the SRES emissions scenarios are derived with the *FUND* model (Tol, 1999). The spatial patterns are taken from the country-specific output of the COSMIC model (Schlesinger and

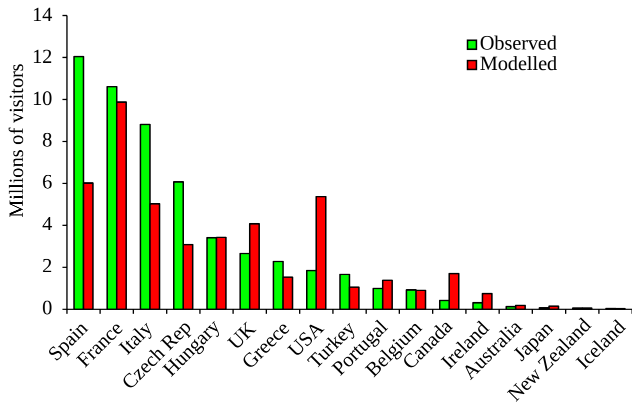

Fig. 3. The most popular destinations of German tourists as observed and as modelled.

Table 1
Market share of arrivals

	1995	2025[a]		
		P	P + E	P + E + C
France	10.79	10.62	7.73	7.67
United States	7.53	7.60	5.63	5.88
Spain	7.07	7.00	5.09	4.84
Italy	5.58	5.52	4.10	3.89
United Kingdom	4.23	4.18	3.07	3.17
Hungary	3.76	3.71	5.63	5.70
Mexico	3.50	3.59	3.71	3.16
Poland	3.46	3.40	5.25	5.52
China	3.41	3.44	7.25	8.17
Austria	3.09	3.04	2.25	2.43
Czech Rep	3.01	2.95	4.51	4.75
Canada	2.96	3.01	1.96	2.90
Germany	2.65	2.63	2.01	2.09
Switzerland	2.08	2.04	1.49	1.62
Greece	1.83	1.82	1.37	1.26
Hong Kong	1.71	1.75	2.60	2.22
Portugal	1.71	1.70	1.22	1.13
Russian Federation	1.66	1.65	2.20	3.11
Turkey	1.28	1.27	1.29	1.28
Malaysia	1.27	1.29	1.76	1.55
Netherlands	1.19	1.17	0.85	0.86
Thailand	1.17	1.21	1.69	1.49
Singapore	1.07	1.11	1.17	1.05
Belgium	1.01	0.98	0.71	0.72
Ireland	0.87	0.85	0.61	0.62

[a]Three scenarios are distinguished for 2025: population growth (P); population and per capita income growth (P + E); population and per capita income growth and climate change (P + E + C). Population and per capita income growth is according to the SRES A1B scenario (Nakicenovic and Swart, 2001; IMAGE) in 2025. Climate change is a 1 °C global warming; the spatial pattern is the average over 14 GCMs (Schlesinger and Williams, 1998).

Williams, 1998). We use the average of the 14 GCMs as our middle scenario, and the standard deviation to derive the minimum and maximum scenarios.

Table 2
Ranking of countries with the highest and lowest fractional change in tourist arrivals through development (left) and climate change (right)

	Development[a]		Climate change[b]
Maldives	5.99	Canada	1.37
Sri Lanka	5.98	Russian Federation	1.31
Bhutan	5.90	Mongolia	1.23
Nepal	5.90	Kyrgyzstan	1.16
Bangladesh	5.89	Iceland	1.15
Mongolia	5.82	Tajikistan	1.15
South Korea	5.76	Finland	1.14
Pakistan	5.75	Zimbabwe	1.14
Afghanistan	5.75	Norway	1.13
India	5.70	Zambia	1.12
China	5.63	Sweden	1.12
Seychelles	4.75	South Korea	1.07
Macedonia	4.12	Kazakhstan	1.05
Albania	4.11	China	1.04
Bulgaria	4.11	Georgia	1.04
Portugal	1.89	Guinea-Bissau	0.74
Andorra	1.89	Benin	0.74
Tuvalu	1.89	Sudan	0.74
Netherlands	1.89	Namibia	0.73
Kiribati	1.88	Chad	0.73
Marshall Islands	1.88	Gambia	0.72
Samoa	1.88	United Arab Emirates	0.72
French Polynesia	1.88	Niger	0.72
Luxembourg	1.88	Burkina Faso	0.72
Belgium	1.88	Kuwait	0.71
Iceland	1.87	Senegal	0.71
Ireland	1.87	Qatar	0.71
Virgin Islands	1.80	Bahrain	0.70
Japan	1.78	Mali	0.69
Canada	1.76	Mauritania	0.69

[a]Arrivals in 2025 without climate change (P + E) relative to 1995.
[b]Arrivals in 2025 with climate change (P + E + C) relative to without climate change.

