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Impacts of short-term climate variability in the UK on demand for domestic and international tourism

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ABSTRACT: The sensitivity of UK tourism to climate variability (on intra- and inter-annual scales) was investigated using empirical statistical models. A set of climate indices (mean monthly and annual temperature, rainfall and sunshine) describes present day variability in climate, while tourism demand is described by a dataset comprising domestic (monthly numbers of tourist nights) and international (annual numbers of trips abroad) tourist flows. An understanding of climate sensitivity based on real data then provided a basis for the examination of potential effects of climate change on the economically important tourism sector. Outbound flows of tourists are more responsive to climate variability of the preceding year, whereas domestic tourism is more responsive to variability within the year of travel. For outward tourism, wetter- and duller-than-average conditions in the year previous to travel seem to encourage more trips abroad. Drier- and warmer-than-average conditions increase same-month domestic trips, but a change in the direction of the association in subsequent months is indicative of inelasticity in the system. The anomalously warm year of 1995 in the UK was used to represent the potential impact of climate change. The results suggest that the generally warmer and drier conditions of 1995 benefited the UK domestic tourist industry by an estimated £309 million, relative to mean climate.

KEY WORDS: Tourism · Climate impacts · Regression analysis

1. INTRODUCTION

International tourism is one of the largest and most rapidly expanding economic activities in the world. In 2003, travel and tourism involved 691 million people internationally and generated €463 million in receipts (WTO 2004). Preliminary figures suggest that tourist arrivals reached an all-time record of 760 million in 2004 (WTO 2005). The UK is ranked 6 in terms of international tourist arrivals and third in terms of tourism expenditure (WTO 2004). In 2003, UK residents made 151 million overnight trips within the UK, spending more than £26 482 million (UKTS 2004). The tourism industry is expected to grow significantly in the future as personal income and leisure time increase, and transportation networks improve. It seems intuitive that short- and long-term variations in climate would influence the tourist industry through its interlinked effects on environment. While a large and established academic community is involved with research of tourism and leisure activities, until recently few studies were undertaken to specifically examine the influence of climate on tourism.

Research themes on climate and tourism over the last decade include: the contribution of tourism to climate change (Gossling 2002, Becken et al. 2003), the provision of climate services for tourists (Lecha & Shackleford 1997), and the impact of climate (and climate change) on the health and comfort of the tourist (Spagnolo & De Dear 2003) including tourism and water supply (Kent et al. 2002), and the environmental tourist resource (Agnew & Viner 2001, Scott et al. 2004). Research has focused in particular on tourism within coastal environments (Turner et al. 1998, Morgan 1999, Jennings 2004), mountain environments (Abegg & Froesch 1994, Mohnl 1996, Whetton et al. 1996, Harrison et al. 1999, Elasser & Burki 2002, Scott et al. 2003) and wetland areas (Wall 1998). Recent reviews of the

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literature on tourism and climate are given in Scott et al. (2005) and Gossling & Hall (2005). A variety of models have been developed to examine the impact of climate on the demand for inbound tourism, outbound tourism (Perry 2000, Maddison 2001, Lise & Tol 2002, Hamilton et al. 2005a,b) and domestic tourism (Agnew 1997, Giles & Perry 1998, Braun et al. 1999). Maddison (2001) used a utility maximisation model to examine the trade-offs between climate and holiday expenditure for British tourists. Lise & Tol (2002) report an optimum temperature of 21°C in the holiday destination of OECD tourists, with the preferred holiday climate varying according to age and income group. Hamilton et al. (2005b) use a simulation model of international tourism flows (arrivals and departures) to generate scenarios of tourist flows for the period 2000–2075. For international tourism, a shift to higher altitude and latitude destinations is anticipated, while domestic tourism is expected to increase in temperate regions where the current climate is sub-optimal.

2. DATA AND METHODOLOGY

Here, we use a 2-stage process to investigate the sensitivity of tourism in the UK to short-term climate variability. In Stage I, historic time series of tourism demand are used to explore the effect of present day climate variability on both international (outbound) and domestic tourism in the UK. In this context, climate is viewed as one element in the decision making process that can act either as a 'pull' factor—encouraging the home-grown tourist to holiday in the UK, or as a 'push' factor—encouraging the UK resident to holiday abroad. In Stage II, the climate sensitivities identified in the historic period are used to explore the potential impacts of climate change. Using the impact models developed in Stage I, we select 1995 as an historic analogue for future climate and attempt to quantify the economic impact of this unusually warm and dry year on the UK domestic tourist industry. The year 1995 was an exceptionally warm year in the UK. The 12 mo period from November 1994 to October 1995 was the warmest on record, and the summer was the driest in a record dating back to 1659 (Hulme 1997).

Step-wise regression models are used to assess the sensitivity of tourism to short-term variation in climate. In step-wise multiple regression analysis, the number of predictors to be selected and the order of entry are decided by statistical entry and removal criteria. At each stage the variables included are reassessed to determine if they contribute to the overall model of the dependent variable. This procedure has the advantage of statistically examining the effect of each candidate variable relative to those variables already included in the regression model (Draper & Smith 1966).

Tourism series are typified by long-term trends that reflect the economic conditions and social preferences for particular destinations; superimposed on these are short-term cycles related to the annual calendar of established holiday periods (school summer holidays, Easter and Christmas). Any long-term trends are removed prior to analyses to enable climate sensitivities to be more clearly identified. Several methods of detrending are considered: the extraction of residuals from a linear trendline, a running mean or polynomial (whichever is the most appropriate for each tourism series) and, the extraction of residuals from a regression model of the tourism series and other economic indicators. The residuals from long-term trends comprise the variables in the model. In the case of climate data, these residuals are the independent predictor variables. In the case of the tourism indicator, they are the dependent predictand. The models are linear across the complete range of climate. The assumption is made, therefore, that the impact of an extreme season will be predictable by the form of model described above. Some part of the predictand value in an extreme season will be caused by climate impact, and this can be predicted by the developed regression equation. This will not be the same as the actual residual (and may be smaller or larger) because the actual residual additionally contains non-climatic effects. Where information is available about the monetary value of the economic indicator, a financial figure can be estimated for the impact due to anomalously warm and dry conditions.

