IMPACT OF CLIMATE ON TOURIST DEMAND

WIETZE LISE [1] and RICHARD S. J. TOL [2, 1, 3]

[1] *Institute for Environmental Studies, Vrije Universiteit, De Boelelaan 1115, 1081 HV Amsterdam, The Netherlands*
E-mail: wietze.lise@ivm.vu.nl
[2] *Center for Marine and Climate Research, Hamburg University, Hamburg, Germany*
[3] *Center for Integrated Study of the Human Dimensions of Global Change, Carnegie Mellon University, Pittsburgh, PA, U.S.A.*

Abstract. Tourism, being volatile and situation-specific, is responsive to climate change. A cross-section analysis is conducted on destinations of OECD tourists and a factor and regression analysis on holiday activities of Dutch tourists, to find optimal temperatures at travel destination for different tourists and different tourist activities. Globally, OECD tourists prefer a temperature of 21 °C (average of the hottest month of the year) at their choice of holiday destination. This indicates that, under a scenario of gradual warming, tourists would spend their holidays in different places than they currently do. The factor and regression analysis suggests that preferences for climates at tourist destinations differ among age and income groups.

1. Introduction

Tourism has become the biggest industry in the world, a fact that is not reflected in the attention research pays to it. O'Hagan and Harrison (1984) blame the lack of adequate data and the special nature of tourism demand. While climate is obviously important for international tourism, only a few tourism studies make a link with climate change. Many tourists find it important to have a high chance of sunny and warm weather at their holiday destination, in order to relax by swimming, sunbathing and sight seeing in foreign places. Yet, it is not known just how important climate is for the destination choice of tourists.

The larger part of the literature on tourist demand (see Crouch, 1995; Lim, 1997; Witt and Witt, 1995, for surveys) takes the climate of tourists' homes and destinations for granted, focusing on factors such as prices and expenditures, and sociological and psychological considerations. In addition, these studies have a short time horizon, assuming that the climate at the tourist destination is constant. In the longer term, however, climate is not constant. Climate is expected to change at an accelerating pace due to human activities, particularly fossil fuel combustion (Houghton et al., 1996). The tourism industry is accustomed to rapid change, due to, amongst others, political stability, price changes, fashion and social trends. Nevertheless, climate change could have major implications for the tourist industry, for instance, by making currently popular areas less attractive and bringing new

Climatic Change **55:** 429–449, 2002.

competitors to the market. This paper investigates the sensitivity of tourist demand for vacation destinations with respect to climate in order to draw conclusions for the possible impact of climate change in the long term. First, a general picture is obtained of the link between tourist demand and temperature. Next, this general picture is unraveled with a case study of Dutch tourists to study the link between the demand for tourist activities during holiday trips and temperature. Finally, we briefly discuss adaptation of tourist suppliers.

The analysis of this paper is based on data sets of two levels. On the macro level, time-series on tourist numbers, destinations, and expenditures at the aggregate, national level are readily available from sources such as the OECD (World Bank, the Organization for Economic Cooperation and Development), WDI (World Development Indicators) CD-ROM and national statistical services. Climate data are obtained from various sources, including Cramer and Leemans' and Schlesinger and Williams' global climate data as well as data from tourist guides. In addition, on the micro level, data were purchased from the CVO (Foundation for Continuous Vacation Surveying). The micro-data consist of over 6,000 trips of Dutch tourists who are asked for their tourist destination and about their activities during their visit. The data include characteristics such as age, income, total holiday expenditure, departure date, destination-code, travel group-size and duration of stay. These micro-data cover only two years, 1988 and 1992. Because of research budget constraints, we could neither obtain more data nor more recent data. This micro dataset is extended by travel distance and travel cost from the worldwide web.

This paper assumes that tourists have complete information about the climatic conditions at the travel destination. This assumption is intuitive as tourists are becoming better informed through use of the internet, and shared experience with friends who have traveled to their intended travel destination.

This paper is organized as follows. Section 2 briefly reviews the literature on tourist demand, and the few studies that look into the relationship between climate and tourism. The paper then continues with a statistical analysis at two levels. More specifically, Section 3 analyses international tourist flows, to explore the sensitivity of tourism to climate in general. Firstly, all tourist arrivals are pooled country-wise to study a general global trend. Secondly, eight individual countries of tourist origin and their travel destinations are considered to verify the extent to which tourist demand is country specific. Finally, a more detailed analysis is performed to explore whether the demand for Dutch tourists differs from that for British tourists. The CVO data are studied at the individual level with a factor and regression analysis in Section 4 to study the demand for tourist activities. This section also studies the link between the demand for activities of Dutch tourists and climate change. Section 5 concludes by highlighting the main findings from both the macro- and the micro analysis and placing these in the context of global climate change.

2. Literature Survey

2.1. TOURIST DEMAND

The number of studies devoted to tourist demand is vast (Lim, 1997; Martin and Witt, 1989; Smeral and Witt, 1996; Witt and Witt, 1995) with a general focus and (Bakkal and Scaperlanda, 1991; Divisekara, 1995; Eymann and Ronning, 1997; Hannigan, 1994; Melenberg and Van Soest, 1996; Opperman, 1994; Pack et al., 1995) with a regional focus, but the impact of climate and climatic change on tourism has received remarkably limited attention. This section focuses on tourist demand alone, to point out which factors other than climate affects the tourist demand.

Witt and Witt (1995) have made a survey of empirical research on tourism demand to conclude that ‘it is not possible to build a single model which is appropriate for all origin destination pairs’ (Witt and Witt, 1995, p. 469). Their finding is confirmed by Crouch (1995) who concludes from his meta-analysis that tourism demand is indeed situation-specific. The analysis of this paper confirms this conclusion although, at the same time, some remarkable generalities are found.

Lim (1997) has reviewed existing studies on tourism demand which use regression techniques. Most models are linear or log-linear, based on annual time series data and mainly include economic variables. The lack of sufficient data is seen as a clear limitation of these models. Usage of yearly data does not capture the volatile character of the tourism sector; even the length of time series cannot compensate for this. Alternatively, cross section data could be used to focus on linkages between tourist choices and economic and climate data, which is the approach taken in the fourth section of this paper.

Ryan (1991) has argued that time series on tourism are susceptible to variations in macroeconomic growth which may lead to heteroscedasticity: in times of recession tourism appears to be income inelastic, while in times of growth tourism becomes income elastic. Ryan (1991) has provided a qualitative approach to tourist demand. The choice of a travel destination is a complex process. Tourism is a fast changing industry, which has developed recently and is now globally the biggest industry. Within tourism there are many interlinked processes such as economic demand and social demand. Psychological factors, such as time availability and the need to escape from the daily routine in an organized versus adventurous manner, also play an important role. Psychological considerations can explain a great deal of recent changes in tourist considerations and is, according to Ryan, the most important aspect for explaining tourism demand. Quantitatively, a factor analysis, which reduces a large set of decision variables into a few distinctive and meaningful variables, can be used to analyze data sets on psychological responses for tourist actions at holiday destinations (see Section 4.1).