The effect of temperature change follows from Eqs. (1) and (2), both of which have a quadratic specification. That is, if a cool country gets warmer, it first *attracts more tourists*, until it gets too warm and starts attracting less tourists. The turning point lies at 14 °C (annual 24-h average). Similarly, if a cool country gets warmer, it first *generates less tourists* until it gets too warm and starts generating more tourists. The turning point lies at 18 °C (annual 24-h average).

Fig. 4 shows the percentage change in arrivals in 2025, compared to the arrivals under the scenario of economic and population growth, for two arbitrary climate change scenarios, that is, a 1 °C and a 4 °C global warming. The first scenario is realistic; the second is for illustration only. As expected, climate change would lead to a polewards shift of tourism. Moreover, Fig. 4 shows that there will be a shift from lowland to highland tourism; the tourism sectors in Zambia and Zimbabwe, for instance, would benefit greatly from climate change. But that is not the only thing that will change: Fig. 5

Table 3
Market share of departures

	1995	2025[a]		
		P	P + E	P + E + C
Germany	15.47	14.20	10.94	10.59
United States	10.53	11.19	8.63	8.32
United Kingdom	8.68	7.97	6.14	5.96
Russian Federation	4.42	3.92	5.75	4.61
Malaysia	4.28	4.75	6.58	7.43
France	3.87	3.56	2.74	2.73
Canada	3.77	4.01	2.86	2.21
Italy	3.32	3.04	2.34	2.41
Japan	3.17	2.88	1.74	1.75
Hungary	2.71	2.31	3.97	3.90
Austria	2.63	2.41	1.86	1.76
Spain	2.62	2.41	1.85	1.90
Switzerland	2.21	2.03	1.56	1.47
Netherlands	2.13	1.95	1.50	1.47
Mexico	1.75	2.10	2.54	2.81
Sweden	1.26	1.16	0.89	0.78
Romania	1.19	1.01	1.74	1.69
Belgium	1.18	1.08	0.83	0.82
Finland	1.07	0.98	0.75	0.65
Denmark	1.03	0.94	0.73	0.69
China	0.94	0.91	2.10	1.99
Czech Republic	0.93	0.79	1.36	1.30
Poland	0.91	0.77	1.32	1.27
Taiwan	0.87	0.84	1.27	1.42
Turkey	0.83	1.25	1.32	1.31

[a]Three scenarios are distinguished for 2025: population growth (P); population and per capita income growth (P + E); population and per capita income and climate change (P + E + C). Population and per capita income growth is according to the SRES A1B scenario (Nakicenovic and Swart, 2001; IMAGE) in 2025. Climate change is a 1 °C global warming; the spatial pattern is the average over 14 GCMs (Schlesinger and Williams, 1998).

shows that not only countries closer to the poles will become more attractive for tourists, but also that those countries will generate less international tourists—as these countries become more attractive to their own citizens as well.

3.5. Distance travelled

Above, we focus on the travel pattern. The total distance travelled is also a parameter of interest, for instance, because it is closely correlated with energy use and carbon dioxide emissions. The distances between the capital cities of the countries of origin and destination are used in the estimation of bilateral tourism flows. Fig. 6 reports the travelled distances with and without climate change, for the A1B scenario. Without climate change, the distance travelled increases rapidly, in fact even more rapidly than the tourism numbers. With climate change, the upward trend is slightly slower—again largely because the heavy travellers from Northwest Europe stay closer to home. Fig. 6 also shows the maximum and minimum change in distance travelled, +14% (Singapore) and −36% (Canada) in 2075, respectively. The travel pattern is more sensitive to climate change than the total distance travelled; this is no surprise, as things cancel out in the total distance travelled.