The monthly climate series used in the analyses are: Central England temperature (CET); England and Wales sunshine (EWS); and England and Wales rainfall (EWR). Central England temperature (CET) is an aggregate temperature series, compiled from instrumental observations in a region from the southern -border of the Midlands to western East Anglia and extending north to include central Lancashire (Parker et al. 1992). Jones & Hulme (1997) demonstrate a strong correlation between CET and most regions of the British Isles. The EWR series is compiled from 35 rain gauges across England and Wales (Wigley et al. 1984, Gregory et al. 1991, Jones & Conway 1997). The EWS is a series produced by the Hadley Centre from between 10 and 20 synoptic stations across England and Wales (Hulme 1997). Quarterly (December–February; March–May; June–August; September–November) and annual means of climate indices were also computed. Monthly climate anomalies (1980–1996) for each of the climate series are shown in Fig. 1.

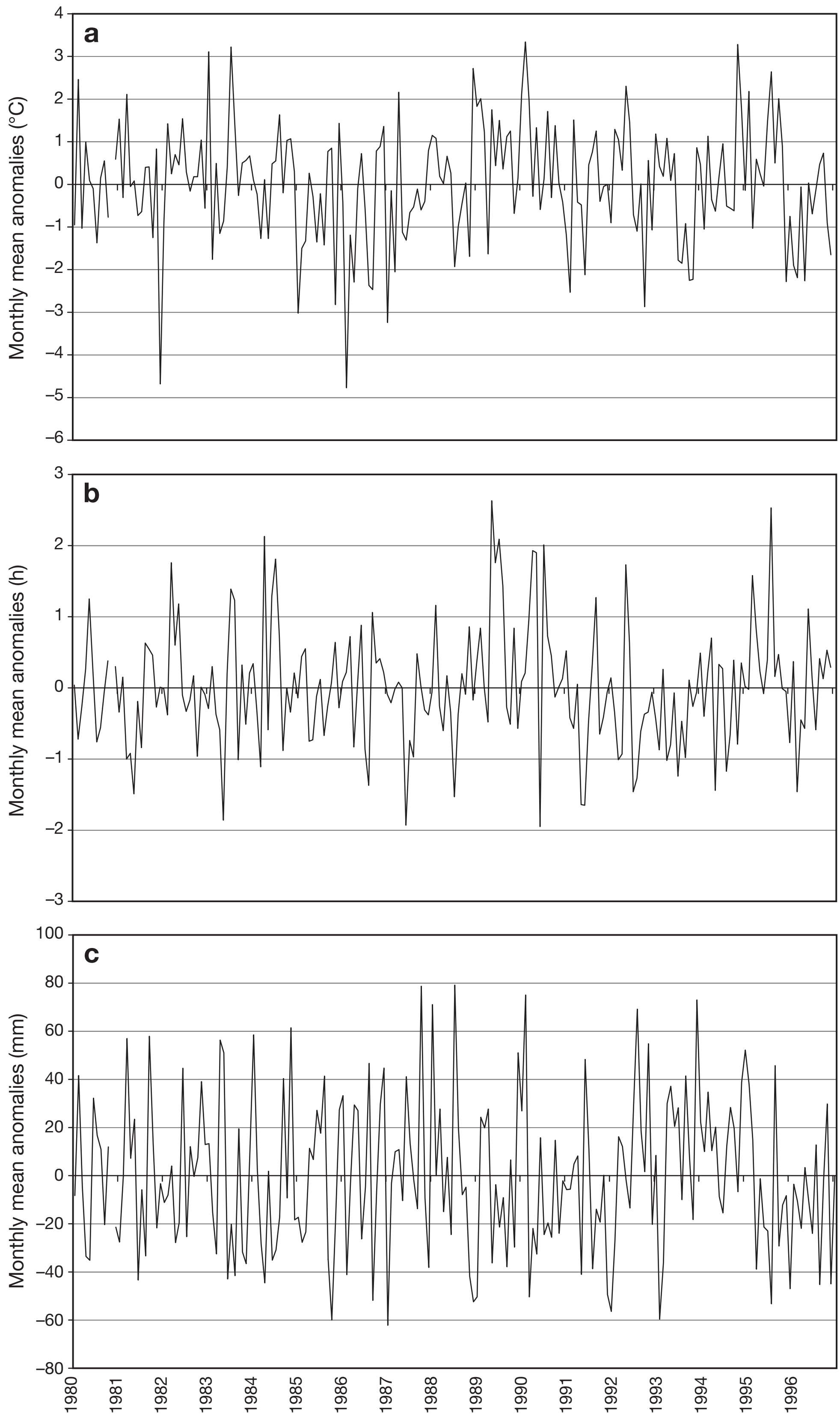

Fig. 1. Monthly climate anomalies (1980–96): (a) Central England temperature (CET), (b) England and Wales Sunshine (EWS), (c) England and Wales rainfall (EWR)

3. INTERNATIONAL TOURISM

The International Passenger Survey (IPS) is the main source of data on international tourism in the UK. It is a sample survey commissioned for the Office for National Statistics (ONS) and several other Government Departments, by the Office of Population Censuses and Surveys (OPCS). The survey collects information about a randomly selected sample of passengers travelling to and from the UK. Results are published by the ONS on a quarterly (in 'MQ6: Overseas travel and tourism') and annual (in 'Travel trends', formerly 'MA6: Overseas travel and tourism', ONS 1994–1996, CSO 1978–1993) basis. A key variable surveyed is the purpose of visit, classified into 4 main categories: (1) holiday; (2) business; (3) visiting friends and relatives; and (4) other purposes. IPS data are collected continuously throughout the year, but are only processed quarterly by 'weighting' to give a national total estimate, so that the minimum period over which detailed analyses are made available is a single quarter. Sampling errors of the 1994 IPS are given as ±1% for overseas residents visiting the UK, and ±0.7% for UK residents travelling abroad.