2.2. CLIMATE AND TOURISM

Within studies on tourist demand, some authors have stressed the need to incorporate climate factors in their analysis. Barry and O'Hagan (1972) have studied British tourist expenditure in Ireland and included a weather index in the descriptive variable list, which turns out to be always insignificant.

Syriopoulos and Sinclair (1993) have studied the choice of British, German, American, French and Swedish tourists for a destination in a Mediterranean country: Greece, Spain, Portugal, Italy and Turkey using the AIDS (almost ideal demand system) model. They use time series from 1960–87 and consider several types of costs. Climate is considered in their model by studying price elasticities between tourists from 'cold' countries to 'warm' countries.

Various authors have looked at the potential impact of climate change on the tourism and recreational industry. UKCCIRG (1991, 1996) has qualitatively discussed the impact of climate change on tourism in Great Britain. Mendelsohn and Markowski (1999) and Loomis and Crespi (1999) have investigated the impact of climate change on outdoor recreation in the U.S.A. Agnew (1997) has looked at the quantitative impacts of weather variability on tourism in the U.K. Wall (1988) has looked at the impact of climate change on skiing in Canada. Gable (1997) has looked at the implication of climate change and sea level rise for tourism supply in the Caribbean.

To our knowledge, Maddison (1998) is the only quantitative study that looks at tourist demand in the context of climate change. Using a pooled travel-cost model (PTCM), Maddison estimates the importance to British tourists of climate at the holiday destination. Maddison (1998) also calculates the change in consumer surplus for certain climate changes. This model is adapted for Dutch tourists in Section 3.3 and compared to his result.

3. Sensitivity of International Tourist Demand to Climate

This section discusses the sensitivity of destination choices by international tourists to climate. We investigate this relationship using three data-sets. The first data-set is crude but covers almost the whole world. The third data-set is very detailed but covers only Dutch tourists. The second data-set is somewhere in between, covering selected OECD countries with some detail. Our analyses of the three different data-sets are necessarily mutually inconsistent; we simply cannot include the same explanatory variables in all regressions. Nonetheless, the analyses are constructed such that climate parts are comparable.

3.1. GLOBAL PERSPECTIVE

To study the sensitivity of tourist demand to climate at the international level, data from the World Development Indicators CD-ROM (World Bank, 1998) on the total numbers of tourist arrivals and departures per country are used. The origins and the destinations of these tourists are, however, not provided. As a result, travel distances and costs are unknown. Nevertheless, these data can be used to estimate which factors are decisive for making a country of destination popular in terms of number of visitors. Climate is represented by temperature and precipitation. We use the average temperature of the warmest month over the last 30 years, using the IIASA database for mean monthly values of temperature on a global terrestrial grid by Leemans and Cramer (1991). The temperature of the capital of a country is assumed to be representative for the entire country. Precipitation is taken from Schlesinger and Williams (1999), who report monthly total rainfall for whole countries; we use the total rainfall over June, July and August, the main OECD tourist season.* The crudeness of the analysis is compensated by the fact that there are data for 17 years (1980–1996) for 210 countries. All data are pooled together and treated as cross-section data, which gives 1730 observations. The model is estimated with Ordinary Least Squares.**

The estimated model is:

$$\begin{aligned}\mathrm{LN}\mathit{ARRIVALS} \;=\; & \beta_0 + \beta_1 \mathit{YEAR} + \beta_2 \mathit{AREA} + \beta_4 \mathit{POPDEN} + \beta_5 \mathit{COAST} + \\ & + \beta_6 \mathit{GDPPC} + \beta_7 \mathit{TW} + \beta_8 \mathit{TW}^2 + \beta_9 \mathit{PS} + \beta_{10} \mathit{PS}^2 + \text{error}\end{aligned} \tag{1}$$

Table I defines the variables. The two main climate variables are temperature and precipitation, both in the main tourist season.

The natural logarithm of the number of tourist arrivals is used throughout the paper. This leads to a considerably higher statistical significance for the explanatory variables than in the case where the number of tourist arrivals is used as an independent variable. The variable *YEAR* is included to filter out all unexplained trends. The variable *AREA* accounts for the possibility that bigger countries can receive more tourists. This is only true in a limited sense, as a lot of tourists can be accommodated in a small place. The variable *COAST* captures the potential for beach holidays. The variable *GDPPC* captures destination price levels as well as tourists' dislike for poverty. *TW* and *PS* are the climate. Table II shows the results.

* Climate variables for other periods (e.g., annual average temperature or precipitation, temperature of the coldest month) do not explain tourism behaviour as well. Tourists can be expected to care only about the climate of their destination during their holidays.

** The data could also perhaps be treated as panel data. It may be that, in addition to the explanatory variables, there are country-specific random effects. However, the model is already richly specified, particularly compared to the number of observations in Section 3.2. Using standard OLS in lieu of panel data technique implies efficiency loss, but no bias. The standard errors of the estimated parameters are small enough with OLS to interpret the results. The standard errors are corrected for heteroskedasticity using the method of White (1980).

Table I
Definition of the variables used

Variable	Description	Source
AGE	Average age of the interviewed tourists (years)	CVO
AREA	Land surface area per country (km^2)	WDI
COAST	Total length of the coast of a destination country (km)	www.wri.org
DIST	Distance (as the crow flies) between capitals (km)	www.indo.com/distance
DUR	Number of days spent on holiday (number)	CVO
GDPPC	Country-wise PPP-based per capita income (U.S. $ per year)	WDI
INCOME	Average income of the interviewed tourists (Dutch guilders per year)	CVO
LN *ARRIVALS*	Natural logarithm of the number of international tourist arrivals per country per year	WDI, OECD, CBS
LN*VISITS*	Natural logarithm of the number visits to a destination country by a Dutch tourist	CVO
PDAY	Average daily expenditure per person (Dutch guilders per day)	CVO, www.airfair.nl
LN *PERSON*	Natural logarithm of the number of persons traveling	CVO
POP	Total population (number)	WDI
POPDEN	Population density (number per square km)	WDI
*Q*1	Dummy for the first quarter (winter)	CVO
*Q*2	Dummy for the second quarter (spring)	CVO
*Q*3	Dummy for the third quarter (summer)	CVO
PQ	Total precipitation in the quarter of traveling (inch per month)	http://traveleshop.com/
TQ	Average day and night temperature in the quarter of traveling (°C)	menus/weather.shtml
TW	Average day and night temperature of the warmest month (°C)	Cramer and Leemans
PS	Average cumulative precipitation in June, July and August (cm/summer)	Schlesinger and Williams
YEAR	Year of observation	CVO, WDI, IIASA

Obviously, we could have added other explanatory variables, such as exchange rates and crime rates. However, such data are hard to interpret. What matters, probably, is the exchange rate at the (unknown) time of booking, and the crime noticed by tourists – for which data are hard to get – rather than the annual average exchange rate or general crime rates – for which data can be gotten. The main interest of this paper is the estimated climate sensitivity of tourist destination choice. Sensitivity analyses around model (1) suggest that we can estimate that with sufficient confidence. See below.

Not surprisingly, the explanatory value of the model is low (an R^2 of 0.50). The results are convincing because the (statistically significant) estimates of the parameters of major interest (temperature) are plausible (see below), stable over the sample, and robust to variations in the model specification.