Fig. 7 shows the change in total distance travelled for the six SRES scenarios. The difference ranges between −4% and −7% in 2075, which is small compared to the projected increase in travel. Here as well, the pattern of travel changes more than total travel.

4. Sensitivity analyses

The model and the results presented above depend on a number of parameters, each of which is uncertain. We showed the sensitivity to differences in the scenarios of population growth, economic growth and greenhouse gas emissions. In this section, we report further sensitivity analyses.

The country-specific attractiveness indices are based on distance to the power -1.7×10^{-4}, a number we have kept constant. However, one may argue that travel speed will continue to increase, and travel costs continue to fall relative to other costs. Both factors would make distance less of a deterrent. We therefore, arbitrarily, reduce the distance parameter to -0.8×10^{-4} in 2080, with a linear decline. We interpret this as decreasing relative travel costs. Fig. 8 shows the change in tourist arrivals, which, in total numbers, is relatively small. As one would expect, remote locations—which are, because of their remoteness, currently not so popular—would see a large relative increase in arrivals. This is true for the Pacific island nations, which would see their tourist numbers increase by more than 50% in 2075 relative to the case of constant travel costs. New Zealand would gain most, over 60%. This happens at the expense of countries in Europe and the Middle East, which would see a decline of up to 12%.[12] Fig. 8 also shows the change induced by climate change for the scenarios with constant and declining travel costs. The impact of climate change in 2075 on arrivals changes between −4% and +3% because of declining travel costs. With declining travel costs, the number of visitors to cool and temperate countries increases with climate change, as distant, warm countries become more accessible; visitor numbers to warm and tropical countries decrease, as tourists pass them by to fly further polewards. Note that, in the case of the alternative scenarios, the effect on climate change is small compared to the effect on the baseline.

[12]The pattern of change would be qualitatively the same but reversed in sign if travel costs would increase, say because of an international tax on kerosene.