From the available series, we selected annual data (numbers of trips) for outward travel from the UK to all countries (international: INT), to provide a general view of the influence of weather on international tourism. The outward tourism series covers the period 1972–1996 (Fig. 2). A long-term upward trend is apparent, from a base of 7.4 million trips per year in 1972 rising to 27 million trips per year in 1996.

It is very unlikely that climate variability is the only or even the main influence on tourism. Therefore, the relationship with other explanatory variables was also explored, as a means of adjusting the tourism series prior to analysis with climate variables. The other explanatory variables considered are: (1) for outward tourism—exchange rates, UK GDP, consumer prices in the destination country, and UK retail prices; (2) for domestic tourism—UK GDP, retail prices, and exchange rates.

3.1. Exchange rates

Two series were considered: (1) Sterling exchange rates, and (2) exchange rates of the European Community (EC) in ECU (European Currency Unit, a composite monetary unit consisting of a basket of EC currencies that served as the predecessor to the Euro). Both datasets are included, since it is uncertain how differences that exist between these 2 series may affect tourism. We expect sterling exchange rates to be negatively related to domestic tourism, and positively related to outward tourism. Similarly, increases in the ECU exchange rate for other countries' currency should negatively affect tourist flows from the UK. Exchange rates of the ECU (1971–1996) have been obtained from EUROSTAT (1997a) for Germany, Spain, France, Italy, and the US. Sterling exchange rates have been obtained for the major currencies: US Dollar (1969–1997), French Franc (1969–1997), German Mark (1969–1997), Italian Lira (1969–1997), Spanish Peseta (1973–1997), ECU (1984–1997), and the Sterling Exchange Rate Index (1969–1997; 1985 = 100). These were extracted from various sources: 'Financial statistics' (ONS 1978–1997), 'Economic trends' (ONS 1971–1996), and the 'Annual abstract of statistics' (ONS 1972–1998).

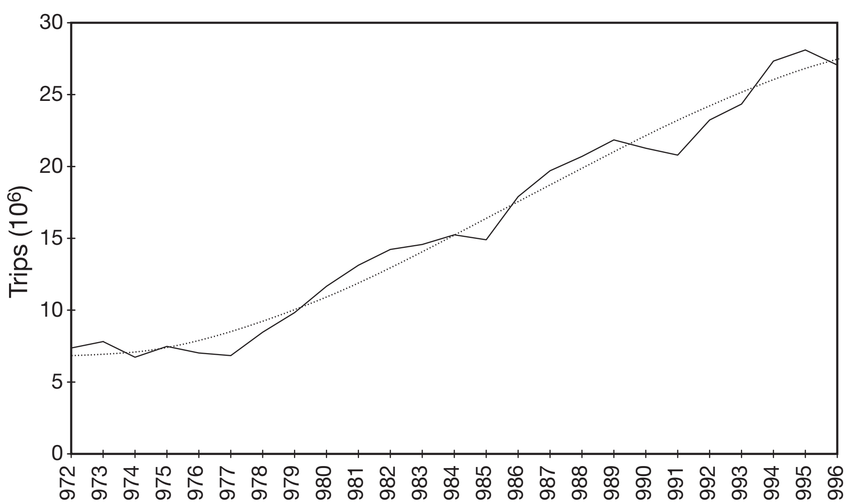

Fig 2. Outward tourism; dotted line: polynomial fit to data for illustrative purposes only (sources: Central Statistical Office 1978–1993; Office for National Statistics 1994–1996)

3.2. UK retail prices

UK retail prices are available for petrol and oil (1974–1997), entertainment and recreation (1974–1997), fares and other travel costs (1974–1997), and the general Retail Price Index (RPI; 1972–1997). These are expressed as monthly indices in the 'Monthly digest of statistics' (ONS 1971–1997) and have been averaged to compute an annual figure. As a measure of the trend in prices for tourism-related goods relative to other goods and services, a ratio of price indices for petrol and oil, for fares and other travel costs, and for entertainment and recreation were also computed as a ratio of the general RPI. We expect the general RPI and domestic tourism to be negatively related, with increasing costs deterring holiday trips. There may be a positive relationship with outward international tourism flows, i.e. as UK holidays become more expensive due to rising prices, holidays abroad may become more attractive.

3.3. Indices of consumer prices for European countries

These include a general consumer price index, hotel charges, restaurant prices and travel prices (data published in OECD 1972–1996, 1998). The indices are expressed as a percentage year-on-year change for France, Germany, Italy, Spain, and the UK (1971–1997 for general consumer prices, and 1971–1994 for other indices). International tourism is dependent to some extent on the relative level of prices, which are themselves partially a function of exchange-rate relationships and inflation-rate differentials (EUROSTAT 1995a,b). As prices increase in another country we would expect that tourism from the UK to the destination country might decrease.

3.4. Gross Domestic Product (GDP)

This variable is used as a measure of per capita wealth, and thus economic viability for tourism in general. Growth in GDP is in general favourable for tourism (EUROSTAT 1995a) but, at the same time, if disposable income increases, expensive tourist trips abroad may rise at the expense of domestic tourism. As a measure of relative wealth it may be useful to compute the ratio of UK GDP to the GDP for other countries in the analysis. UK GDP (GDP at factor cost) is extracted from the 'Monthly digest of statistics' (ONS 1971–1997), while GDP for other countries (GDP at market price per head and current exchange rates in ECU) is extracted from 'EUROSTAT: National accounts' (EUROSTAT 1995c, 1997b,c). GDP for the UK and for other countries (Germany, Spain, France, Italy, and the US) is available as a series from 1970 to 1996.

The outward tourism series (Fig. 2) is clearly affected by explanatory variables additional to climate, showing a strong upward trend with some evidence of cyclicity superimposed. To fully investigate the contribution from climate alone, some means of removing variation in the series resulting from social and economic factors must be found. Several possible methods were considered:

- Extracting residuals from a linear trend or polynomial fit;
- Subtracting the most significant standardised non-weather explanatory variable (e.g. GDP from the standardised tourism series);
- De-trending the most significant standardised non-weather explanatory variable (by computing residuals from a linear or polynomial fit) and subtracting from the similarly de-trended and standardised tourism series; and
- Computing residuals from a step-wise multiple regression using all significant standardised non-weather explanatory variables as predictors of the tourism series.

