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Summary

We use an updated and extended version of the Hamburg Tourism Model to simulate the effect of development and climate change on tourism. Model extensions are the explicit modelling of domestic tourism and the inclusion of tourist expenditures. We also use the model to examine the impact of sea level rise on tourism demand. Climate change would shift patterns of tourism towards higher altitudes and latitudes. Domestic tourism may double in colder countries and fall by 20% in warmer countries (relative to the baseline without climate change). For some countries international tourism may treble whereas for others it may cut in half. International tourism is more (less) important than is domestic tourism in colder (warmer) places. Therefore, climate change may double tourist expenditures in colder countries, and halve them in warmer countries. In most places, the impact of climate change is small compared to the impact of population and economic growth. The quantitative results are sensitive to parameter choices, but the qualitative pattern is robust.

Keywords: Climate Change, International Tourism, Domestic Tourism

JEL Classification: L83, Q54

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1. Introduction

Climate is an important factor in the destination choice of tourists. Previous versions of the Hamburg Tourism Model (HTM) found that climate change shifts international tourism flows towards higher altitudes and latitudes (Hamilton *et al.*, 2005a, b). The redistribution of tourism flows could negatively affect countries and regions that depend heavily on income from tourism. On the other hand, it could also bring benefits to places that are currently not popular with tourists. The size of this impact is potentially important economically; tourism and recreation is, after health care, the second largest economic activity in the world.

Quantitative studies that examine the impact of climate change on tourism use a variety of approaches, and they are carried out at different levels of spatial resolution. Approaches include: estimating changes to the supply of tourism services (e.g. Elsasser and Messerli, 2001), estimating changes in the climatic attractiveness as measured by comfort indices (e.g. Scott *et al.*, 2004) and estimating the statistical relationship between tourism demand and climate (e.g. Lise and Tol, 2002). The first of these approaches is typically carried out at the scale of a region within a country or even for particular resorts. The extensive data requirements restrict the index studies to focussing on smaller regions or particular destinations within larger areas (see below for the exception). The statistical demand studies have been carried out for tourists from particular countries travelling to the rest of the world.

The lack of a global overview and the inclusion of substitution between destinations, both aspects that have been overlooked in the studies of the impact of climate change on tourism, were motivating factors behind the design and development of HTM. The HTM is a global model of tourism demand that does not look into detail at any one country let alone at any tourism resort. HTM does, however, allow for a synoptic overview, including the most important interactions. Apart from the previous versions of HTM, another study examines the impact of climate change on tourism at the global scale. Amelung (2006) depicts comfort index scores for the world on a 0.5 x 0.5 degree grid. Unfortunately, tourism data is not available at such a scale, making it difficult to connect tourism demand with the associated index value.

Domestic tourism accounts for 86% of total tourism (Bigano *et al.*, 2004). Despite its size in comparison to international tourism, there are relatively few studies that analyse domestic tourism demand. These often focus on domestic tourists of one country or in one region of a particular country (for example, Coenen and van Eekeren, 2003; Seddighi and Shearing, 1997). Furthermore, domestic tourism has been overlooked in the research on climate change and tourism. On the whole the focus has been on international tourism or tourism is examined in general not distinguishing between the two types of tourism.

In particular, substitution between domestic and international tourism needs to be examined. In the previous versions of HTM it is assumed that the change in the absolute numbers of domestic tourists equals the change in the absolute numbers of international departures, without considering the actual number of domestic tourists. Recently collected data on domestic tourism (Bigano *et al.*, 2004) allows us to consider this aspect and explicitly model the trade-off between holidays in the home country and abroad.

Another major shortcoming of earlier versions of HTM was that it stopped at tourist numbers and at the examination of the impact of climate change purely in terms of a change in temperature. In this paper, we extend the model to include tourist expenditures. This allows us to estimate the economic implications of climate-change-induced changes in tourism. Berrittella *et al.* (in press) do this using HTM, version 1.0, and a computable general equilibrium model, but only for six world regions. Our economic approach is far simpler, but it does include all countries individually. In addition, the HTM is used to examine the impact of sea level rise on domestic and international tourism. This extends the analysis beyond temperature change to the indirect impacts of climate change.

The paper proceeds as follows. Section 2 discusses the data. Section 3 presents the model, its calibration and validation. Section 4 shows the base results and sensitivity analyses. Section 5 concludes.

2. The data

Data are crucially important to a simulation model like HTM. In this section, we briefly describe and discuss the data and the procedures to fill missing observations.

2.1. International arrivals and departures

The source and the limitations of the dataset on international arrivals and departures for 1995, and the subsequent estimation of missing data points are described in Hamilton *et al*. (2005a). For completeness, the equations used to estimate arrivals and departures are presented again here. First, the equation for arrivals (see table 1 for a description of the variables used):

(1)
$$\ln A_d = \underset{0.97}{5.97} + \underset{0.96}{2.05} \cdot 10^{-7} G_d + \underset{0.07}{0.22} T_d - \underset{2.21}{7.91} \cdot 10^{-3} T_d^2 + \underset{3.03}{7.15} \cdot 10^{-5} C_d + \underset{0.09}{0.80} \ln Y_d$$
$$N = 139; R_{adj}^2 = 0.54$$

and second, the equation for departures:

(2)
$$\ln \frac{D_o}{P_o} = \underset{17.05}{1.51} - \underset{0.17}{0.18} T_o + \underset{16.82}{4.83} \cdot 10^{-3} T_o^2 - \underset{4.22}{5.56} \cdot 10^{-2} B_o + \underset{0.09}{0.86} \ln Y_o - \underset{0.13}{0.23} \ln G_o$$
$$N = 99; R_{adj}^2 = 0.66$$

Note that these equations are also the basis of the model.

2.2. Domestic tourism

The model has been extended to not only cover international tourism flows but also *domestic* tourism. This requires an extensive global database of the amount of domestic tourism trips per country in the base year.

For most countries, the volume of domestic tourist flows is derived using 1997 data contained in the Euromonitor (2002) database. For some other countries, we rely upon alternative sources, such as national statistical offices, other governmental institutions or trade associations. Data are mostly in the form of number of trips to destinations beyond a non-negligible distance from the place of residence, and involve at least one overnight stay. For some countries, data in this format were not available, and we resorted to either the number of registered guests in hotels, campsites, hostels etc., or the ratio between the number of overnight stays and the average length of stay. The latter formats underestimate domestic tourism by excluding trips to friends and relatives; nevertheless, we included such data for completeness, relying on the fact that dropping them did not lead to any dramatic change.

In general, the number of domestic tourists is less than the population of the origin country. However in 22 countries, residents were domestic tourists more than once per year. An examination of the characteristics of such countries shows that these are in general rich countries, they are endowed with plenty of opportunities for domestic tourism and they are large (or at least medium-sized). This definition fits in particular to the Scandinavian countries (e.g., 4.8 domestic tourists per resident in Sweden) but also Canada, Australia, and the USA.[1] In the USA, the combination of a large national area, a large number of tourist sites and high income per capita contribute to explain why, on average, an average American took a domestic holiday 3.7 times in 1997. Distance from the rest of the world is also important, and this is most probably the explanation for the many domestic holidays in Australia and New Zealand.

We filled the missing observations using two regressions. We interpolated total tourist numbers, *D+H*, where *H* is the number of domestic tourists, using

$$\ln\frac{D_o+H_o}{P_o} = -\underset{0.83}{1.67} + \underset{0.10}{0.93}\ln Y_o \qquad (3)$$
$$N=63; R^2_{adj}=0.60$$

Note that (3) is not limited from above; we capped (3) at 12 holidays per person per year. The number of tourists may exceed the number of people, which implies that people take a holiday more than once a year. Note that we measure population numbers in thousands. The parameters imply that in countries with an income of $10,000 per person per year, the average number of trips taken per person is one per year.

The ratio of domestic to total holidays was interpolated using

$$\ln\frac{H_o}{D_o+H_o} = -\underset{1.19}{3.75} + \underset{0.42}{0.83}\cdot 10^{-1}\ln G_o + \underset{0.30}{0.93}\cdot 10^{-1}\ln C_o + \underset{0.32}{0.16}\cdot 10^{-1}T_o - \underset{1.11}{0.29}\cdot 10^{-3}T_o^2$$
$$+\left(\underset{0.12}{0.16} - \underset{1.24}{4.43}\cdot 10^{-7}Y_o\right)\ln Y_o \qquad (4)$$
$$N=63; R^2_{adj}=0.36$$

The individual temperature parameters are not statistically significant from zero at the 5% level, but they are jointly significant. “Observations” for 1995 were derived from 1997 observations by dividing the latter by the population and per capita income growth between 1995 and 1997, correcting the latter for the income elasticity of (3) and (4). The income elasticity of domestic holidays is positive for countries with low incomes but falls as income grows and eventually goes negative. See Figure 1. Qualitatively, this pattern is not surprising. In very poor countries, only the upper income class have holidays and they prefer to travel abroad, also because domestic holidays may be expensive too (cf. Equation 6). As a country gets richer, the middle income class have holidays too, and they first prefer cheap, domestic holidays. The share of domestic in total holidays only starts to fall if the lower income class are rich enough to afford a holiday abroad; with the estimates of Equation (4), this happens if average income exceeds $360,000, a high number. We perform sensitivity analysis on this specification below.