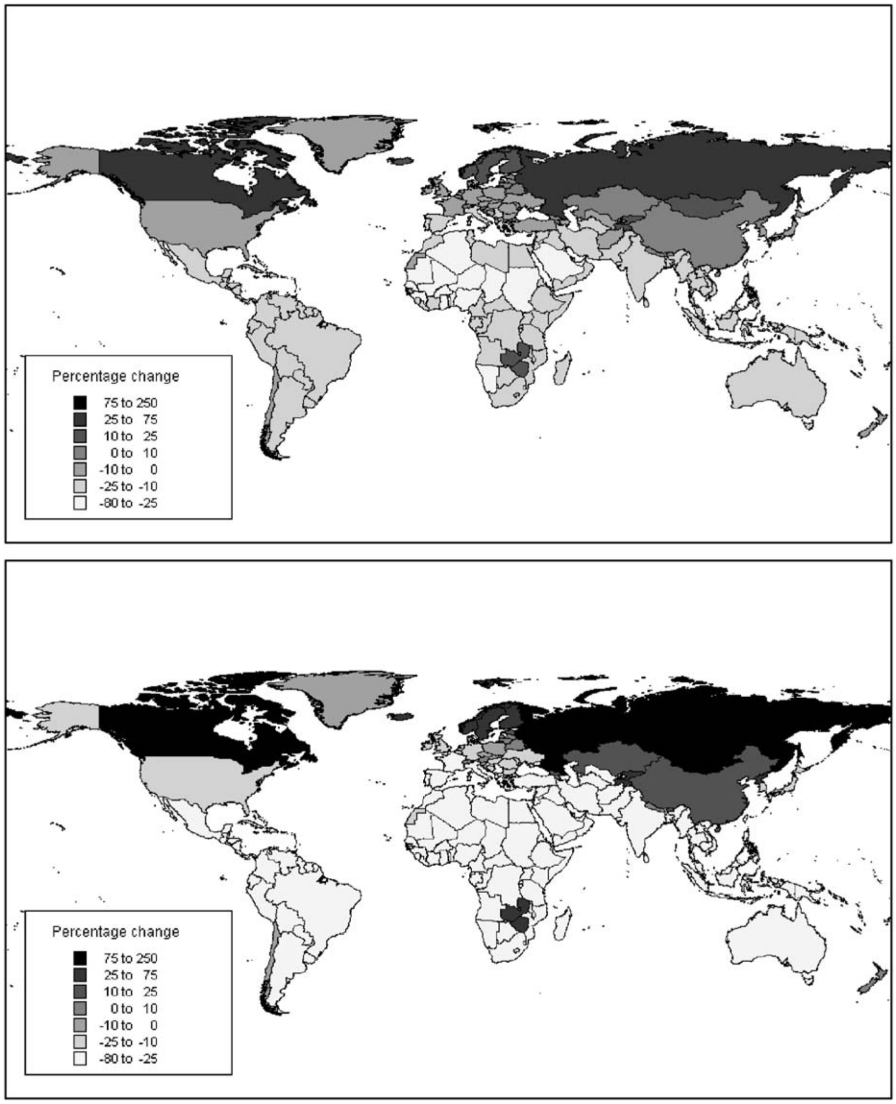

Fig. 4. The percentage change in arrivals as a result of a 1 °C (top) and a 4 °C (bottom) global warming in 2025.

In the analyses above, we use an income elasticity of tourism demand of 0.86, which is the best estimate for the cross-section of 1997. This implies that tourism is a necessary good, not a luxury good, as one would expect. Cross-section may not be the best way of estimating income elasticities. Crouch (1995) reports the results of a meta-analysis of tourism demand. He finds an income elasticity of 1.86, with a standard deviation of 1.78 (encompassing our estimate). We use this as an alternative estimate. Fig. 9 displays the results for the A1B scenario with and without climate change. Obviously, tourism grows much faster with the higher income elasticity than with the lower one. With our estimate, the average growth rate of the number of international travellers between 1995 and 2075 is 3.2% per annum; with Crouch's estimate, the growth rate is 7.5% per year.[13] For both income elasticities, the effect of temperature change on the total distance travelled is small, never exceeding 7%. However, the pattern is qualitatively different. In the A1B scenario, poorer countries grow faster than richer countries. This implies that the share of currently poor countries in the international tourism market expands much more rapidly with a high income elasticity than with a low one. As the currently poor countries are in hot places, the share of tourists heading for cool places (relative to home) increases more rapidly with a high income

[13]In 2075, the number of international trips reaches 120 billion, or about one international holiday per month per person *on average*. This is hard to imagine, as there would need to be a substantial number of people travelling much more than that. Then again, in 1930 it was probably unimaginable that Germans take on average more than one foreign holiday a year.