Table II

Regression results for the global and national tourist destination models[a]

	World	Canada	France	Germany	Italy	Japan	Netherlands	Neth. (CVO)	U.K.	U.S.A.
Constant	–1*	24	–18	–117***	–91***	–124***	–70***	11	–90**	28*
	(1)	(25)	(32)	(29)	(28)	(28)	(11)	(101)	(35)	(25)
YEAR	0.4***	–1.6*	–0.1	5.4***	3.7**	5.7***	2.8***	–0.5	3.9**	–1.5*
10^{-2}	(0.0)	(1.2)	(1.7)	(1.5)	(1.4)	(1.4)	(0.6)	(5.1)	(1.8)	(1.3)
DIST		–1.3***	–2.5***	–1.5***	–1.5***	–2.4***	–12.1***	-1.5***	-1.4***	–1.9***
10^{-4}		(0.1)	(0.1)	(0.1)	(0.2)	(0.6)	(0.9)	(0.5)	(0.2)	(0.1)
AREA	0.3*	0.3*	–4.4***	–3.5***	–3.6***	–0.1	4.8***	–0.1	–3.4***	1.6***
10^{-7}	(0.2)	(0.3)	(0.5)	(0.3)	(0.3)	(0.4)	(0.5)	(0.5)	(0.7)	(0.3)
POPDEN	0.3***	5.0***	–2.8*	–0.4	–0.7	3.4*	3.9***	–0.2	–11.6***	3.2**
10^{-3}	(0.1)	(1.7)	(2.0)	(1.3)	(2.0)	(2.0)	(0.6)	(0.6)	(4.8)	(1.3)
COAST	7.9***	10.4***	5.1***	4.0***	–1.7*	4.5***	1.5*	–0.2	0.9	5.5***
10^{-5}	(0.7)	(0.8)	(1.2)	(1.1)	(1.3)	(1.5)	(0.9)	(0.7)	(2.1)	(1.7)
GDPPC	2.1***	0.7***	2.9***	1.6***	2.3***	1.6***	0.8***	1.3***	1.5***	0.4**
10^{-4}	(0.1)	(0.1)	(0.3)	(0.2)	(0.2)	(0.3)	(0.1)	(0.2)	(0.4)	(0.2)
TW	0.44***	1.58***	2.99***	2.01***	2.33***	1.87***	1.93***	0.04	2.28***	1.15***
	(0.05)	(0.10)	(0.23)	(0.09)	(0.08)	(0.10)	(0.23)	(0.05)	(0.22)	(0.09)
TW^2	–1.04***	–3.44***	–6.84***	–4.36***	–4.81***	–3.98***	–4.04***	0.06	-4.90***	–2.42***
10^{-2}	(0.11)	(0.23)	(0.56)	(0.24)	(0.21)	(0.28)	(0.55)	(0.15)	(0.43)	(0.25)
PS	–0.08**	1.67***	0.41*	1.26***	2.92***	0.68	–1.91***		1.03*	2.23***
10^{-1}	(0.03)	(0.24)	(0.39)	(0.38)	(0.46)	(0.91)	(0.50)		(0.56)	(0.36)
PS^2	0.04*	–3.76***	–2.57***	–4.06***	–7.50***	0.04	4.79***		–2.01**	–3.95***
10^{-3}	(0.02)	(0.47)	(0.69)	(0.63)	(0.87)	(2.56)	(1.02)		(0.88)	(0.58)
# Observations	1686	158	156	170	140	145	376	187	157	159
R^2	0.50	0.95	0.94	0.93	0.96	0.93	0.67	0.54	0.84	0.91

[a] Regression of the natural logarithm of the number of arrivals in a country, either from all other countries (World) or from a particular country (Canada to U.S.A.). Heteroskedasticity-consistent standard deviations are given in brackets.

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Table III
Optimal precipitation and temperature

	Full model				No precipitation		Simple model [a]	
	Opt. precip.		Opt. temp.		Opt. temp.		Opt. temp.	
Netherlands	20.0***	(6.7)	23.9***	(4.3)	23.5***	(3.7)	21.7***	(5.0)
Japan	–950.0	($4\ 10^5$)	23.6***	(2.1)	22.4***	(1.8)	21.4***	(3.0)
France	8.1*	(7.9)	21.8***	(2.4)	21.5***	(2.2)	22.4***	(1.8)
Germany	15.5**	(5.3)	23.1***	(1.7)	21.7***	(2.0)	21.4***	(1.6)
Canada	22.3***	(4.3)	23.0***	(2.1)	21.1***	(2.0)	21.3***	(2.6)
Italy	19.5***	(3.8)	24.2***	(1.3)	21.4***	(1.9)	21.8***	(1.8)
U.S.A.	28.3***	(6.2)	23.8***	(3.1)	21.0***	(2.8)	20.3***	(1.5)
U.K.	25.5*	(17.9)	23.3***	(3.0)	22.5***	(1.8)	22.1***	(1.7)
World	99.5*	(67.1)	21.0***	(3.4)	21.2***	(2.7)	20.9***	(1.9)

[a] This model only includes year, distance, and temperature as explanatory variables.

The inclusion of both temperature and temperature-squared implies that there is an optimal summer temperature for tourism. The optimal temperature (T^{opt}) follows from:

$$T^{opt} = \frac{-\beta_7}{2\beta_8}\,. \tag{2}$$

Its standard deviation ($\sigma_{T^{opt}}$) is approximated with its first-order Taylor expansion:

$$\sigma^2_{T^{opt}} \approx \frac{1}{4\beta_8^2}\sigma^2_{\beta_7} + \frac{\beta_7^2}{4\beta_8^4}\sigma^2_{\beta_8} - \frac{\beta_7}{2\beta_8^3}\sigma_{\beta_7,\beta_8}\,. \tag{3}$$

It turns out that the optimal temperature is about 21 °C, with a standard deviation of 3 °C; see Table III. This is reasonable given that this is the average over day and night temperatures in the warmest month (*TW*). The optimal temperature corresponds to the present temperatures found in northern Spain, southern France, northern Italy, the former Yugoslavia and Uganda. The first three are well-known tourist resorts, the former Yugoslavia used to be, and Uganda may become one. Using different climate indices, Maddison's (1998) temperature optimum (for the British) is also found in the European part of the Mediterranean.

Tourists prefer dry places over wet ones, but there is no clear optimum amount of rainfall.

The optimal temperature occurs in countries with many beaches. It may be that tourists care more about the presence of the beach than about the climate. The implications of climatic change would then be dramatically different. To test this, we excluded the explanatory variable *COAST* from the regression. The variable *AREA* then becomes significant – there is a high correlation (0.56) between *AREA* and *COAST* – so we also ran regressions with neither *AREA* nor *COAST* and with

Table IV
The effect of area, coastal length and precipitation on the optimal temperature

Area	Coast	Prec.	Optimal TW		# Observations	R^2
No	No	No	21.1	(1.6)	1731	0.41
Yes	No	No	20.6	(1.8)	1731	0.44
No	Yes	No	21.2	(1.8)	1700	0.49
Yes	Yes	No	21.2	(1.8)	1700	0.49
No	No	Yes	20.9	(2.5)	1712	0.41
Yes	No	Yes	20.4	(2.7)	1712	0.44
No	Yes	Yes	21.1	(2.7)	1686	0.50
Yes	Yes	Yes	21.0	(3.4)	1686	0.50

only *COAST*. Table IV displays the results. It shows that the estimated influence of temperature on international tourist arrivals is independent of whether *AREA* or *COAST* is used as an explanatory variable. The optimal holiday temperature varies between 20.6 °C and 21.1 °C, a difference that is not statistically significant. In fact, the correlation between coastal length and temperature is quite low (0.03). Both beaches and a nice climate attract tourists. See Table II.