Exploratory correlations were first used to identify significant non-weather influences on annual outward tourism (Table 1). The ECU Sterling exchange rate demonstrates a significant negative association with outward tourist flows ($r = -0.947$; $p < 0.01$), while significant positive associations are shown between outward tourism and per capita GDP at market prices and current exchange rates, the RPI, the ECU exchange rate for Spain and the UK, and UK GDP. Pronounced autocorrelation (at an annual lag, $r = 0.987$; $p < 0.01$) indicates the importance of persistence or memory in the tourism series.

The value of each method for extracting residuals from the tourism series may be judged by its performance in the regression model. That is, methods producing a higher adjusted R^2 (the coefficient of determination) are viewed to be more appropriate, since they allow the influence of climate to be seen more clearly. The most appropriate method of de-trending, as described above, is found to be the simplest means of adjusting the series, i.e. by computing residuals from a linear or polynomial fit.

Table 1. Correlation coefficients (r) for unadjusted international tourism series annual number of trips abroad (INT) and a selection of economic indices. All correlations significant at p = 0.01 (2-tailed). GECU: per capita Gross Domestic Product at market prices and current ECU (European currency unit) exchange rates for 15 EU member countries (GECU_15) and for the UK (GECU_UK). RPI: retail price index; PPS: purchasing power standards

Non-climate indicator	r
Annual lag in tourism series	0.987
Polynomial fit	0.990
ECU sterling exchange rate	–0.947
GECU_E15	0.981
GECU_UK	0.972
General RPI (1987 = 100)	0.978
Ratio of entertainment and recreation RPI to general RPI	0.981
Ratio of fares RPI to general RPI	0.891
RPI for entertainment and recreation (1987 = 100)	0.978
RPI for fares (1987 = 100)	0.985
RPI for petrol and oil (1987 = 100)	0.952
Spain ECU exchange rate	0.950
UK ECU exchange rate	0.835
UK GDP (1980 = 100)	0.974
UK per capita GDP (PPS)	0.986

Step-wise multiple regression was performed with the annual tourism series as the predictand and climate variables at 0 lag, and with monthly and annual lags as predictors. Parsimony was considered an important objective since the regression line may be unstable if too many independent variables are included in the model when the sample number is relatively small. In this regard, step-wise procedures and expert judgment were used to select an optimal set of independent variables.

Two alternative regression models of climate and outward tourism are presented (Table 2). Table 2a shows results for the unadjusted tourism series. The predictors comprise a tourism persistence term (an annual lag in the tourism series, INT_p), the annual trend (YEAR), and the mean annual and August CET in the previous year ($CETANN_p$ and $CETAUG_p$, respectively), and account for an adjusted 99.5% of variance in annual outward tourism. However, a tolerance of 0.04 for INT_p and YEAR indicates an unacceptable level of multi-colinearity and, consequently, the relative strength of the explanatory variables and their joint effect are judged unreliable.

In the second model presented (Table 2b), the tourism series is adjusted prior to analyses to induce stationarity. Influential factors for adjusted outward tourism seem to be rainfall and sunshine in the previous year to travel, with wetter annual conditions and a duller-than-average July encouraging more trips abroad. An examination of the partial correlation coefficients suggests that there is little difference between the relative contributions of these climate indices. A third term (an annual lag in the tourism series, INT_p) was included to capture any remaining memory in the tourism series not accounted for by the polynomial fit. There is no obvious sign of multi-colinearity among the predictor variables (tolerance varies between 0.5 and 0.97, and the condition index varies between 1 and 1.7). Further, inspection of a normal probability plot and a scatterplot of the standardised residuals and predicted values shows no serious violations of the underlying assumptions of regression analysis. We might expect that long-haul holidays are booked further in advance than domestic holidays and would therefore be more influenced by the climate of the previous year than the same year of travel. In keeping with this hypothesis, the results demonstrate that rainfall and sunshine in the year prior to travel is the only significant aspect of climate for international holiday tourism.

Table 2. International tourism (annual number of trips abroad by UK residents). (a) Unadjusted series. Adjusted $R^2 = 0.995$; $F_{4,19} = 1063.38$, $p < 0.05$; Durbin-Watson statistic (D-W) = 2.09. (b) Adjusted tourism and climate series. Adjusted $R^2 = 0.700$; $F_{3,20} = 18.91$, $p < 0.05$; D-W = 2.72. $_p$: previous year; INT: international tourism series annual number of trips abroad; CET: Central England temperature series; EWS: England and Wales sunshine; EWR: England and Wales rainfall; YEAR: annual linear trend; ANN: mean annual value; AUG: mean monthly climate value for August; JUL: mean monthly climate value for July

Independent variables:	Beta (standardised) p < 0.05	Partial correlation
(a) Unadjusted series		
INT_p	0.648	0.882
$CETANN_p$	−0.065	−0.511
YEAR	0.380	0.746
$CETAUG_p$	−0.066	−0.551
(b) Adjusted tourism and climate series		
$EWRANN_p$	0.432	0.592
$EWSJUL_p$	−0.417	−0.583
INT_p	0.370	0.581

4. DOMESTIC TOURISM

The domestic tourism series comprises monthly numbers of tourist nights (all accommodation types) spent in the UK by UK residents (in millions) from January 1980 to December 1995 (Resource Centre for Access to Data on Europe [Rcade] database, compiled from EUROSTAT sources). Although values from 1988 and 1989 are missing in the Rcade series, the figures are very similar to the UK Tourist Survey (UKTS). Averages for the overlapping period of the UKTS and Rcade series were computed, and were not found to be significantly different. UKTS data were therefore used to fill in gaps in the Rcade series and update the series to 1996 (Fig. 3). In 1984 the UKTS was re-based; total number of tourism nights was 550×10^6 for the old series, and 565×10^6 according to the new series. The old series was adjusted by the ratio of these 2 numbers. Since the UKTS was changed in 1989, it is possible that data after 1988 are not directly comparable to those in the preceding period. A dummy term was therefore introduced—DUMMY88—having a value of 1 for each year up to and including 1988 and 0 thereafter.