For the total (domestic and foreign) number of tourists, the world total is 12.0% higher if we include the interpolated tourist numbers, that is, 4.0 billion versus 3.6 billion tourists. The observed world total includes those countries for which we have observed both domestic tourists and international arrivals. For domestic tourists only, the observations add up to 3.1 billion tourists, and 3.5 billion tourists with interpolation, a 12.1% increase.

[1] Poland, ranking 8th, is particularly active notwithstanding substantially lower per capita income than the rest of the top 10 countries.

Note that Equation (2) can be used to derive international departures, just like Equations (3) and (4) can. The correlation coefficient between these two alternatives is 99.8% (for 1995). Equation (2) was used in version 1.0 and 1.1 of HTM. Here, we use Equations (3) and (4). In the new specification, we have the total number of holidays as well as the trade-off between holidays at home and abroad. In Equation (2), the number of international holidays goes up with a constant income elasticity of 0.86. In Equations (3) and (4), the income elasticity is 0.80 at a (hypothetical) zero income, rising to 0.93 at an income of $36,000, and to 1.00 at an income of $53,000. In the new specification, the number of international holidays accelerates faster.

2.3 *Economic impacts*

As well as simulating the changes in tourist numbers, the model has been extended to include the direct economic impacts of tourism, that is through the simulation of the length of stay and the average expenditure per day. The WTO (2002) provides data on the number of nights international tourists stay in selected countries. Dividing the number of nights by the number of international tourists leads to the average length of stay of international tourists, *S*. This can be modelled as

$$\begin{aligned} &S_d = \underset{0.61}{2.13} - \underset{0.62}{2.58} L_d - \underset{0.79}{1.91} \cdot 10^{-6} G_d + \underset{0.40}{2.06} \cdot 10^{-1} T_d + \underset{0.78}{1.72} \cdot 10^{-4} C_d \\ &N = 55; R^2_{adj} = 0.40 \end{aligned} \quad (5)$$

where *L* is a dummy for measurement in hotels only (as opposed to all establishments). All parameters are significantly different from zero. The income per capita in the destination country does not affect the length of stay. The interpretation of equation (5) is that tourists stay longer in hotter countries, in smaller countries and in countries with longer coasts but tourists spend less time in the destination country if they are accommodated in a hotel.

WRI (2002) has data on the total expenditures of international tourists. Dividing total expenditures by the number of arrivals and their length of stay yields expenditure per international tourist per day, *E*, which can be modelled as

$$\begin{aligned} &E_d = -\underset{200}{611} + \underset{0.007}{0.029} Y_d + \underset{71}{295} X_d \\ &N = 47; R^2_{adj} = 0.31 \end{aligned} \quad (6)$$

where *X* is the ratio of the purchasing power parity exchange rate to the market exchange rate. Expenditures increase linearly with the average per capita income in the holiday country. This is as expected. Surprisingly, there is no significant relationship between the average income of the tourists and their expenditures. There is also no significant relationship between expenditures and income distributions, a measured by the Gini coefficient, in either the destination or the origin country. Per capita income is measured in market exchange dollars. The second explanatory variable in (6) is the ratio of purchasing power and market exchange rates. This ratio is high (up to 5) for the least developed countries and around 1 for developed economies. If we combine the two effects, plotting expenditures against destination countries ranked by per capita income – see Figure 1 – Equation (6) says that expenditures per tourist per day first *fall* with per capita income, then *increase* linearly with per capita income if the latter is above $10,000 per person per year. The increase is as expected, as per capita income is a rough proxy for price levels. Holidays are more expensive in poorer countries, probably because international tourists tend to be restricted to luxury resorts. Note that Figure 1 shows an expenditure index; accordingly, we use Equation (6) to *change* expenditures; expenditures in the calibration year are as observed.

3. The model

We here present the Hamburg Tourism Model, version 1.2. HTM. Version 1.0 is specified and applied in Hamilton *et al.* (2005a), and HTM1.1 is specified and applied in Hamilton *et al.* (2005b). The current version of the model explicitly considers domestic tourism and includes tourist expenditures.

The goal of our model is to describe, at a high level of geographic disaggregation, the reactions to climate change of tourist behaviour, both in terms of changes in their (domestic and international) numbers and in terms of changes in their expenditure decisions. This has been performed through the following steps. First, we construct a matrix of tourism flows from one country to the next. Second, we perturb this matrix with scenarios of population, income, and climate change. Third, we compute the resulting changes in the average length of stay and expenditures.

The data concerns the number of domestic tourists, international departures, and international arrivals per country. For international tourism, we also need the matrix of bilateral flows of tourists from one country to the next. That matrix is largely unobserved. In order to build this matrix, we take Equation (1), multiply it with the distance (in kilometres) between the capital cities raised to the power $1.7 \cdot 10^{-4}$, and allocate the tourists from a particular country to all other countries proportional to the result. This procedure delivers the results for the base year 1995.

For other years, we use a similar approach. The total number of tourists per country follows from Equation (3). This is divided into domestic and international tourists using Equation (4), holding everything constant except for temperature and per capita income. Note that the ratio of Equation (4) is not necessarily smaller than unity; we restrict the ratio of domestic to total tourists to lie between 0.01 and 0.99. Note also that the temperature parameters of (4) are highly uncertain. The domestic to total tourist ratio is at a maximum at a temperature of 30°C. This would imply that, except for in the very hottest countries, global warming would result in more and more domestic holidays. We therefore replace the temperature parameters of (4) with those of Equation (2), which imply that the domestic-to-international ratio is at a maximum at 18°C. We perform sensitivity analysis on this specification below.

For the simulation years, we allocate international departures in the same way as we build the matrix of bilateral tourist flows, keeping everything as in 1995 except for per capita income and temperature. We also keep area constant. Tol (2004) argues that full coastal protection against sea level rise would be economically viable, even for small island countries. We perform a sensitivity analysis below in which sea level rise erodes beaches.

The change in the length of stay follows readily from (5). The change in expenditure per tourist per day follows from (6). Following Tol (2004), we let the ratio of purchasing power to market exchange rate fall with per capita income, using an income elasticity of 0.28. We put a lower bound on (6) which equals the observed lower bound in 1995.

Scenarios for population and per capita income growth are taken from the *IMAGE* 2.2 implementation of the IPCC SRES scenarios (IMAGE Team, 2002; Nakicenovic and Swart, 2001). The original scenarios are specified for 17 world regions. The growth rates of countries in each region are assumed equal to the regional growth rate. Scenarios for the global mean temperature are derived from the *FUND* model (Tol, 2002), using the same population and economic scenarios and the corresponding scenarios for energy efficiency improvements and decarbonisation. The global mean temperature change is downscaled to national means using the *COSMIC* model (Schlesinger and Williams, 1995).

The 1995 model values for the total number of tourists, the number of domestic tourists, the length of stay, and the expenditures are as observed. We do not have data for other years to validate this part of the model. We can validate international arrivals and departures, however. Figure A1 compares the model results for international arrivals to the observations for 1980, 1985, 1990, and 1995. The correlation between observed and modelled international arrivals in 1995 is almost perfect, largely because of calibration. For the other years, the correspondence between observations and modelled values is never below 92%. Figure A2 compares model results and data for international departures. Between 1985 and 1995, the correspondence between observations and model results is between 91 and 94%. For 1980, this drops to 79%, which is still a reasonable performance given the fact that data are patchy, not just for international tourism, but also for per capita income.