Besides climate, tourists' choices are determined by other factors. The number of arrivals increased significantly over time. Larger countries attract more tourists, but this effect is only barely significant. More densely populated countries attract significantly more tourists; tourists prefer a certain level of provision of services (transport, hotels, museums, etc.) that cannot be found in lightly populated regions. Countries with long coastlines attract significantly more tourists, as do countries with a higher per capita income; the explanation for the latter is that poverty apparently deters tourists, even though holidays in poor countries may be cheap.

3.2. DIFFERENT COUNTRIES OF ORIGIN

The above model gives a general picture about the sensitivity of tourist demand to climate at the international level for tourists of all origins. It may be, however, that tourists from different nationalities have different tastes for the climate of and the distance to their holiday destination, as is indeed found by Crouch (1995) and Witt and Witt (1995). For verifying the difference in tastes among tourists from different nations, appropriate data are a real constraint. The OECD publishes data on tourist destinations and origins for selected countries. Their 1997 report (OECD, 1997) is used, which has data for the period 1984–1995, for the destination countries in the OECD from the countries of origin listed in Table V. For the Netherlands, the more detailed internet-database of the Central Bureau of Statistics

Table V
The countries which are included in the analysis

Both in 1988 and 1992	Australia, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Indonesia, Ireland, Israel, Italy, Luxembourg, Malta, Morocco, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Tunisia, Turkey, United Kingdom
Only in 1988	Bulgaria
Only in 1992	Iceland, New Zealand, Slovenia

is used (http://www.cbs.nl), covering 1970 to 1995 and more European countries (the destinations Canada and Japan are added from the OECD data). The data are the total, annual number of, for example, Germans or Italians arriving in, for example, France or the Netherlands. There are many missing observations; some countries report on the basis of residence, others on nationality; and some countries only count visitors whereas others count tourists separately. Such crude data only allow for a simple model to be estimated. As before, the purpose is to test whether there is an optimal temperature by treating the time-series as cross-section data.

The estimated model per origin country is:

$$\begin{aligned} \mathrm{LN}\mathit{ARRIVALS} = {} & \beta_0 + \beta_1 \mathit{YEAR} + \beta_2 \mathit{AREA} + \beta_4 \mathit{POPDEN} + \beta_5 \mathit{COAST} + \\ & + \beta_6 \mathit{GDPPC} + \beta_7 \mathit{TW} + \beta_8 \mathit{TW}^2 + \beta_9 \mathit{PS} + \beta_{10} \mathit{PS}^2 + \\ & + \beta_{11} \mathit{DIST} + \text{error} \end{aligned} \tag{4}$$

Table I defines the variables.

Table II presents the estimated parameters and a summary of the results. The estimated optimal temperatures for the individual countries do not deviate significantly from the world estimate of 21.0 °C. The optimal temperature varies between the French who prefer 21.8 °C and Italians who prefer 24.2 °C at their country of holiday destination. This difference, however, is not significantly different from zero. Standard deviations vary between 2 °C and 4 °C.

If the number of arrivals (rather than its natural logarithm) is used as a dependent variable, the estimated temperature optimum is somewhat different, but not significantly so. In the linear model, however, the temperature optimum for tourists from Canada and Japan cannot be estimated with any accuracy, as the t-statistics of the temperature variables become too low.

Opinions on precipitation are more diverse on precipitation than on temperature. No clearly optimal rainfall can be found for all tourists and those from France, the U.K. and, particularly, Japan. Dutch tourists apparently prefer rather wet or rather dry conditions: a minimum number of Dutch tourists are found around 20 cm of rain per summer. Tourists of other nationalities have a clear optimum precipitation, ranging from 15 cm/summer for Germans to 28 cm/summer for U.S. citizens. These differences are significant. An optimum amount of rainfall is intuitively plausible, as tourists would prefer both sunny weather and a lush vegetation.

The other explanatory variables tell a more diverse story. Tourist numbers significantly increased over time, except for France, where the number of international trips remained constant, and for Canada and the U.S.A., where numbers may have fallen. Distance, or perhaps travel cost, deters tourists. Dutch and U.S. tourists prefer to travel to large countries, Canadians have the same tendency but are largely indifferent, whereas other Europeans prefer to travel to small countries. The Japanese are indifferent. All other things being equal, small countries may attract proportionally more OECD tourists because frequent international travelers prefer to visit as many countries as possible in their life. The findings for North America may be explained by the distance factor; Canadians take holidays in the U.S., while U.S. Americans travel to Canada. Many Dutch people spend their holidays in nearby Germany. The Japanese are again indifferent. U.K. and, to a lesser extent, French tourists prefer lightly populated countries (recall that this dataset contains travel within the OECD only), whereas Canadian, Dutch, U.S. and, to a lesser extent, Japanese tourists rather visit densely populated places. Germans and Italians are indifferent. Tourists of all nationalities prefer to travel to countries with long coastlines, except for the British, who are largely indifferent. The Italians seem to prefer countries with little coast. Tourists of all nationalities prefer to travel to richer countries; this is surprising, as there is little absolute poverty in the OECD; apparently, relative poverty deters too, and is stronger than the cost of living effect.

The other explanatory variables do not influence the estimated temperature preferences. Table III shows the estimated optimum temperature for the full model (4) as well as for reduced versions of that. The estimated optima are not significantly different. Table IV shows the results of a further sensitivity analysis, for all tourists only, focusing on area, coastline and precipitation. Also in this case, the estimated optimum temperature is insensitive to the specification of the model.

Since the results of the macro analysis are quite crude, it is useful to undertake a more detailed analysis with micro data. Therefore, aggregated Dutch micro data are the basis of the analysis in the next subsection.

3.3. DUTCH TOURISTS

In order to refine the analysis of tourist demand a PTCM is estimated for the particular case of Dutch tourists. This type of model was chosen to allow a comparison of our results with an earlier study (Maddison, 1998) on tourism demand for British tourists, and to show the difference in tastes of tourists from two different countries for a destination climate. This comparison is made possible by aggregating the CVO data set into quarterly data per destination. After deleting all destination countries with missing data, excluding the trips from the origin to the origin (the Netherlands), and by considering four seasons and two years (1988 and 1992), 177 valid observations remain. Table V gives an exhaustive list of included destination countries. Business trips are excluded from the data set.