4.1. Exploratory analysis

Without adjusting the series for non-stationary processes and seasonal cycles, domestic tourism and same-month CET appears to be non-linear (Fig. 4). However, the association is clearly linear when the series are adjusted for trend and seasonality, indicating the importance of accounting for these effects within the assessment of climate sensitivity. A regression model can be developed that uses the unadjusted tourism series and includes a term (the number of tourism nights in the

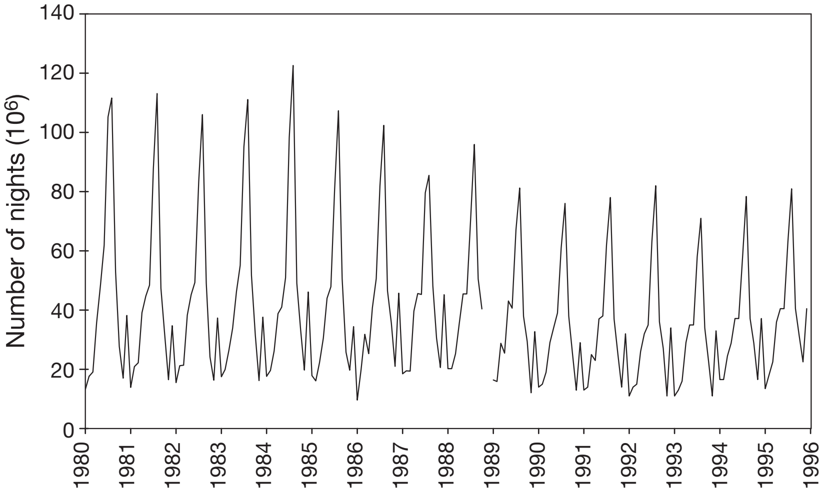

Fig. 3. Monthly domestic tourism in the UK, 1980–1996 (source: Resource Centre for Access to Data on Europe [Rcade]; United Kingdom Tourist Survey [UKTS])

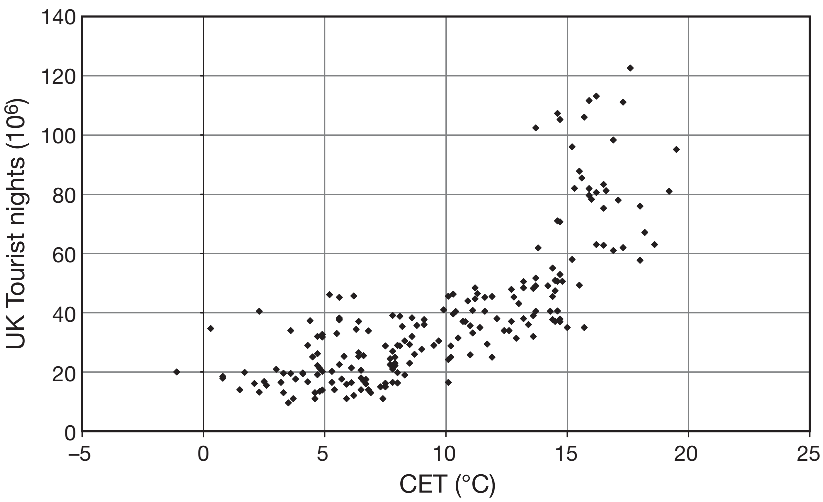

Fig 4. Domestic tourist nights and same-month Central England temperature (CET)

previous month, TN_p) to capture trend and seasonality in the predictand. In this case, the step-wise procedure selects only 1 significant climate variable: same-month CET (Table 3). The dominance of socio-economic factors relative to the influence of climate is indicated by the partial correlation coefficients of 0.937 and 0.173 for TN_p and CET respectively. However, it is likely that non-stationary processes (particularly in the tourism series) and the presence of strong seasonal cycles in both series have affected the regression estimates. In addition, it is hypothesised that the association between domestic tourism and climate may vary throughout the year, a hypothesis that cannot be tested with the non-seasonal model. Subsequent regression models are therefore developed using stationary data on a month-by-month basis.

For each month of the time series, a declining trend was observed (not shown) in the domestic tourism series. The slope of this trend was steepest in July and August, and gentlest in autumn and winter. A change in survey design in 1989 introduced non-homogeneity into the domestic tourism series. In an effort to create a homogenous series while maximising the sample size, *Z*-scores for the tourism data were computed, first for the period 1980–1988, and second for the period 1989–1996. Residuals from a linear trend were then extracted on a month-by-month basis. This is the simplest method of de-trending and seems to fit the data reasonably well. A polynomial fit was not used for the domestic series since there are only a maximum of 17 values for each month, and possible distortion effects at the beginning and end of the series would be important. The adjusted time series for the complete period is shown in Fig. 5.

Correlation coefficients were computed between the domestic tourism residuals and climate anomalies for each month. Of the climate variables considered, temperature clearly has the most important influence on domestic tourism decisions. However, the direction of impact is not so easily understood. In general, association with temperature in the same season is positive, whereas an association with temperature in a previous season is negative. For example, a positive relationship is found between domestic tourism in April and temperature in April (Fig. 6), and a negative relationship between domestic tourism in July and temperature in March (Fig. 7). This suggests that when conditions are cooler than normal in a particular season, people may decide to postpone a domestic holiday until the next season in hope of better weather. Conversely, if conditions are warmer than normal, tourism levels rise in the same season.