4. Results

4.1. Base results

Figure 2 shows some characteristics of the A1B scenario without climate change for 16 major world regions. Currently, the OECD (the regions at the bottom of the graph) dominates tourism, with over half of world tourists but only a fraction of the world population. However, the OECD share has been declining over the last 20 years, and will continue to do so. For most of the 21st century, tourism will be predominantly Asian. Within Asia, East Asia leads first, but South Asia will take over after a few decades. The dominance of the rich countries in international departures is stronger than it is in domestic holidays, and this dominance will decline more gradually. Asia (Africa) has a smaller (bigger) share of international tourism than of domestic tourism, because it has a number of big (many small) countries. The difference between Europe and North America has the same explanation. The pattern of international arrivals is similar to, but smoother than the pattern of international departures; international tourists cross borders, but prefer to travel not too far. The pattern of receipts from domestic and international tourists is different. Here, the OECD first expands its market share as expenditures per tourist per day fall as the poorer countries grow richer – see Equation (6). After 2030, however, the other regions, but particularly Asia, capture a larger share of the market.

The impact of climate change on domestic tourism numbers, both over time and over space is shown in Figure 3. While the world aggregate number of domestic tourists hardly changes due to climate change, individual countries may face dramatic impacts that grow rapidly over time. By 2100, domestic tourism numbers may be up by 100% (Mongolia) or down by 30% (Mali). Roughly speaking, currently colder countries will see an increase in domestic tourism; warmer countries will see a reduction. Exceptions to this are countries at high altitudes surrounded by lower lying countries (e.g., Zambia, Zimbabwe). While colder than their neighbouring countries, they are projected to face roughly the same, absolute warming and therefore break the smooth pattern of the lower panel of Figure 3. Because tourists prefer to stay close to home, high altitude countries (surrounded by low altitude countries) have an advantage over low altitude countries (surrounded by other low altitude countries) with a similar initial climate, because the neighbouring countries of the former are hotter than the neighbouring countries of the latter. Countries at the minimum (0.01) or maximum (0.99) share of domestic tourism in total tourism, are not affected by climate change.

Figure 4 shows the impact of climate change on international tourism arrivals, both over time and over space. Aggregate international tourism falls because of climate change, reaching a maximum decrease of 10% below the scenario without climate change around 2025, and edging towards zero after that. Aggregate international tourism falls because more tourists stay in their home country (cf. Figure 3), particularly tourists from Germany and the UK, who make up a large part of international tourism; tourists from hot countries would increasingly prefer international over domestic holidays, and the share of such tourists gradually increases throughout the century. By 2100, for individual countries, international arrivals may fall by up to 60% of the base value or increase by up to 220% of the base value.. Climate change increases the attractiveness of cooler countries, and reduces that of warmer ones.

Climate change has an impact on total tourism expenditures both over time and over space. This is shown in Figure 5. World aggregate expenditures hardly change, first rising slightly and then falling slightly. The situation is different for individual countries; the impact of climate change ranges from a reduction of 50% to an increase of 130% by 2100. As expected colder countries can expect to receive more tourism money because of climate change, and warmer countries can expect to receive less. The relationship between current climate and impacts of climate change, however, is a lot noisier for expenditures than for international arrivals and domestic tourists.

4.2. Sensitivity analysis

Hamilton *et al.* (2005a, b) report extensive sensitivity analyses on the behaviour of international tourists. These analyses do not harbour any major surprises. If climate change is more severe, so is its impact. The uncertainty about the baseline is large (if there are more and richer people, there would be more tourism), but the effect on the *relative* impact of climate change is minor (although the effect on the *absolute* impact is large). The impact of climate change is sensitive to the specification of the climate preferences, and to whether tourism demand saturates or not. Similar results hold for the current version of the model. The sensitivity analyses reported here focus on domestic tourists and on sea level rise, as these issues were not explored in previous papers.

The effect of altering the income elasticity in Equation (4) for the year 2100 is shown in Figure 6. Specifically, the first (second) parameter was reduced (increased) by one standard deviation. With these parameters, the share of domestic in total tourism starts falling at an annual income of $71,000 per person (rather than $360,000). As a result, international tourism grows at the expense of domestic tourism. As international tourism is more sensitive to climate change than domestic tourism is, this increases the impact of climate change. Figure 6 plots the impact of climate change on arrivals and expenditures, expressed as a percentage increase or decrease, for the base income elasticity against the impact of climate change under the alternative elasticity. The closer the points lie to the straight line in Figure 6 the lesser the estimated impact of the parameter change. Points above the line indicate an increase in the tourism variable under consideration; points below indicate the line a decrease.(Figures 7 and 8 function in the same way). Altering the income elasticity as described, the climate change impacts on arrivals increase everywhere. The climate change impacts on expenditures fall in some places, as the loss of domestic tourism outweighs the gain in international tourism; the climate change impact on global expenditure switches from a negative 2% in the base case to a positive 8% in the alternative case.

Figure 7 shows the effect of changing the temperature sensitivity of international tourism. We use the parameters that were originally estimated for Equation (4) rather than those of Equation (2) (see section 3). Two things happen: firstly, the optimal temperature for domestic holidays increases from 18°C to 30°C. This increases domestic tourism at the expense of international tourism. Secondly, the spread around the optimum is much shallower; this reduces the effect of climate change. The second effect dominates, as is shown in Figure 7. The impact of climate change on domestic tourism is much reduced. The impact on international arrivals is much smaller; the global number of international tourists is only slightly different between the two cases, as in both cases the increases in domestic tourism almost cancel the decreases.

We can also use the model to examine the impact the sea level rise will have on tourism. We take the sea level rise scenario that corresponds to the temperature scenario used elsewhere in this paper. We take the national land losses, without coastal protection, from Hoozemans *et al.* (1993; see also Tol, 2004). We use the proportional land loss to scale both domestic tourism and the attractiveness to international tourists. That is, if the Maldives loses 78% of its territory to sea level rise (as the scenario says), then its domestic to total tourism ratio and its international attractiveness index both fall by 78%.[2] Figure 8 shows the effect on domestic tourism and on international arrivals of including sea level rise. In most countries, the effect of sea level rise on domestic tourism is minimal, as the land loss is minimal. In some countries, however, the effect is dramatic. The same pattern can be seen in international arrivals; most countries gain a little, and some lose a lot. No country gains particularly from the partial loss of the small island states. This crude approach serves only to illustrate the qualitative effect of sea level rise; more sophisticated analyses would take account of the interaction of beach and sun, and deliberate efforts to maintain commercially attractive beach in the face of sea level rise induced erosion.

5. Discussion and conclusion

We present a changed and extended version of the Hamburg Tourism Model (HTM). Specifically, we now model total holiday demand, and the trade-off between domestic and international holidays. We added the direct economic cost of changes in tourism. As in earlier papers (Hamilton *et al.*, 2005a, b), we find that climate change would shift patterns of tourism towards higher altitudes and latitudes. Domestic tourism may double in colder countries and fall by 20% in warmer countries (relative to the baseline without climate change). For some countries international tourism may treble whereas for others it may cut in half. International tourism is more (less) important than is domestic tourism in colder (warmer) places. Therefore, climate change may double tourist expenditures in colder countries, and halve them in warmer countries. However, in most places, the impact of climate change is small compared to the impact of population and economic growth.

The quantitative results are sensitive to parameter choices, both for the baseline and the impact of climate change. The qualitative pattern is robust, however. Interestingly, we find that climate change has a greater impact on tourism than sea level rise does, because the latter heavily affects only a few places.

A potential application of the model is to sustainability analysis. On the one hand, tourists exert substantial pressure on the environment (Goessling, 2002) while ecotourism supports conservation (Goessling, 1999 and Wilson and Tisdell, 2001). Immediate applications include an analysis of the relocation effects due to restrictions on tourist numbers in a particular country (e.g., Bhutan). In Hamilton *et al.* (2005b), we project carbon dioxide emissions from international travel, but other emissions and resource use can be readily added (if the data are available) now that the model includes the length of stay as well. The implications of constraints on emissions and resource use could then be analysed too. In this paper, the attractiveness of a tourist destination consists of a climate component, which changes, and a second, unspecific component, which is kept constant. Splitting the latter would allow for the analysis of other environmental changes – for example, the establishment of national parks.

[2] On the one hand, this underestimates the impact of sea level rise on tourism, because both tourism and land losses are heavily concentrated on the coast. On the other hand, by excluding coastal protection, impacts are overestimated.

The analysis of price instruments to change the behaviour of tourists would require adding costs to the attractiveness index, and splitting "distance" into its price and time components. These are important topics for future research.

References

Amelung, S.B., 2006: *Global (environmental) change and tourism: issues of scale and distribution.* Amelung publishers, Maastricht:.

Berritella, M., A. Bigano, R. Roson and R.S.J. Tol, in press: A general equilibrium analysis of climate change impacts on tourism. *Tourism Management*

Bigano, A., J.M Hamilton, M. Lau, R.S.J. Tol and Y. Zhou, 2004: *A Global Database of Domestic and International Tourist Numbers at National and Subnational Level*. Fondazione Eni E. Mattei Working Papers n. 3.05, Milano, Italy.