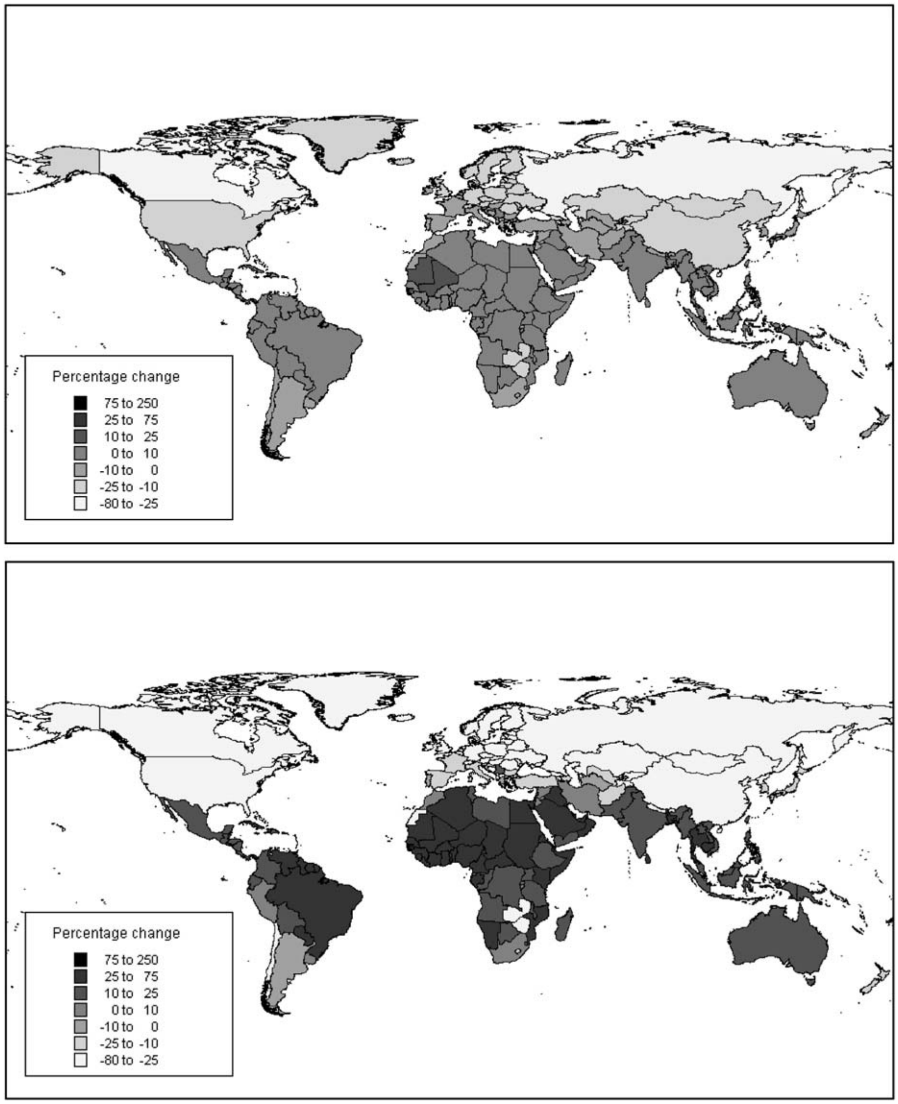

Fig. 5. The percentage change in departures as a result of a 1 °C (top) and a 4 °C (bottom) global warming in 2025.

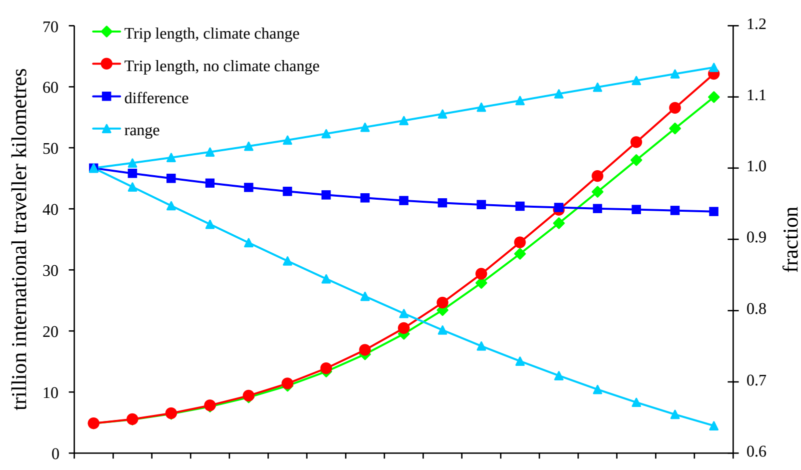

Fig. 6. The total distance travelled with and without climate change (left axis) and the difference between them for the world as a whole, and minimum and maximum difference per country (right axis); results are for the A1B scenario.

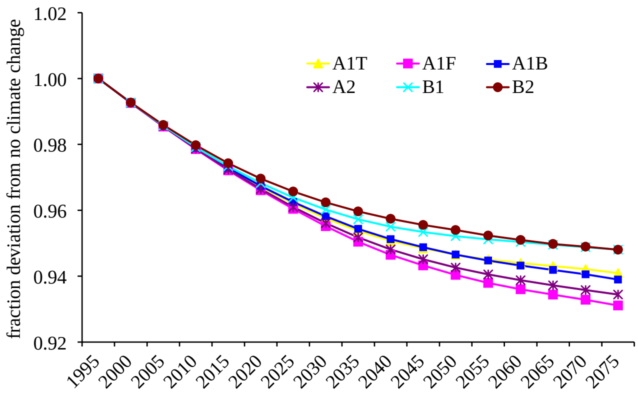

Fig. 7. Climate change induced difference in total distance travelled for the six SRES scenarios, as fraction of the total distance travelled in the corresponding scenario without climate change.

elasticity than with a low one. Climate change accelerates this. In Fig. 9, we therefore see that climate change first suppresses international tourism (for both income elasticities) but then stimulates it (for the high income elasticity).