Table 3. Regression model for unadjusted domestic tourism (monthly tourist nights) and climate series. Adjusted R^2 = 0.948; $F_{2,184}$ = 1722.98, $p < 0.05$; D-W = 1.618; tolerance = 0.423. $_p$: previous year; TN: unadjusted tourism nights; CET: same-month Central England temperature

Independent variables:	Beta (standardised) $p < 0.05$	Partial correlation
TN_p	0.927	0.937
CET	0.061	0.173

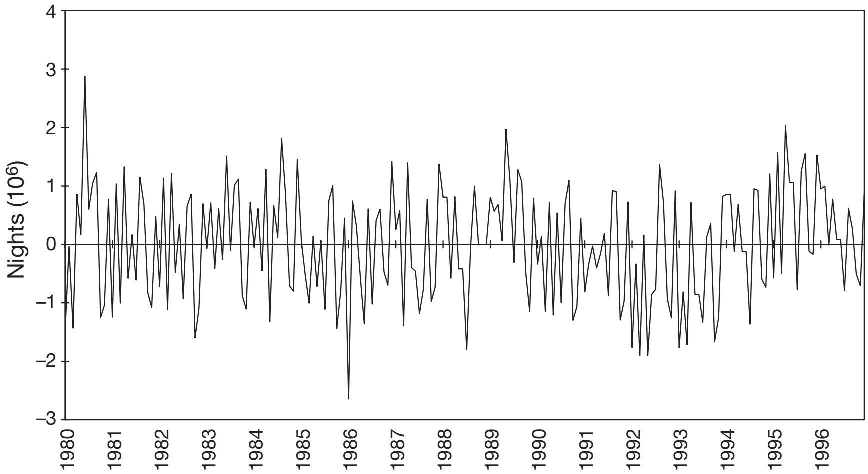

Fig. 5. Adjusted monthly domestic tourism in the UK, 1980–1996

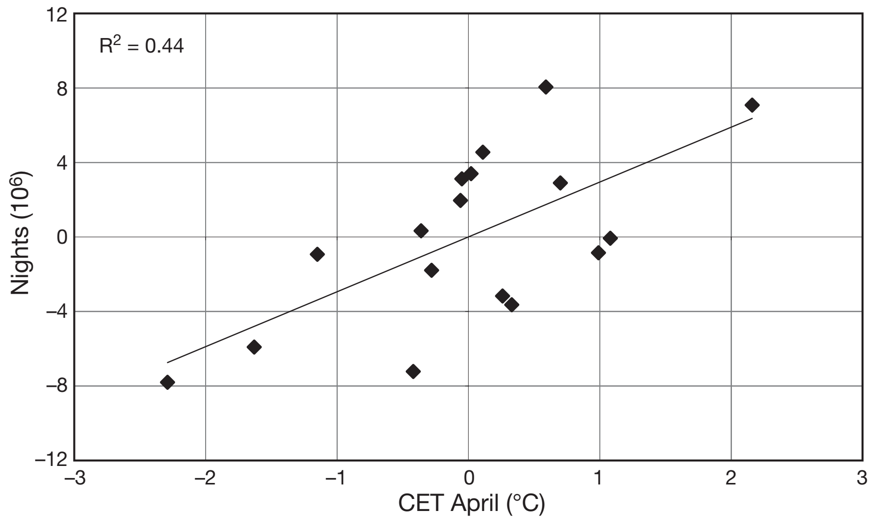

Fig. 6. Tourism in April and April Central England temperature (CET)

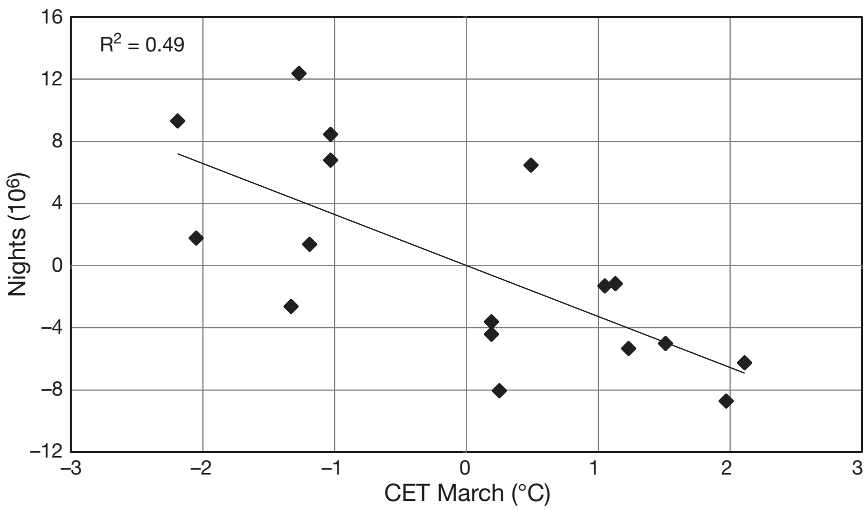

Fig. 7. Tourism in July and March Central England temperature (CET)

4.2. Regression models

Domestic tourism in March and April appears particularly sensitive to short-term variation in climate (Table 4), with between 70 and 76% of variance explained by climate indices, after adjusting for trend and seasonality. It is possible that fewer holidays are booked in advance at this time of the year, allowing greater spontaneity of booking in accordance with prevailing climate conditions. In contrast, none of the candidate predictor variables met the criteria to be entered into the regression models for domestic tourism in February or October. These are less popular months for holidaying in the UK, and it is likely that factors other than climate determine demand.

The tourism series, lagged by 1 mo, was offered as a candidate predictor (in addition to climate variables) in the step-wise regression models. Although linear trends in tourism nights were accounted for prior to analysis, the selection of this variable in the regression models for 5 months of the year (January, March, August, November and December) suggests that 'memory' in the tourism series remains a significant factor in determining the level of tourism in subsequent months (Table 5). Indeed, for August tourism, once the number of tourist nights in July has been included in the model, climate is not a significant factor in explaining remaining variance. Thus, for the UK, domestic tourism in February, August, and October is not responsive to short-term climate variability.