Coenen and van Eekeren, 2003: A study of demand for domestic tourism by Swedish households using a two-staged budgeting model. *Scandinavian Journal of Hospitality and Tourism*, **3** (2), 114-133

Elsasser, H. and P. Messerli, 2001: The Vulnerability of the Snow Industry in the Swiss Alps. *Journal of Mountain Research and Development*, **21**(4), 335-339.

Euromonitor,2002: *Global Market Information Database*, retrieved from http://www.euromonitor.com/gmid/default.asp

Goessling, S., 1999:Ecotourism: a means to safeguard biodiversity and ecosystem functions. *Ecological Economics*, **29**, 303-320.

Goessling, S., 2002: Global environmental consequences of tourism. *Global Environmental Change*, **12**, 283-302.

Hamilton, J.M., D.J. Maddison and R.S.J. Tol, 2005a: Climate change and international tourism: a simulation study. *Global Environmental Change*, **15** (3), 253-266.

Hamilton, J.M., D.J. Maddison and R.S.J. Tol, 2005b: The effects of climate change on international tourism. *Climate Research*, **29**, 255-268.

Hoozemans, F.M.J., M. Marchand. and H.A. Pennekamp.,1993: *A Global Vulnerability Analysis: Vulnerability Assessment for Population, Coastal Wetlands and Rice Production and a Global Scale (second, revised edition)*, Delft Hydraulics, Delft, the Netherlands.

IMAGE Team, 2001: *The IMAGE 2.2 Implementation of the SRES Scenarios: A Comprehensive Analysis of Emissions, Climate Change and Impacts in the 21st Century*. RIVM CD-ROM Publication 481508018. National Institute for Public Health and the Environment, Bilthoven, the Netherlands.

Lise, W. and R.S.J. Tol, 2002: Impact of climate on tourism demand. *Climatic Change*, **55(4)**, 429-449.

Maddison, D.J.,2001: In search of warmer climates? The impact of climate change on flows of British tourists. *Climatic Change* **49**, 193-208.

Nakicenovic, N. and R.J. Swart, 2001: *IPCC Special Report on Emissions Scenarios*. Cambridge University Press, Cambridge, UK.

Schlesinger, M.E. and L.J. Williams, 1998: *COSMIC 1.1 Country-Specific Model for Intertemporal Climate*. Electric Power Research Institute, Palo Alto, USA.

Scott**,** D**.**, G. McBoyle and M. Schwarzentruber, 2004: Climate change and the distribution of climatic resources for tourism in North America *Climate Research* 27, 105-117

Seddighi, H.R. and D.F. Shearing, 1997: The demand for tourism in North East England with special reference to Northumbria: an empirical analysis. *Tourism Management*, **18** (8), 499-511.

Tol, R.S.J., 2002: 'Welfare Specification and Optimal Control of Climate Change: An Application of *FUND*', *Energy Economics*, **24** (4), 367-376.

Tol, R.S.J., 2004: *The Double Trade-Off between Adaptation and Mitigation for Sea Level Rise: An Application of* FUND, Research Unit Sustainability and Global Change **FNU-48**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg (submitted to *Adaptation and Mitigation Strategies for Global Change)*

Wilson, C. and C. Tisdell,2001: Sea turtles as a non-consumptive resource especially in Australia. *Tourism Management* **23**, 279-288.

WRI, 2002: World Resources Database *2002-2003*. World Resources Institute, Washington D.C, USA.

WTO, 2002: *Yearbook of Tourism Statistics*. World Tourism Organization, Madrid, Spain.

Variable	**Description**
A	Total arrivals per year
G	Land area (km^2)
T	Annual average temperature (C°)
C	Length of coastline (km)
Y	Per capita income
D	Total departures per year
P	Population (in thousands)
B	The number of countries with shared land borders
H	Total domestic tourist trips per year
S	Average length of stay of international tourists
E	Average expenditure of international tourists per day
L	Equal to 1 when the length of stay data is for hotels only, otherwise 0
X	The ratio of purchasing power parity to the market exchange rate
d	The destination country
o	The origin country

Table 1: Definition of the variables

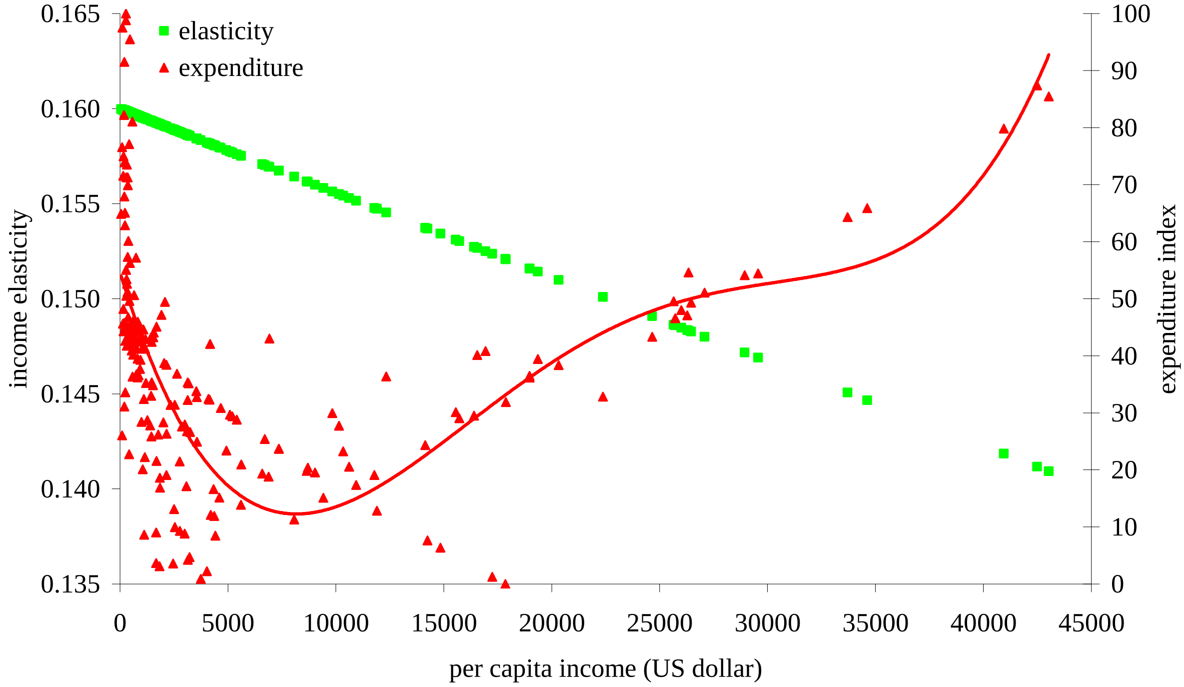


Figure 1. The income elasticity of the ratio of domestic to total tourists (left axis), and expenditures per tourist per day as a function (indexed, right axis) of per capita income.