Eq. (1) gives the sensitivity of international tourist arrivals to temperature. The parameters are uncertain. Rather than a sensitivity analysis on the parameters as estimated in Eq. (1), we take the parameters from comparable studies, which have used different data and different specifications. Lise and Tol (2002) report parameters for the world as well as for selected OECD countries.[14] Italian tourists prefer the highest temperatures (optimal temperature around 24 °C), while the globally averaged tourists prefer the lowest temperatures (optimal temperature around 20 °C); Eq. (1) suggests that the optimal temperature is around 14 °C. Fig. 10 compares the climate-change-induced change in tourist arrivals in 2075 under the SRES A1B scenario with the three alternative specifications. Comparing the world tourists of Lise and Tol (2002) to our tourists, we find that the overall impact of climate change is fairly similar; the scatter plot shows almost a line of 45°. However, the cooler countries benefit a bit more with the parameters of Lise and Tol (2002), and the warmer countries lose a bit more. Also, the minimum and maximum changes are larger; this is because the world tourists of Lise and Tol (2002) do not only prefer higher temperatures, their preferences are also sharper, that is, the attractiveness of a destination outside the optimal climate falls more rapidly than in case of the parameters reported in Eq. (1). This effect is even more pronounced in the case of the Italian tourists of Lise and Tol (2002); their preferences are so sharp that, in fact, climate change dominates the socio-economic scenario; climate change may decimate tourist numbers to almost nought, or increase arrivals by a factor 18. However, the Italian results are a sensitivity analysis only, as Italians are not representative.

[14]Maddison (2001) and Hamilton (2003) use other climate parameters than we do here. We use the average of the day and night temperatures over the entire year.

Fig. 11 shows the effects of varying the climate sensitivity. In the base case, the equilibrium rise of the global mean temperature for a doubling of the atmospheric concentration of carbon dioxide is 2.5 °C; this is changed to 1.5 and 4.5 °C. The results are as expected. Slower climate change leads to lower impacts of climate change, and faster climate change to higher impacts.

5. Discussion and conclusion

We present a simulation model of international tourism, and develop scenarios of changes in international arrivals and departures because of changes in population numbers, per capita income, and climate change. A model like this is for testing sensitivities rather than making predictions. Results are qualitative, not quantitative.

The model shows that the past growth of international tourism may well continue unabated in the medium to long term. The main driver is economic growth, and the growth of international tourism will therefore be concentrated in those regions with the highest economic growth; had we used a higher income elasticity, this conclusion would have been even stronger. Although intercontinental tourism will also grow, mass tourism is likely to continue to prefer destinations closer to home. Uncertainties about future population and economic growth, and uncertainties about elasticities and future travel costs make the projections of international tourist numbers very uncertain.

Climate change would lead to a gradual shift of tourist destinations towards higher latitudes and altitudes. Climate change would also imply that the currently dominant group of international tourists—sun and beach lovers from Western Europe—would stay closer to home, implying a relatively small fall of total international tourist numbers and total distance travelled. The changes in the patterns are greater than the changes in the aggregate numbers. The changes induced by climate change are generally much smaller than those resulting from population and economic growth are.

The model described in this paper is, to our knowledge, the first in its kind. As all early models, it leaves much to be desired. Although the model is reasonably good at reproducing current patterns of international tourism, long-term studies of tourism demand are rare—and the empirical basis of the model is therefore weak. This is even truer for the effects of climate change on

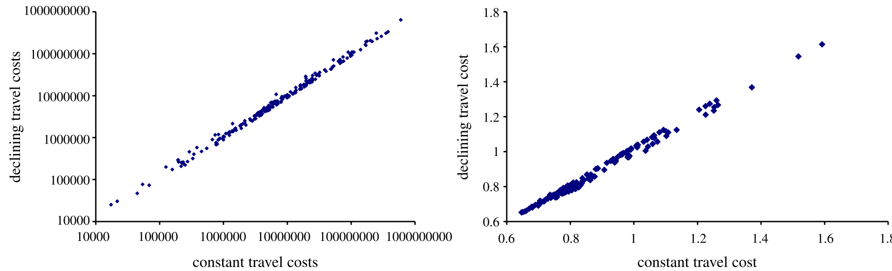

Fig. 8. Tourist arrivals per country in 2075 (A1B), constant travel costs versus declining travel costs; the left panel displays absolute numbers of travellers without climate change; the right panel displays the effect induced by climate change, expressed as a fraction of the case without climate change.