In terms of the decision to holiday in the UK, the climate of the preceding few months seems more critical than longer time periods. However, what is not so apparent is the direction of climate impact. Autumn tourism aside, the direction of climate impact is positive with temperature in the same month (January, April and December) and negative with temperature in previous months (March and June). The partial correlation coefficients for domestic tourism and temperature vary from −0.57 for April CET and

Table 4. Monthly regression models for adjusted domestic tourism (TN): summary statistics. Adj: adjusted; D-W: Durban-Watson statistic; Tolerance: measure of collinearity; VIF: variance inflation factor

Month	Adj R^2	F	p	No. of predictors	df	D-W	Tolerance	VIF
Jan	0.671	10.5	0.001	3	11	2.24	0.87–0.94	1.06–1.15
Feb[a]	–							
Mar	0.700	12.3	0.000	4	11	2.90	0.79–0.94	1.06–1.20
Apr	0.760	12.7	0.001	3	12	1.91	0.80–0.93	1.08–1.26
May	0.203	4.8	0.045	1	14	2.37	1	1
Jun	0.282	6.9	0.020	1	14	1.23	1	1
Jul	0.413	11.5	0.004	1	14	1.20	1	1
Aug	0.472	14.4	0.002	1	14	1.71	1	1
Sep	0.594	12.0	0.001	2	13	1.88	0.54	1.85
Oct[a]	–							
Nov	0.656	13.4	0.001	2	11	2.13	0.87	1.15
Dec	0.821	20.9	0.027	3	10	2.73	0.91–0.98	1.02–1.09

[a]No variables met the entry criteria

June tourism, to –0.81 for February CET and March tourism. With the exception of March domestic tourism, sunshine is not as strong an indicator of domestic tourism as temperature and rainfall. It is selected as a significant independent variable in only 3 of the monthly regression models (January, March and April). However, sunshine (mean for January and February) assumes the greatest contribution to tourism in March (partial correlation 0.84; $p < 0.05$). Rainfall has a significant weak to moderate contribution (partial correlation between 0.38 and –0.67; $p < 0.05$) in 5 months of the year, the direction of impact being negative with rainfall in the same month and positive with rainfall in previous months.

Changes in the direction of climate impact for same-month associations compared to previous-month associations may indicate a degree of inelasticity in the system. The results suggest that when conditions are wetter, cooler and duller than average between January and April, holidays are postponed for a few months in the hope of better conditions.

Table 5. Variables included in the monthly regression models. $_p$: previous year; PMA: prior moving average; TN: adjusted tourism nights; DUMMY88: dummy variable with value of 1 up to 1988 and 0 thereafter. See Table 2 for further abbreviations. Examination of normal probability plots, and standardised residuals from regression models, indicate no serious violations of underlying assumptions of regression analysis. Climate indices in **bold**

Month	Independent variables	Beta (standardised) p < 0.05	Partial correlation
Jan	TNDEC$_p$	0.845	0.840
	EWSJAN$_p$	–0.457	–0.650
	CETJAN$_p$	0.410	0.616
Mar	**EWSPMA$_{Jan–Feb}$**	0.709	0.835
	CETFEB	–0.638	–0.811
	DUMMY88	–0.460	–0.692
	TNFEB	0.344	0.615
Apr	**CETAPR**	0.643	0.636
	EWRPMA$_{Jan–Mar}$	0.639	0.380
	EWSJAN	–0.376	–0.287
May	**EWRPMA$_{Feb–Apr}$**	0.506	0.506
Jun	**CETAPR**	–0.574	–0.574
Jul	**EWRJUL**	–0.672	–0.672
Aug	TNJUL	0.712	0.712
Sep	**CETPMA$_{Jul–Aug}$**	1.075	0.800
	EWRJUL	0.573	0.579
Nov	TNOCT	0.555	0.692
	CETOCT	0.465	0.626
Dec	TNNOV	0.755	0.895
	EWRPMA$_{Sep–Nov}$	0.638	0.854
	CETDEC	0.404	0.724

5. POTENTIAL IMPACTS OF CLIMATE CHANGE

We explored the use of the UK domestic holiday tourism expenditure series to illustrate the monetary impact of extreme warmth on tourism. The series was extracted from the UKTS. The original data were expressed as monthly percentages of annual total expenditure (£ million). We converted these figures to monthly expenditure in £ million. Fig. 8 shows the monthly tourism expenditure series from 1989 (the start of the new UKTS) to 1996. Annual total tourism expenditure exhibits a gradual upward trend from £7410 million in 1989 to £9365 million in 1996. This trend is more pronounced in the shoulder tourist seasons.

There are clearly defined seasonal cycles in monthly expenditure, peaking each year in August and reaching a nadir in January. A minor peak in expenditure is observed each year in December. With such a short series we cannot analyse the months separately, since only 8 data points would be available for each set of analyses. Nor can we usefully perform an analysis of all expenditure and climate series since the results would be dominated by the strong seasonal cycles. Instead, we used the longer tourist bed-nights series to

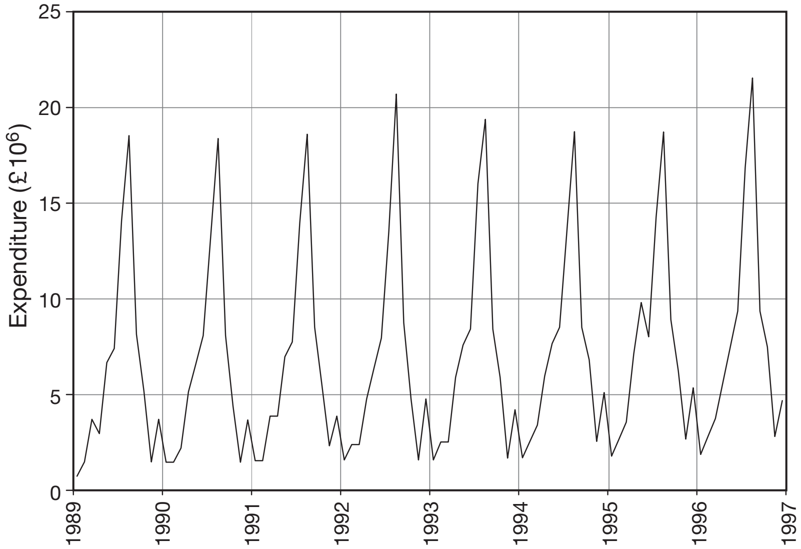

Fig. 8. UK monthly domestic holiday expenditure, 1989–1996 (source: UKTS)

estimate the potential impact of climate change on a month-by-month basis and convert this to a monetary impact using the UKTS tourism expenditure series.

The monthly climate residuals for 1995, an anomalously warm and dry year, are used to represent the potential impact of climate change. The regression models developed in Section 4 are used to estimate the monthly percentage difference in tourist nights for 1995 climate indices relative to mean climate indices. Assuming that an increase in tourism bed-nights will be accompanied by a pro rata increase in expenditure, the monthly impact in bed-nights is then converted to monetary terms (£ million) using the domestic holiday expenditure series. The economic impact is only estimated for those months for which a significant climate signal has been identified in the tourism series (Section 4.2 , Tables 4 & 5).