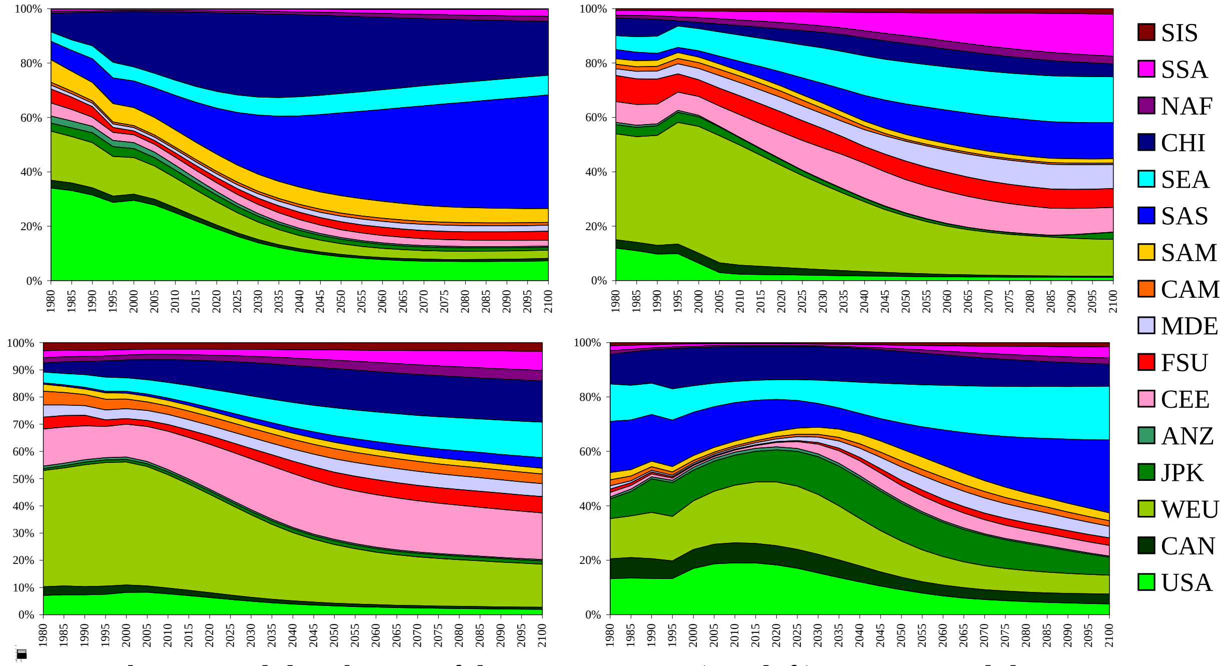


Figure 2. The regional distribution of domestic tourists (top, left), international departures (top, right), international arrivals (bottom, left) and tourism receipts (bottom, right) for the A1B scenarios without climate change. The regions are, from top to bottom: Small Island States; Sub-Saharan Africa; North Africa; China, North Korea and Mongolia; South East Asia; South Asia; South America; Central America; Middle East; Former Soviet Union; Central and Eastern Europe; Australia and New Zealand; Japan and South Korea; Western Europe; Canada, and the USA.

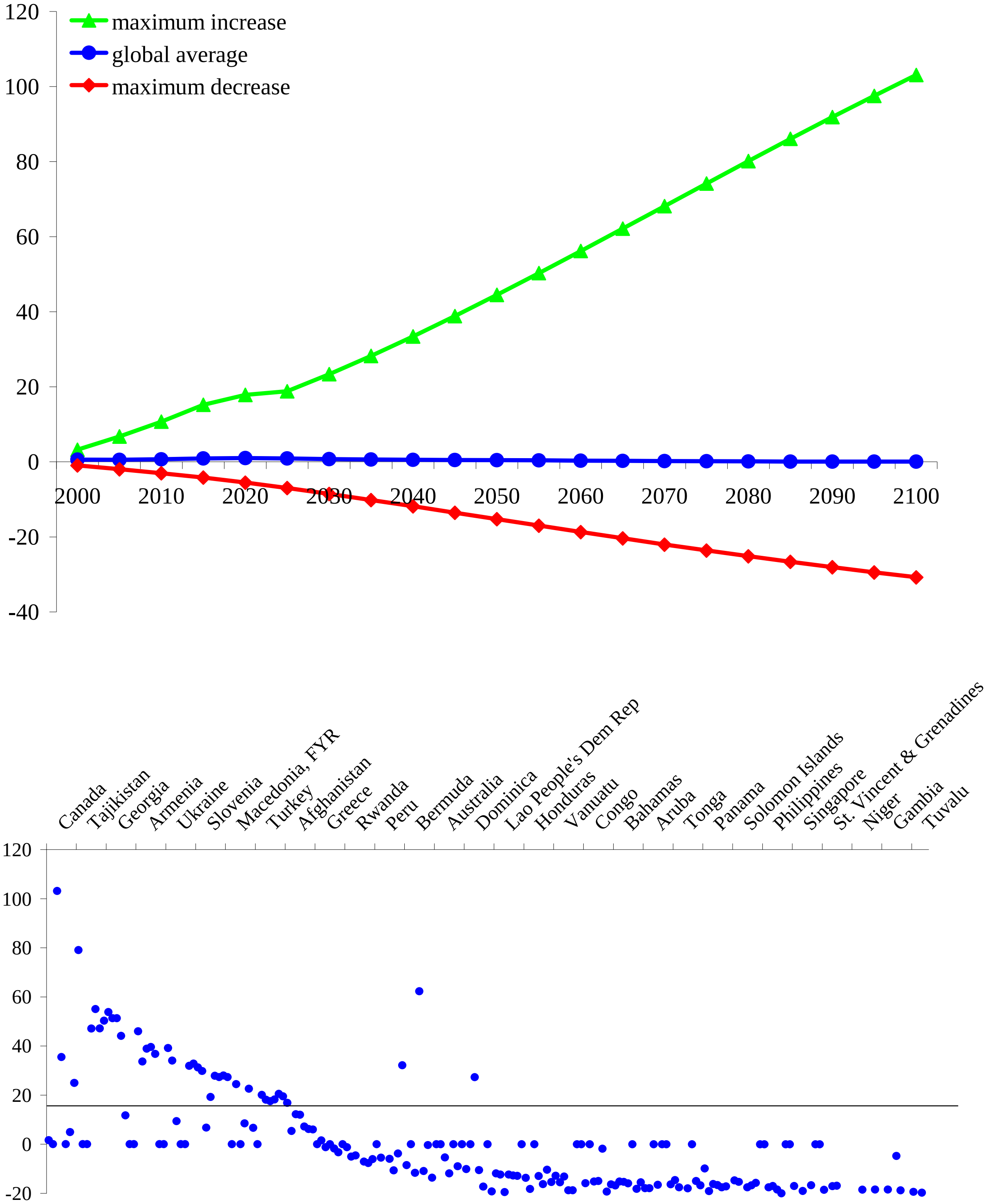
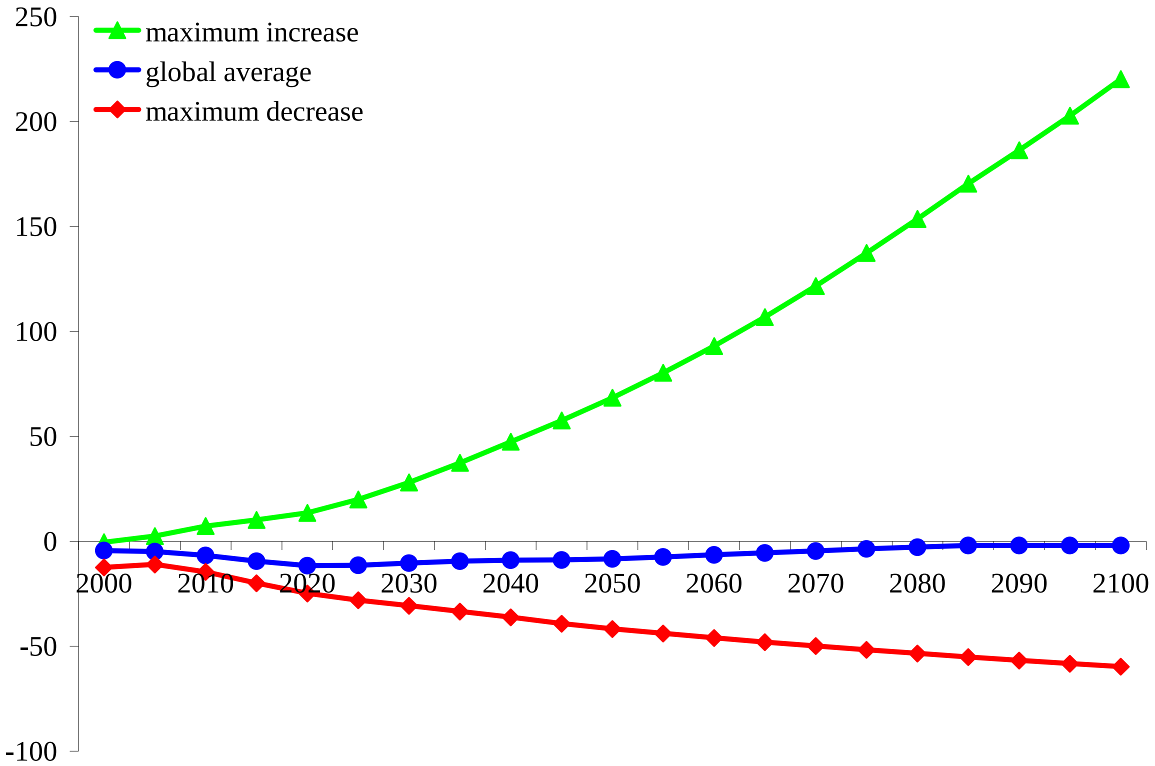


Figure 3. The effect of climate change on domestic tourist numbers, as a percentage of the numbers without climate change; top panel: world average, maximum increase (positive), and maximum decrease (negative); bottom panel: impact in 2100, countries ranked to their annual average temperature in 1961-1990.