Each destination has a number of climatic characteristics, such as temperature, rainfall and hours of sunshine. Climate data (average daily maximum temperature and precipitation) were obtained from http://traveleshop.com/menus/weather.shtml, a standard source of such data for tourists and tourist operators, comprising 30 year averages over major cities in the world. Climate data are quarterly (January–February–March, April–May–June, July–August–September, October–November–December).

Each destination also has a number of non-climatic characteristics, such as distance and airfare to reach that destination. Following Maddison (1998), the distance between Amsterdam and the capital of the country of destination is based on the great circles distance (see http://www.indo.com/distance/). The CVO data only contains a variable on the total travel expenditure, which are travel costs plus expenditures at the holiday destination. Expenditure at destination are approximated by subtracting the travel cost. The cheapest airfare to a destination is taken as a proxy for the travel cost (see http://www.airfair.nl). We assumed that each person, either traveling in a group or alone, pays the same (minimum) airfare, neglecting travelers who are prepared to pay more for traveling. It also neglects that tourist destinations can also be reached by other modes of transport. Due to the crude fix of the travel costs, it is possible that it can exceed the total expenditure on a holiday. Thereupon, by assumption, the travel cost is calculated is such a way that it does never exceed 80% of the total expenditure on a holiday.

Table V shows the countries that are included in the analysis. Table I defines the variables that are included in the analysis.

The following tourist demand equation is estimated to find which variables contribute most to the number of tourists a certain country attracts. This model is also known as PTCM. The main limitation of PTCM is that it assumes that the included descriptive variables are constant over all visited tourist sites.

$$\begin{aligned} \mathrm{LN}\mathit{VISITS} = {} & \beta_0 + \beta_1 \mathit{FARE} + \beta_2 \mathit{GDP} + \beta_3 \mathit{POP} + \beta_4 \mathit{POPDEN} + \\ & + \beta_5 \mathit{COAST} + \beta_6 \mathit{PDAY} + \beta_7 \mathit{DIST} + \beta_8 \mathit{TQ} + \beta_9 \mathit{TQ}^2 + \\ & + \beta_{10} \mathit{PQ} + \beta_{11} \mathit{Q1} + \beta_{12} \mathit{Q2} + \beta_{13} \mathit{Q3} + \text{error} \end{aligned} \tag{5}$$

This model is the same as the model of Maddison and differs from our previous model (4) in the sense that *FARE* and *PDAY* were not yet included, while *GDP* and *POP* are substituted for *GDPPC* and *AREA*. Tourists are expected to prefer cheap destinations which can be reached at a low travel cost. For a further explanation of the included variables in PCTM, we refer to Maddison (1998). Table VI summarizes the main statistics of the estimated equation.

Comparing our results with Maddison (1998), population, population density and temperature have become insignificant, while distance has become positively significant. This indicates that the population, population density and the temperature do not matter for Dutch tourists, while it matters for British tourists. Further,

Table VI

Log-linear regression of climate on the number of visitors in a country: a comparison between Dutch and British tourists

	British tourists (Maddison), 1994	Dutch Tourists (CVO), 1988 and 1992
Constant	–8.3	4.1***
	(0.5)	(0.5)
FARE	–5.6***	–0.30**
10^{-2}	(1.0)	(0.12)
GDP	7.3***	0.022***
10^{-4}	(1.5)	(0.004)
POP	1.4**	7.1
10^{-6}	(0.6)	(4.7)
POPDEN	2.0***	1.2
10^{-4}	(0.6)	(6.5)
COAST	1.4***	–0.025***
10^{-3}	(0.3)	(0.007)
PDAY	1.3**	0.85***
10^{-2}	(0.5)	(0.22)
DIST	7.6	19*
10^{-5}	(5.9)	(11)
TQ	0.17***	–0.007
	(0.04)	(0.065)
TQ^2	–3.0***	0.066
10^{-2}	(1.0)	(0.184)
PQ	–0.11	11.1
10^{-3}	(0.13)	(9.4)
*Q*1	0.11	–0.17
	(0.25)	(0.34)
*Q*2	–0.28	0.17
	(0.24)	(0.37)
*Q*3	–0.13	0.67
	(0.24)	(0.41)
Optimal *TQ*	29.3***	
# Observations	305	177
R^2	0.50	0.47

the regression result indicates that Dutch tourists prefer a longer distance to the holiday destination, while British tourists do not have such a preference. The signs of *FARE*(–) *GDP*(+) and *PDAY*(–) are significant and the same for Dutch and British tourists, while the coastal length is positively correlated for British and negatively correlated for Dutch tourists; a result we also found in the previous subsection. This indicates that Dutch and British tourists prefer to spend their holidays in richer and cheaper countries at a relatively low travel cost.

4. Sensitivity of Demand for Dutch Tourist Activities to Climate

4.1. DEMAND FOR DUTCH TOURIST ACTIVITIES

In the previous section we have analyzed which factors influence the destinations demanded by international tourists. In this section we continue with the analysis of tourist demand, but refine the question to the type of activity demanded by Dutch tourists traveling abroad. Therefore we conduct a factor analysis (a standard procedure in SPSS) on a set of twenty-five dummy variables (defined in Table VII) concerning the choice of activity during a holiday multiplied with the natural logarithm of the number of people participating in a trip. The purpose of the factor analysis is to reduce this set of 25 activities into related groups of activities and to indicate their priorities. A factor analysis transforms the original set of 25 activities into orthogonal *factors*, also known as principal components, by assigning *factor loadings* to each activity, which are weights normalized between minus one and one. Factor loadings greater than or equal to 0.5, are called dominating factors; these factors symbolize the main considerations within a decision. The factors are ordered in such a way that the explained variance is maximized. It is customary in a factor analysis to include only factors which have an eigenvalue larger than one (Harman, 1967). Table VII shows the factor loadings of the resulting factors. The dominating factor loadings are in bold case. The rotated factor matrix is used here to maximize the distinction between dominated and undominated factor loadings.

Table VII shows that the 25 activities can be divided into nine factors. It is also customary in a factor analysis to give an intuitive interpretation to each factor. Factor one clearly represents a beach holiday, where tourists mainly choose sunbathing, visiting a beach and swimming. This factor explains already 16% of the total variation and, therefore, constitutes the most important tourist activity. Factor two includes five activities, which are all related to sightseeing, namely, touring by car, walking, visiting a monument or museum and eating in a restaurant. This factor explains 8% of the total variation. The third factor consists of a group of tourists who mainly spend their holiday by low-budget traveling via public transport (bus, train or excursion steamer). The fourth factor contains tourists who visit day-attractions such as the zoo or an amusement park. Sport is the main activity in the fifth factor. This factor consists of cycling, sailing, rowing, canoeing or windsurfing. Horse and pony riding, also a sports activity, almost dominates here with

Table VII

Factor loadings for the demand of activities of Dutch tourists traveling abroad [a]