Overall, the warmer drier conditions of 1995 are estimated to have benefited the UK domestic tourism industry (Table 6). In percentage terms, the greatest gains in bed-nights are seen for April and October (19 and 15% increase for 1995 climate indices relative to mean climate, respectively). Although the regression models estimated that warmer than average conditions in April 1995 increased tourism nights in April (perhaps through system inelasticity), a decrease (3.6% relative to mean climate) was estimated for tourism in June (perhaps through system inelasticity).

Tourism expenditure displays a similar seasonal pattern to tourism bed-nights, with a July and August peak corresponding to the school holidays. Therefore, although the percentage change in July bed-nights relative to the mean is ranked fifth, this translates to the second-largest monthly impact in monetary terms (+£84 million). April tourism has the highest monetary increase (+£98 million), corresponding to the typical time of the Easter vacation. The overall estimated impact of an anomalously warm year is an increase of £309 million in tourism expenditure.

Although the analysis is indicative of the potential impacts of generally warmer and drier conditions on present-day tourism, historical analogues should not be viewed in isolation, but should be considered in conjunction with future scenarios of how social and economic conditions may evolve in future decades. As long as climate-sensitivities are identified and modelled at appropriate scales of analyses, and the interrelationships between climate, tourism and other environmental, social, economic and political factors are evaluated, it is likely that the tourist industry will adapt to future climate change.

Table 6. Estimated monthly impacts of an anomalously warm year (1995) on domestic bed-nights. Source of expenditure data: UKTS (1991–95)

Month	(1) Estimated tourism nights for 1995 climate (million)	(2) Estimated tourism nights for average climate (million)	(1) Expressed as a percentage of (2)	Mean monthly expenditure £ million	Estimated impact £ million
Jan	13.9	12.7	109.1	158	14
Mar	20.6	20.0	102.8	288	8
Apr	41.4	34.8	119.0	513	98
May	40.0	39.0	102.3	704	16
Jun	44.3	46.0	96.4	815	–30
Jul	65.7	62.0	106.0	1407	84
Sep	52.4	49.5	105.8	847	49
Oct	15.1	13.1	115.4	192	29
Dec	44.5	40.8	108.9	433	39
Total					309

6. DISCUSSION AND CONCLUSIONS

A 2-stage approach was used in this analysis, by firstly adjusting the tourist series for non-climate influences, and secondly examining the remaining variance for the presence of a climate signature. International tourism is generally less spontaneous than domestic tourism with bookings made well in advance of the time of travel. It is therefore not surprising that the association is stronger with the climate of the year previous to travel than that of the current year. Rainfall and sunshine have a greater impact on international tourism than temperature. Wetter annual conditions and a duller-than-average July in the year prior to travel appear to encourage more trips abroad.

Rainfall and temperature indices are appropriate climate indicators of domestic tourism. In general, the models indicate that the association with rainfall in the same month is negative, whereas an association with rainfall in a previous season is positive. Wetter- and cooler-than-average conditions between January and April seem to encourage more holidays to be taken at other times of the year. Tourism in March and April seem most responsive to climate variability, while tourism in February, August and October are least responsive. Using the anomalous warmth of 1995 to represent the potential impact of climate change, the results suggest that the generally warmer and drier conditions of 1995 (especially in spring and summer) benefited the tourist industry by an estimated £309 million relative to mean climate. The percentage impact of the anomalous warmth of 1995 in terms of tourist nights is least in June (–3.6%) and greatest in April and October (+19% in April; +15% in October). Although the monetary impact of the unusual warmth of 1995 is negative for June (–£30 million), it is positive for the other months of the year for which a climate signal has been identified, ranking first for April (+£98 million) and second for July (+£84 million).

Giles & Perry (1998) highlighted (in a qualitative sense) the benefits of the anomalously warm weather of 1995 in enhancing the image of the UK as a tourist resort. Agnew (1997) quantified the costs of this anomalously warm year to the UK tourist industry. It was concluded that while the number of trips and occupancy rates increased in 1995, the anomalous warmth of 1995 cost the industry an estimated £239 million. This figure was based on regression analyses of quarterly unadjusted expenditure data. The expenditure series included travel costs paid by an employer on behalf of a worker away on business, which may have obscured some of the climate sensitivity. In addition, the regression estimates developed from a seasonal analysis of such a short time series may be unreliable. Until longer expenditure time series become available, it may be more appropriate to base a cost analysis on the models developed for the longer series of tourism nights or bed occupancy rates.

There are a number of sources of error in the approach we have taken. One set of errors surrounds the processing of the data. For example, the removal of non-climate influences from the raw data sets is difficult and requires subjective decisions that may affect the outcomes of analyses. These difficulties are heightened by the relatively short length of the tourism series (17 yr in the case of domestic tourism). A further set of problems concern the integrity of the long-term tourism series. First, it is difficult to account for changes in base, especially if the overlap period is short. Second, a change in survey technique and design may mean that subsequent values in the tourism series are not directly comparable to previous values. Third, there may be step-like changes in the series resulting from world shocks such as the terrorist attack in New York in September 2001, the effect of severe acute respiratory syndrome (SARS) and the Iraq war in 2002, and the tsunami in Asia in December 2004. Despite these drawbacks, the datasets used here are the best available for our purpose. The concerns regarding data quality can be addressed by improvements in data collection techniques, and by careful documentation of non-climatic shocks.

There is no doubt that climate variability and change are both issues that should be of concern to the tourism industry, and this is amply demonstrated even by the brief analyses presented here. At present, these challenges are viewed within the industry as long-term global problems in a sector in which strategic decisions are made in the short-term. Tourism models of climate sensitivities based on real data provide a baseline against which adaptive responses to future climate variability and change can be evaluated. Armed with such knowledge of present-day climate sensitivities, the tourist industry will be better equipped to minimise the risks of climate change and capitalise on the benefits.

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