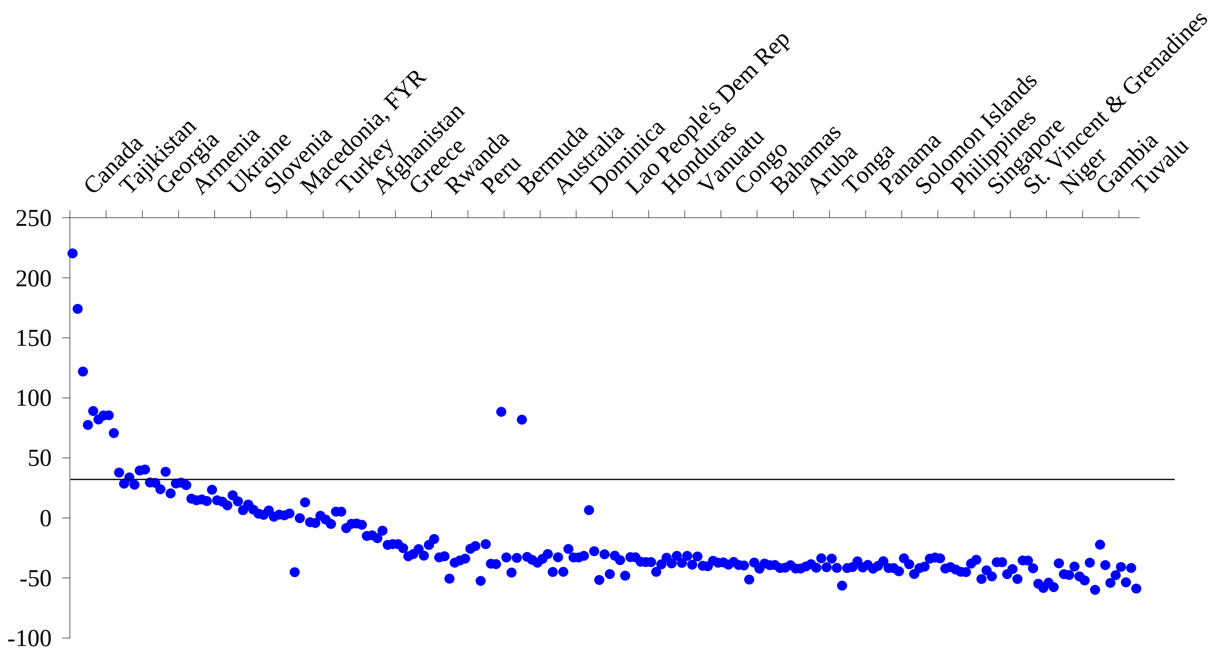


Figure 4. The effect of climate change on international tourist arrivals, as a percentage of the numbers without climate change; top panel: world average, maximum increase, and maximum decrease; bottom panel: impact in 2100, countries ranked to their annual average temperature in 1961-1990.

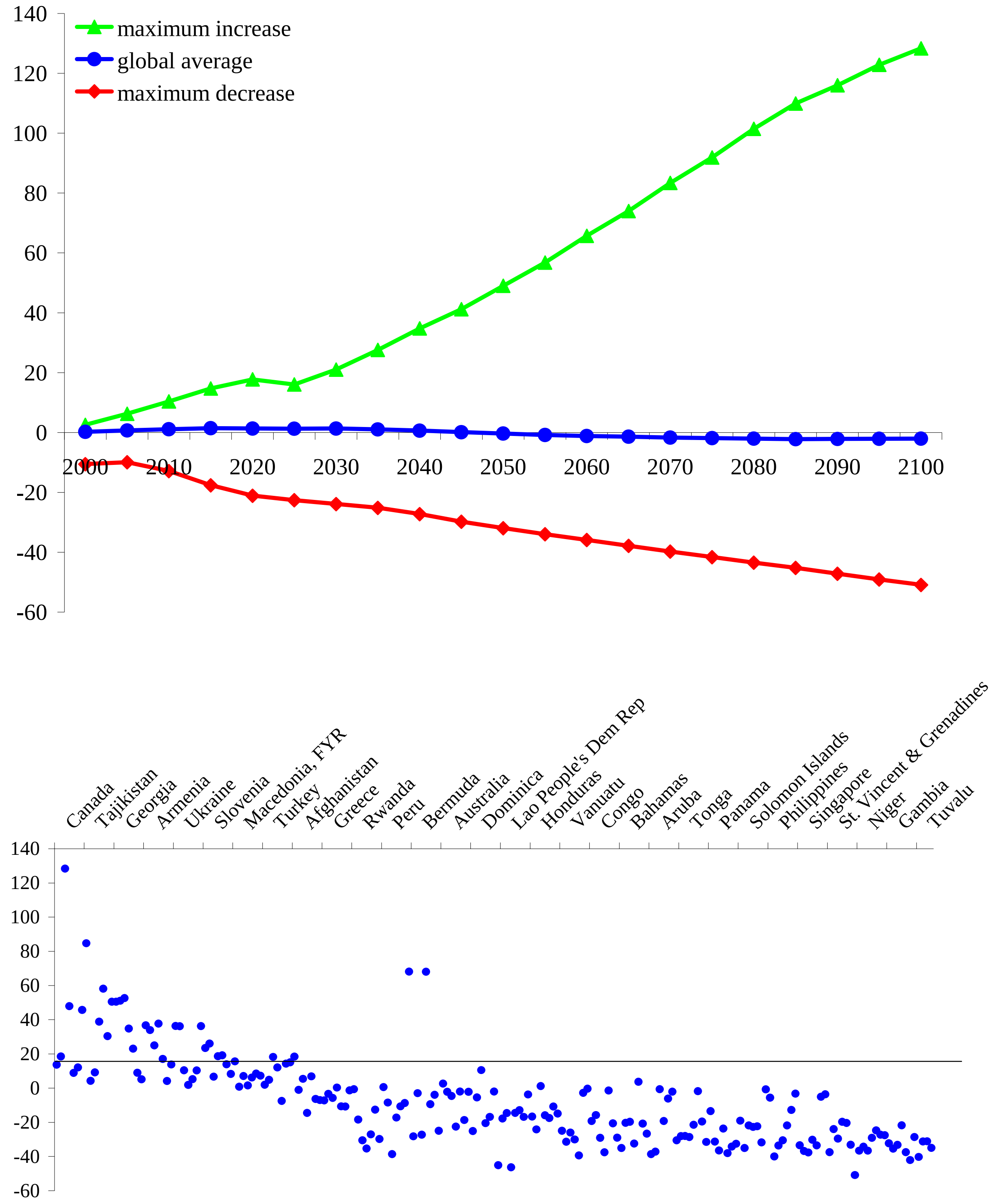
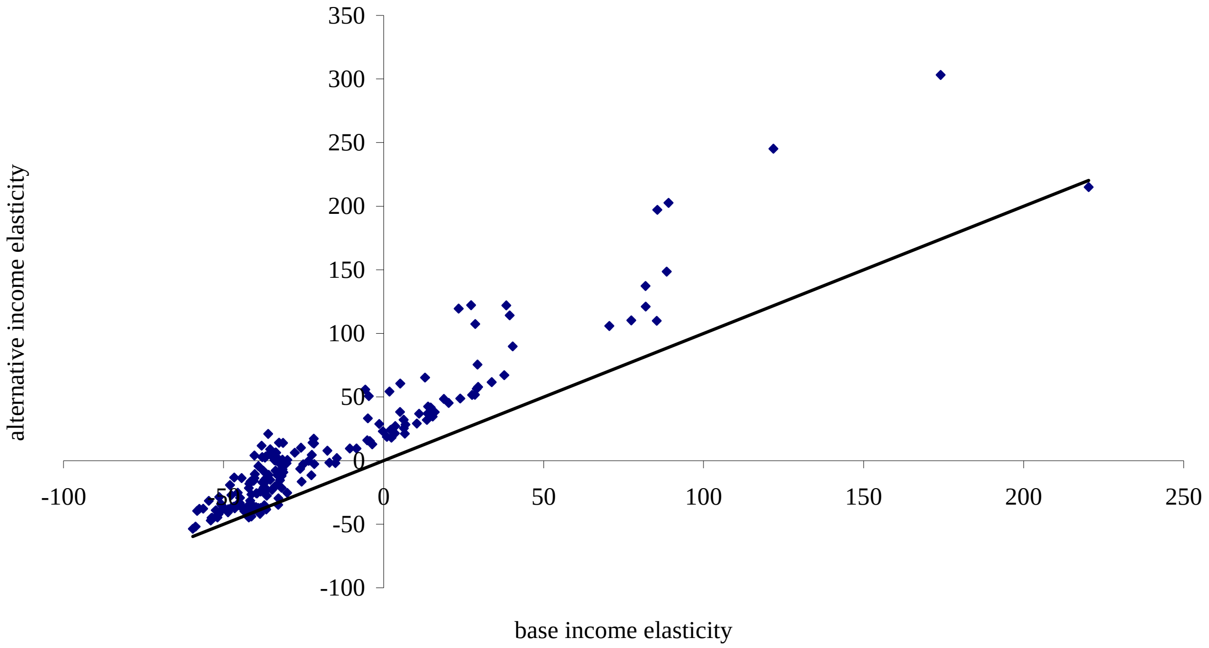


Figure 5. The effect of climate change on total tourism expenditures, as a percentage of the numbers without climate change; top panel: world average, maximum increase, and maximum decrease; bottom panel: impact in 2100, countries ranked to their annual average temperature in 1961-1990.