	Factor								
	1	2	3	4	5	6	7	8	9
1. Touring by car	0.30	**0.62**	–0.34	0.29					0.10
2. Touring by bicycle					**0.58**			0.26	–0.19
3. Touring by bus or train			**0.76**						–0.10
4. Touring by excursion steamer	0.12		**0.53**	0.22					
5. Going for a walk	0.16	**0.58**			0.11	0.46	–0.11	0.11	
6. Visiting an amusement or recreation park	0.14			**0.72**					
7. Visiting the zoo or safari park		0.14		**0.74**					
8. Visiting a folkloristic event	0.14	0.20	0.28				0.27	0.18	0.19
9. Visiting a monument, old cities or churches	0.11	**0.75**	0.29						
10. Visiting a museum	–0.13	**0.52**	0.48						
11. Eating in a restaurant or bistro	0.30	**0.50**	0.20	0.15		0.34			
12. Visiting a theatre, concert hall or cinema	–0.10		0.43				**0.57**		
13. Outing to a café or dancing	0.24		0.39		0.10	**0.51**	0.17		
14. Sunbathing	**0.82**	0.14							
15. Visiting a beach	**0.83**		0.12						
16. Visiting a sauna		–0.16		0.10	–0.12	0.30		0.10	**0.68**
17. Swimming	**0.72**	0.25		0.13	0.16			0.20	0.15
18. Sailing, rowing, canoeing	0.12	0.30	–0.10		**0.51**			0.11	0.31
19. Windsurfing	0.23				**0.61**		0.15	–0.41	
20. Fishing	0.16	0.20			0.15	–0.17			**0.58**
21. Playing tennis or squash	0.21		–0.12		0.10	0.12	0.30	**0.53**	–0.13
22. Playing miniature golf				0.15	0.15			**0.73**	0.10
23. Playing golf							**0.81**		
24. Horse or pony riding		–0.14	0.16	0.16	*0.496*		–0.12	0.11	0.19
25. Skiing or cross-country skiing	–0.17		–0.15			**0.72**			
Percentage of variance explained:	15.7	7.9	5.5	5.1	4.9	4.6	4.2	4.1	4.0

[a] Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization. Dominating factors are displayed in bold faces. Empty cells have factor loadings with an absolute value lower than 0.1.

a factor loading of 0.496. The sixth, seventh, eighth and ninth factor, respectively, join two activities, namely, skiing and outing, playing golf and visiting a theatre, playing tennis and miniature golf, and visiting a sauna and fishing.

In Lise and Tol (1999), a factor analysis is performed by distinguishing between winter and summer tourists in 1988 and 1992. It was found that the activities of summer tourists did not change much in spite of a hot summer in 1992 as compared to a normal summer in 1988. That the effect of Dutch summer weather on tourists is limited can also be demonstrated by data on total tourist numbers (domestic and abroad) for the period 1969–1995. These data suggest that a summer which is 1 °C warmer than average, increases the number of domestic holidays in the same year by 4.7% (standard deviation: 2.2%), and increases the number of foreign holidays in the following year by 3.1% (standard deviation: 1.5%) (Tol, 2000). There are two possible explanations for this. Firstly, Dutch tourists may expect a bad summer to follow a good one. This mistrust is unwarranted, as the correlation coefficient between successive summers is a positive 0.52. CBS (1993) finds that snowfall in popular ski-resorts in this season is a good predictor for next season's visitor numbers. An alternative explanation is that the money saved on a cheap domestic holiday for this year is spent on a more expensive foreign trip next year.

4.2. SENSITIVITY TO CLIMATE AND OTHER VARIABLES

To obtain the sensitivity of demand for vacation activities of Dutch tourists to climate and other variables, the calculated factors of the previous subsection are used as dependent variables in a regression analysis. Mendelsohn and Markowski (1999), for instance, also used the demand for tourist activities as dependent variable. They measured this as the total number of days spent in a state of the U.S. on a certain activity. The factors of the previous subsection give the best possible fix for the demand of Dutch tourist activities given the limitation of the CVO dataset.

The list of descriptive variables to be included in the model consists of all variables included in Equations (4) and (5) appended by two new variables measuring age and income. We expect age to be generally negatively correlated to each activity as younger people are generally more active, while we expect a mixed sign for income. We decided to substitute the per capita GDP for the joined use of GDP and population as this is probably a better measure of wealth. Furthermore, the total size of a country is also included as a variable. It is not expected that all variables have the same sign in the regression, because the analysis covers various groups of tourists, with different socio-economic characteristics and different climate preferences.

The following model is estimated, using linear regression:

$$\begin{aligned}\text{Factor } i \;=\; & \beta_0 + \beta_1 YEAR + \beta_2 AREA + \beta_3 POPDEN + \beta_4 COAST + \\ & + \beta_5 GDPPC + \beta_6 TQ + \beta_7 TQ^2 + \beta_8 PQ + \beta_9 DIST + \\ & + \beta_{10} FARE + \beta_{11} PDAY + \beta_{12} INCOME + \beta_{13} AGE + \text{error}\end{aligned} \tag{6}$$

Table VIII shows the results.

Let us first consider the climate variables in the model. In general, we find that tourists prefer a higher temperature for undertaking their activities. One significant exception is found for skiing, which has a significant minimum temperature of 22 °C. Obviously, such a climate is not suitable for skiing. In three cases we find a statistically significant optimal temperature. While the optimal temperatures are nearly constant for the country-wise tourists flows, more variation is found when tourist activities are considered; cf. Table VIII. We find an optimal temperature

Table VIII

Log-linear regression results for the demand of activities of Dutch tourists traveling abroad [a]

	Factor								
	1	2	3	4	5	6	7	8	9
	Interpretation of factor								
	Beach holiday	Sight-seeing	Public transport	Amuse-ment park	Sport holiday	Skiing, café	Theatre, mini-golf	Tennis, fishing	Sauna,
(Constant)	–10	–14	24*	–22	–40***	11	5	19	4
	(13)	(14)	(14)	(15)	(15)	(14)	(14)	(15)	(15)
YEAR	5.1	6.9	–12.0*	10.8	19.7***	–4.8	–2.7	–9.8	–2.0
10^{-3}	(6.4)	(7.2)	(6.9)	(7.4)	(7.4)	(7.1)	(7.0)	(7.6)	(7.6)
AREA	2.9	0.3	–3.6	1.4	1.7	7.0***	1.6	1.6	–7.7
10^{-8}	(2.2)	(2.5)	(2.4)	(2.6)	(2.6)	(2.5)	(2.5)	(2.7)	(2.6)
POPDEN	–4.8	2.8	2.4	10.7***	2.5	–4.6**	–0.4	2.9	–5.7***
10^{-4}	(1.7)	(1.9)	(1.9)	(2.0)	(2.0)	(1.9)	(1.9)	(2.1)	(2.0)
COAST	–5.1***	7.4***	8.0***	1.1	1.5	–18.1***	5.2**	–4.3*	8.9***
10^{-6}	(2.0)	(2.2)	(2.1)	(2.2)	(2.3)	(2.2)	(2.1)	(2.3)	(2.3)
GDPPC	–4.4***	3.1***	–5.0***	2.4***	1.9***	1.0*	–0.3	0.4	0.8***
10^{-5}	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.7)	(0.6)
TQ	–1.3	2.3**	2.8***	6.3***	0.1	–14.1***	0.7	4.0***	–0.5
10^{-2}	(0.9)	(1.0)	(0.9)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)
TQ^2	19.9***	–5.3	–6.9**	–20.6***	5.3	32.5***	–2.8	–11.0***	–1.5
10^{-4}	(3.0)	(3.4)	(3.2)	(3.4)	(3.5)	(3.3)	(3.3)	(3.6)	(3.5)
PQ	0.9	4.3**	–1.5	–2.8	5.5***	–3.2*	1.5	–1.7	0.8
10^{-2}	(1.5)	(1.7)	(1.6)	(1.7)	(1.7)	(1.7)	(1.6)	(1.8)	(1.8)
DIST	–1.3***	–0.4*	0.4*	1.1***	–0.05	1.2***	–0.2	0.6***	–0.2
10^{-4}	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
FARE	1.1***	–0.2	–0.4**	0.03	–0.2	–0.7***	–0.02	–0.4**	0.2
10^{-3}	(0.1)	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
PDAY	–1.8***	–2.9***	1.7***	–1.0***	–0.8***	–0.1	0.3	–0.3	–0.5**
10^{-3}	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
INCOME	3.8***	6.8***	–1.9**	0.5	–0.2	0.3	1.3	1.0	2.5**
10^{-6}	(0.9)	(1.0)	(0.9)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)
AGE	–1.1***	–0.5***	0.1	–0.6***	–0.4***	–0.6***	0.0	–0.5***	–0.3***
10^{-2}	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Optimal *TQ*			20.1**	15.4***		21.7*** [b]		18.3***	
			(5.3)	(1.8)		(1.4)		(4.3)	
# observations	4384	4384	4384	4384	4384	4384	4384	4384	4384
R^2	0.28	0.11	0.08	0.05	0.03	0.17	0.01	0.02	0.02