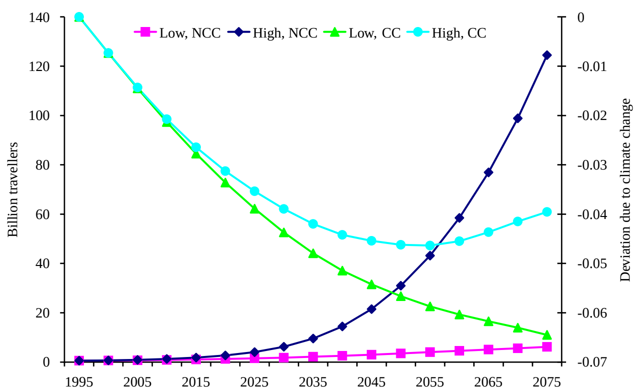

Fig. 9. The total number of international tourists in the A1B scenario with climate change (CC—right axis, fraction deviation) and without (NCC—left axis, total numbers) for the base estimate of the income elasticity of tourism demand (low) and an alternative estimate (high).

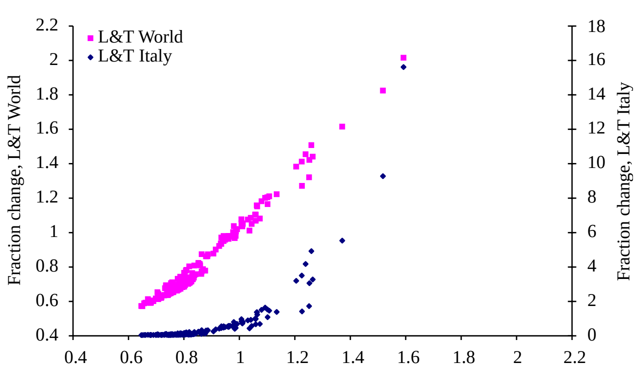

Fig. 10. Climate change induced change to tourist arrivals per country in 2075 (A1B), tourist behaviour according to Eq. (1) versus according to Lise and Tol (2002); of the latter, world average tourist behaviour and Italian tourist behaviour is shown.

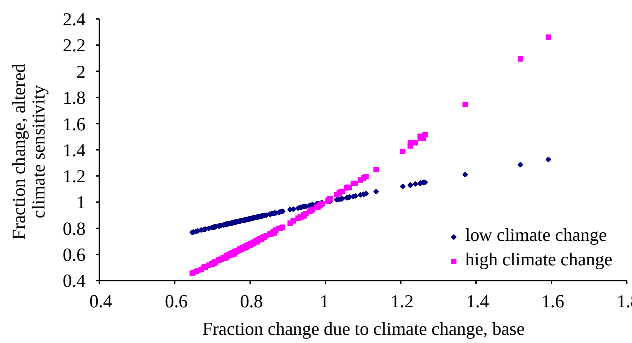

Fig. 11. Climate change induced change to tourist arrivals per country in 2075 (A1B) for medium climate change versus high and low climate change.

tourist destination choice, where the model is based on only a few studies from a limited set of countries. The projections neglect that changes in preferences, age structure, working hours and life styles would also affect tourist behaviour. The model operates at a national scale, with annual time steps. We use a single specification of the model, with sensitivity analyses on the parameters only. Particularly, we project international tourism demand with a constant income elasticity, ignoring possible saturation. This is all deferred to future research.

The paper is a hopefully convincing demonstration that, erratic as individual tourists may be, mass tourist movements can be modelled and projected into the future. As tourism is an important driving force of global environmental change, this is a step towards the prediction of human impacts on the environment and, via climate change, for example, of environmental change on human behaviour.

Acknowledgements

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