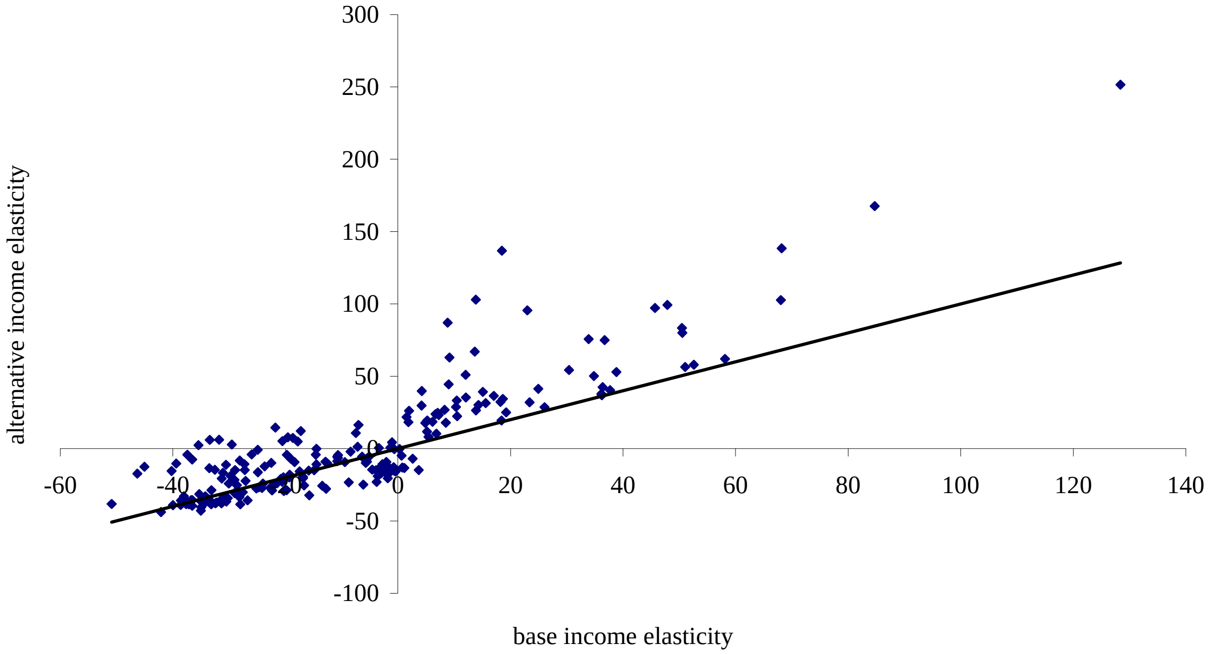


Figure 6. The effect of changing the income elasticity of Equation (4) on the impact of climate change on international arrivals (top panel) and tourism expenditures (bottom panel) in the year 2100; change is measured as percentage deviation from the case without climate change.

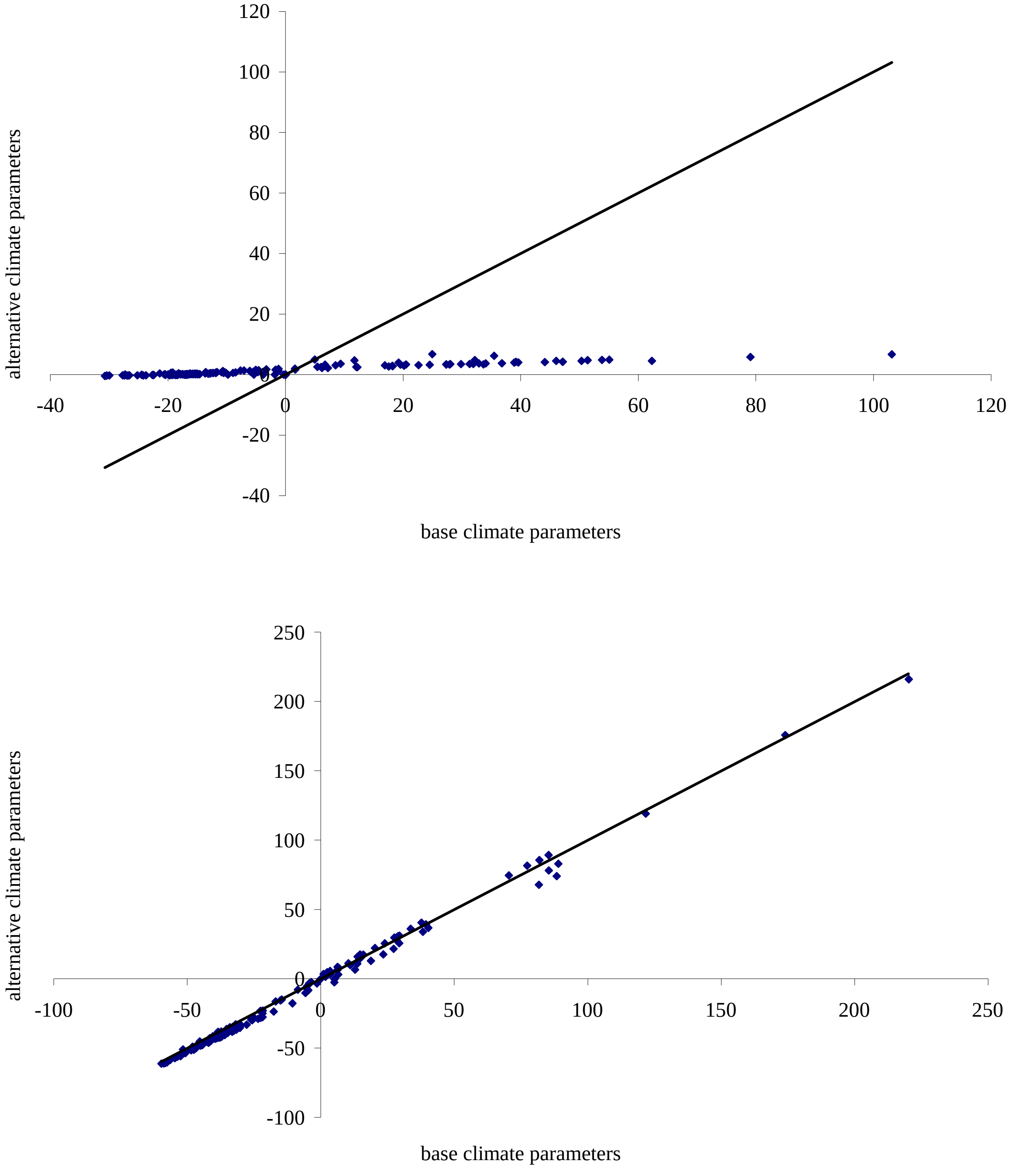


Figure 7. The effect of changing the temperature parameters of Equation (4) on the impact of climate change on domestic tourists (top panel) and international arrivals (bottom panel) in the year 2100; change is measured as percentage deviation from the case without climate change.