[a] Regression on holiday activity as expressed by a factor. Standard deviations are given in brackets.
[b] Minimum desired temperature.

of 20 °C for (low budget) travelers by public transport, 15 °C for visitors to an amusement park, and 18 °C for tennis players or miniature golf players. The substantially lower temperature for visiting an amusement park is probably caused by the fact that amusement parks are generally situated in richer countries (*GDPPC* is positively significant), which probably have milder climates. It is remarkable that we do not find an optimal temperature for beach tourists. This may be caused by the heterogeneity of this group willing to visit a beach irrespective of the climate of the destination.

The expected negative sign for rainfall in the destination countries is not found. The sign is positive for a sightseeing and a sport holiday, while it is negative for a skiing holiday. An explanation for this anomaly is that wetter destination countries may have better facilities for undertaking these activities. The negative sign (significant with 90% confidence) for skiing is harder to explain, but may be caused by the fact that the amount of precipitation is relatively low during the skiing season, while the amount of snow for skiing is still sufficient.

Let use now turn to the interpretation of the result for the socio-economic variables. The coefficient for *AGE* is always negative and significant for seven activities. Hence, the demand for activities is highest among young people. All other socio-economic variables have mixed signs. Rich people prefer beach and sightseeing holidays, while they avoid touring by public transport. This is the reason why we labeled the latter group as low budget travelers. Rich people are also interested in elite (sport) activities such as playing golf or visiting a theatre, playing tennis or miniature golf, but this link is only significant for tourists that visit a sauna and go fishing. A low daily expenditure generally explains most of the activities, except for low budget traveling. Furthermore, for most tourists the travel fare is a restriction in their choice for a holiday destination. This is not true for beach tourists, who are prepared to pay a higher travel fare in order to be sure of good climate. While beach holidays and low budget traveling is preferred in relatively poorer countries (measured by a low *GDPPC*), other activities are generally preferred in relatively richer countries. It is remarkable to find that countries with a shorter coastline attract more beach tourists. This is a result which we also found for Dutch tourists with model (4) and (5) in Section 3.2 and 3.3. That a short coastline motivates skiing is expected as skiing is generally performed in mountainous countries without any coasts. Furthermore, skiing is preferably performed in lowly populated and large countries. The increase or decrease between 1988 and 1992 can be read from *YEAR*. We see that sport holidays are getting more popular, while low budget traveling is loosing its popularity.

5. Discussion and Conclusions

The analysis of this paper leads to the conclusion that climate is an important consideration for tourists' choice of destination. This should not surprise anyone. However, this paper finds that climate matters in a *regular* way that can be *quantified*. We find that an average temperature of about 21 °C is the ideal for the large bulk of international tourists. This preference is largely independent of the tourist's origin. This implies that climate change will have a strong effect on tourism demand. However, we cannot simply say that the currently popular tourist resorts will travel polewards with global warming.

This is because only the broad patterns are regular, not the details. We find small differences in behavior of Dutch tourists from 1988 to 1992. Age and income are important explanatory variables, suggestive of significant trends in the behavior of Dutch tourists over longer periods of time. Unfortunately, the limitations of the data (or rather our budget to purchase data) do not allow further exploration. The factor and regression analysis show that different dominant holiday activities imply different preferences for holiday climates. Younger and richer people do different things during their vacations than do older and poorer tourists. This suggests that preferences for climates at tourist destinations differ among age and income groups. It also suggests that, however regular the macro-preferences may be, there is little reason to assume that current aggregate preferences will resemble future aggregate preferences, as the economic and demographic make-up of the population will be quite different.

To assess future aggregate preferences would require quite detailed projections. Obviously, the micro-study reported here would need to be replicated for more years and many more countries. In that process, other relevant climate indicators should be included as well to get a more complete picture on the sensitivity of tourist demand to climate change.

This study suggests that people's preferred vacation activities are largely independent of climate. Instead, people purchase a climate that suits their holiday plans. A gradual warming would thus induce tourists to seek different holiday destinations, or travel at different times during the year. Climate change is therefore likely to lead to drastic changes in tourist behavior. However, one cannot predict such changes without scenarios of preferred vacation activities in the future.

Although very responsive, tourists probably do not care much about climate change. They substitute one destination for another, or one travel date for another.

Some people have the freedom to take a holiday whenever they want, but others do not, and the ratio between the two will be different in the future. Vacation periods are often tied to seasons of the home climate, national and school holidays, and agreements at work. Changes in economic structure, demography, and air conditioning could loosen these ties. Because of this, and the reasons indicated above, it is very hard to predict changes in tourist behavior due to climate change.

Whereas tourists can readily change their behavior if the climate changes, suppliers of tourism services are not always able to do so. Tour operators can rapidly change their product. It does not matter much whether they sell a ticket to A or to B. The competition in the tourist sector is such that the profit margins are low anyway. Competition also guarantees that novel consumer preferences, because of climate change or otherwise, are rapidly catered for. Owners of hotels and resorts are less flexible. However, the tourist industry changes so fast that most investments have a very short pay back period. Currently, the tourist industry consists of many small and medium-size players. However, consolidation is ongoing, including vertical integration (e.g., travel agencies operating aircraft and hotels). This would reduce the flexibility of the sector as a whole, but would probably lead to an increase of professionalism. The impact on vulnerability is unclear.

Although tourists and probably tourist operators are adaptable enough to cope with climate change, the same cannot be said of local providers of tourist services and local economies dependent on tourism revenues. They would see the attractiveness of their region to tourists change beyond control. Some would benefit and some would lose, but local losses may be dramatic, particularly in regions with few alternatives and a culture of immobility.

Acknowledgements

Financial support by the European Commission, Directorate-General XII (ENV4-CT97-0448), the U.S. National Science Foundation through the Center for Integrated Study of the Human Dimensions of Global Change (SBR-9521914), and the Michael Otto Foundation for Environmental Protection is gratefully acknowledged. Comments of Luke Brander, Kees Dorland, Peter Mulder, Xander Olsthoorn, three anonymous referees, and participants at a seminar at the Delhi School of Economics, Delhi, India, August 5, 1999; the European Course in Advanced Statistics, Garpenberg, Sweden, September 5–10, 1999; the EMF Workshop on Climate Change Impacts and Integrated Assessment, Snowmass, CO, U.S.A., July 26–August 4, 2000; and the RICAMARE Workshop on Climate Change Impacts on the Mediterranean, Milan, Italy, February 9–10, 2001, have greatly helped to improve the contents and exposition of this paper. All errors and opinions are ours.

References

Agnew, M. D.: 1997, 'Tourism', in Palutikof, J. P., Subak, S., and Agnew, M. D. (eds.), *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995*, University of East Anglia, Norwich, pp. 139–148.

Bakkal, I. and Scaperlanda, A.: 1991, 'Characteristics of U.S. Demand for European Tourism: A Translog Approach', *Weltwirtschaftliches Archiv* **127**, 119–137.

Barry, K. and O'Hagan, J.: 1972, 'An Econometric Study of British Tourist Expenditure in Ireland', *Econom. Soc. Rev.* **3**, 143–161.

CBS: 1993, *Nederlanders op Wintersport 1978–1992*, **1993-20**, Central Bureau of Statistics (CBS), The Hague.

Crouch, G. I.: 1995, 'A Meta-Analysis of Tourism Demand', *Ann. Tourism Res.* **22**, 103–118.

Divisekera, S.: 1995, 'An Econometric Model of International Visitor Flows to Australia', *Aust. Econ. Papers* **34**, 291–308.

Eymann, A. and Ronning, G.: 1997, 'Microeconometric Models of Tourists' Destination Choice', *Region. Sci. Urban Econom.* **27**, 735–761.

Gable, F. J.: 1997, 'Climate Change Impacts on Caribbean Coastal Areas and Tourism', *J. Coastal Res.* **27**, 49–70.

Hannigan, K.: 1994, 'A Regional Analysis of Tourism Growth in Ireland', *Regional Studies* **28**, 208–214.

Harman, H. H.: 1967, *Modern Factor Analysis*, University of Chicago Press, Chicago.

Houghton, J. T., Meiro Filho, L. G., Callander, B. A., Harris, N., Kattenberg, A., and Maskell, K. (eds.): 1996, *Climate Change 1995: The Science of Climate Change – Contribution of Working Group I to the Second Assessment Report of the Intergovernmenal Panel on Climate Change*, Cambridge University Press, Cambridge.

Leemans, R. and Cramer, W. P.: 1991, *The IIASA Database for Mean Monthly Values of Temperature, Precipitation and Cloudiness on a Global Terrestrial Grid*, RR-91-18, International Institute for Applied Systems Analysis, Laxenburg.

Lim, C.: 1997, 'Review of International Tourism Demand Models', *Ann. Tourism Res.* **24**, 835–849.

Lise, W. and Tol, R. S. J.: 1999, *On the Impact of Climate on Tourist Destination Choice*, Working Paper W-99/30, Institute for Environmental Studies, Amsterdam.

Loomis, J. B. and Crespi, J.: 1999, 'Estimated Effects of Climate Change on Use and Benefits of Selected Outdoor Recreation Activities in the United States', in Mendelsohn, R. O. and Neumann, J. E. (eds.), *The Impact of Climate Change on the United States Economy*, pp. 289–314, Cambridge University Press, Cambridge.

Maddison, D. J.: 1998, 'In Search of Warmer Climates: The Impact of Climate Change on Flows of British Tourists', in Maddison, D. J., *Measuring the Impact of Climate Change on Britain*, University of Strathclyde, Strathclyde, pp. 129–157.

Martin, C. A. and Witt, S. F.: 1989, 'Forecasting Tourism Demand: A Comparison of the Accuracy of Several Quantitative Methods', *Int. J. Forecasting* **5**, 7–19.

Melenberg, B. and Van Soest, A.: 1996, 'Parametric and Semi-Parametric Modelling of Vacation Expenditures', *J. Appl. Econometrics* **11**, 59–76.

Mendelsohn, R. O. and Markowski, M.: 1999, 'The Impact of Climate Change on Outdoor Recreation', in Mendelsohn, R. O. and Neumann, J. E. (eds.), *The Impact of Climate Change on the United States Economy*, Cambridge University Press, Cambridge, pp. 267–288.

OECD: 1997, *Tourism Policy and International Tourism in OECD Countries*, OCDE/GD(97)173, Organisation for Economic Cooperation and Development, Paris.

O'Hagan, J. W. and Harrison, M. J.: 1984, 'Market Shares of U.S. Tourist Expenditure in Europe: An Econometric Analysis', *Appl. Econom.* **16**, 919–931.

Opperman, M.: 1994, 'Regional Aspects of Tourism in New Zealand', *Regional Studies* **28**, 155–167.

Pack, A., Clewer, A., and Sinclair, M. T.: 1995, 'Regional Concentration and Dispersal of Tourism Demand in the U.K.', *Regional Studies* **29**, 570–576.

Ryan, C.: 1991, *Recreational Tourism: A Social Science Perspective*, International Thomson Business Press, London.

Smeral, E. and Witt, S. F.: 1996, 'Econometric Forecasts of Tourism Demand to 2005', *Ann. Tourism Res.* **23**, 891–907.

Syriopoulos, T. C. and Sinclair, M. T.: 1993, 'An Econometric Study of Tourism Demand: The AIDS Model of U.S. and European Tourism in Mediterranean Countries', *Appl. Econom.* **25**, 1541–1552.

Tol, R. S. J. (ed.): 2000, *Weather Impacts on Natural, Social and Economic Systems in the Netherlands*, Report R00-02, Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

UKCCIRG: 1991, *The Potential Effects of Climate Change in the United Kingdom*, United Kingdom Climate Change Impacts Review Group (UKCCIRG), First Report, prepared at the request of the Department of Environment, HMSO, London.

UKCCIRG: 1996, *Review of he Potential Effects of Climate Change in the United Kingdom*, United Kingdom Climate Change Impacts Review Group (UKCCIRG), Second Report, prepared at the request of the Department of Environment, HMSO, London.

Wall, G.: 1988, *Implications of Climate Change for Tourism and Recreation in Ontario*, CCD 88-05, Environment Canada, Downsview.

White, H.: 1980, 'A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity', *Econometrica* **48**, 817–838.

Witt, S. F. and Witt, C. A.: 1995, 'Forecasting Tourism Demand: A Review of Empirical Research', *Int. J. Forecasting* **11**, 447–475.

World Bank: 1998, *Word Bank Development Indicators CD-ROM*, World Bank, Washington, D.C.

(Received 5 September 2000; in revised form 12 March 2002)