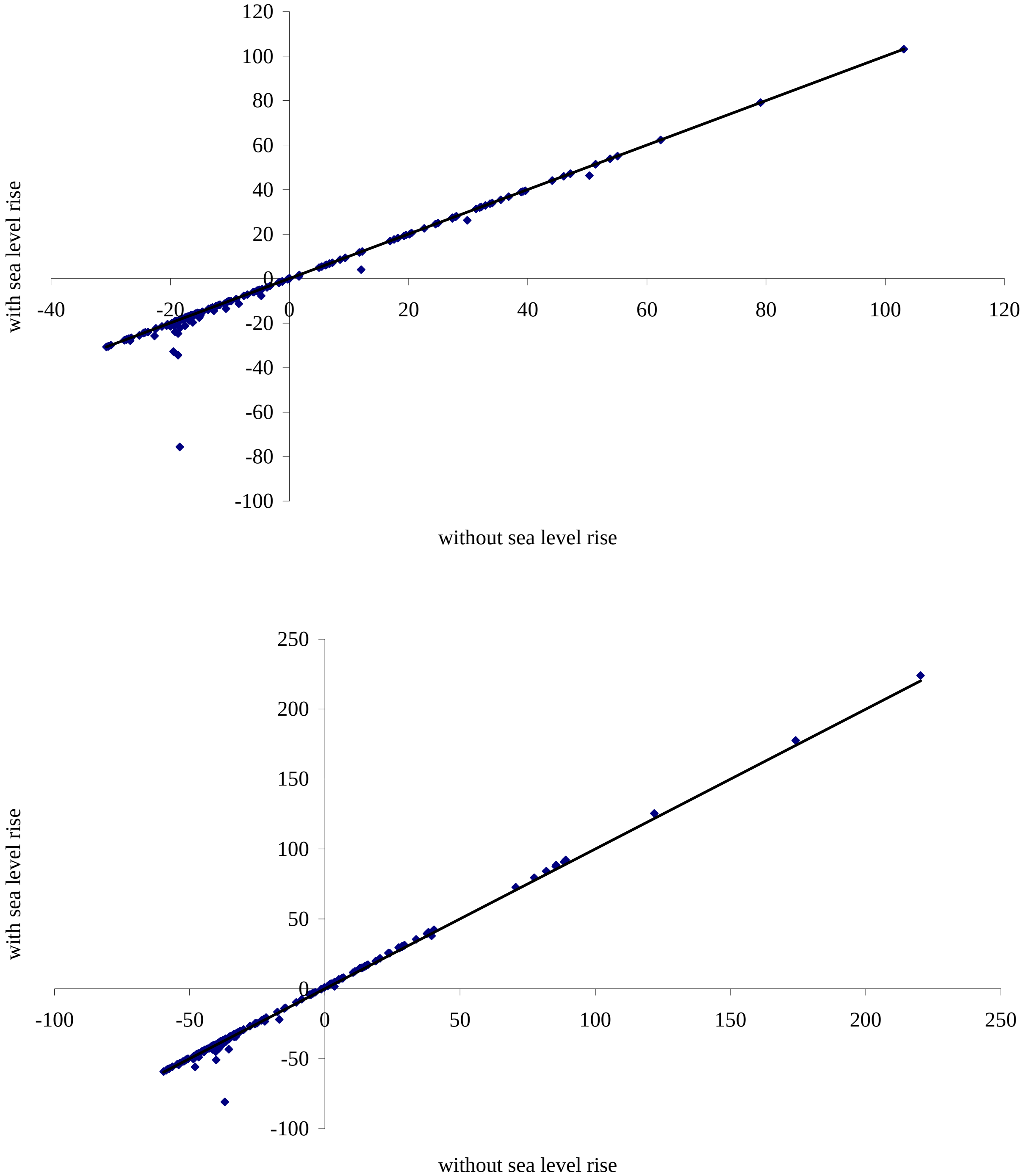


Figure 8. The effect of including sea level rise on the impact of climate change on domestic tourists (top panel) and international arrivals (bottom panel) in the year 2100; change is measured as percentage deviation from the case without climate change.

Appendix Model validation

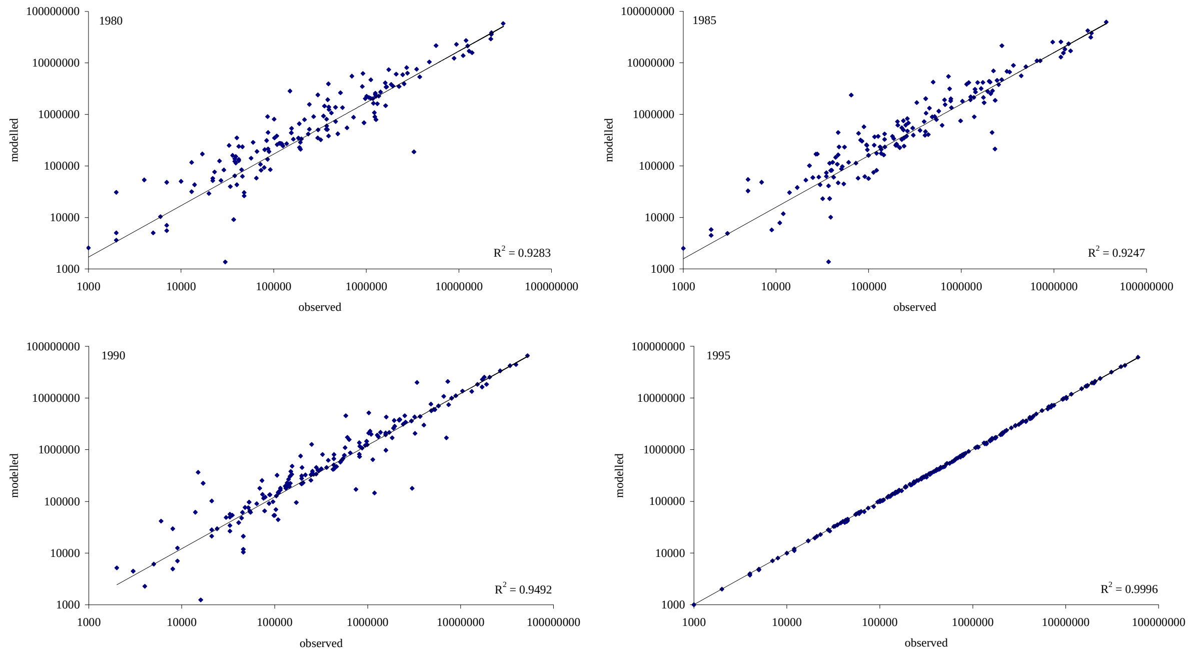


Figure A1. Observed versus modelled international arrivals in 1980, 1985, 1990 and 1995.

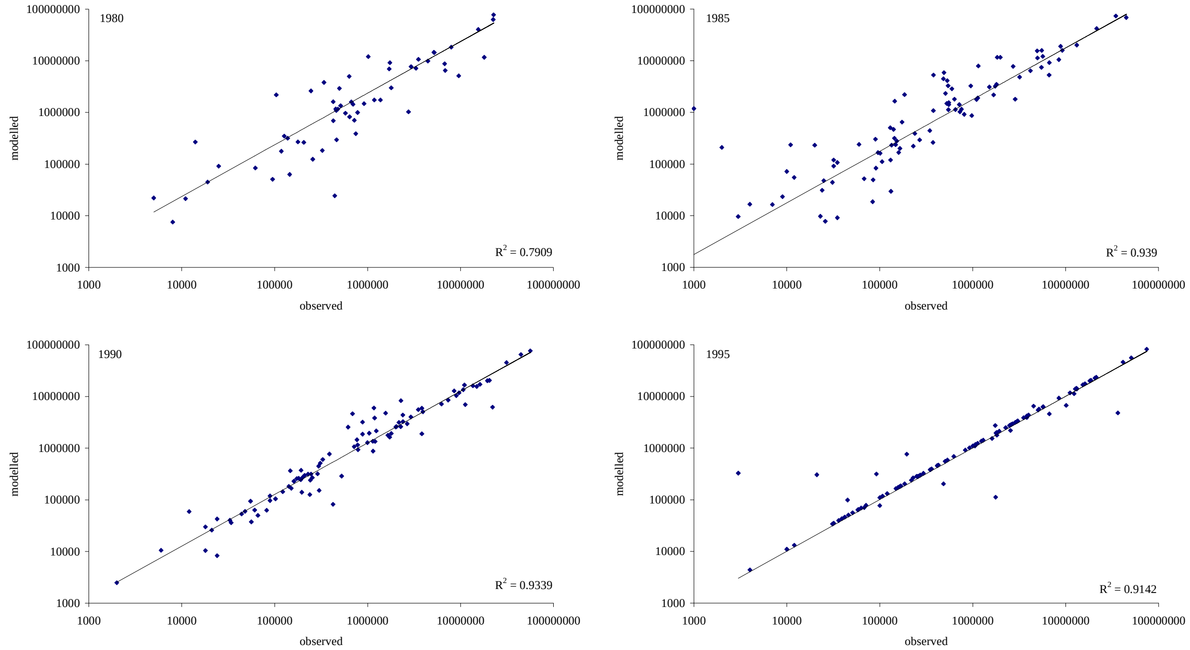


Figure A2. Observed versus modelled international departures in 1980, 1985, 1990 and 1995.

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