A General Equilibrium Analysis of Climate Change Impacts on Tourism

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NOTA DI LAVORO 127.2004

OCTOBER 2004

CCMP – Climate Change Modelling and Policy

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Summary

This paper studies the economic implications of climate-change-induced variations in tourism demand, using a world CGE model. The model is first re-calibrated at some future years, obtaining hypothetical benchmark equilibria, which are subsequently perturbed by shocks, simulating the effects of climate change. We portray the impact of climate change on tourism by means of two sets of shocks, occurring simultaneously. The first shocks translate predicted variations in tourist flows into changes of consumption preferences for domestically produced goods. The second shocks reallocate income across world regions, simulating the effect of higher or lower tourists' expenditure. Our analysis highlights that variations in tourist flows will affect regional economies in a way that is directly related to the sign and magnitude of flow variations. At a global scale, climate change will ultimately lead to a welfare loss, unevenly spread across regions.

Keywords: Climate change, Computable general equilibrium models, Tourism

JEL Classification: D58, L83, Q51, Q54

We had useful discussions about the topics of this paper with Carlo Carraro, Sam Fankhauser, Jacqueline Hamilton, Marzio Galeotti, Francesco Bosello, Marco Lazzarin, Andrea Galvan, Claudia Kemfert, Hans Kremers, Hom Pant, Katrin Rehdanz, Kerstin Ronneberger and Guy Jakeman. The Volkswagen Foundation through the ECOBICE project, the EU DG Research Environment and Climate Programme through the DINAS-Coast project (EVK2-2000-22024), the US National Science Foundation through the Center for Integrated Study of the Human Dimensions of Global Change (SBR-9521914), the Michael Otto Foundation for Environmental Protection, and the Ecological and Environmental Economics programme at ICTP-Trieste provided welcome financial support.

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1. Introduction

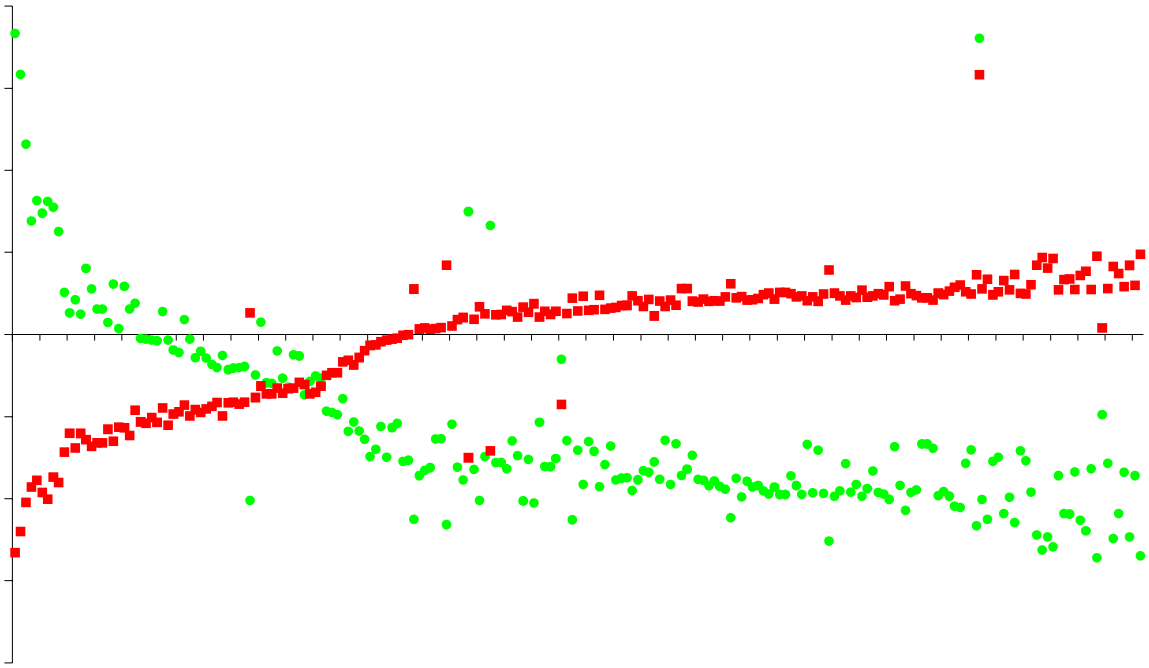
amount *where*

et al.

2. Estimates of changes in international tourist flows

et al.

	Interregional		Intrarregional	
	Arrivals	**Departures**	**Arrivals**	**Departures**
USA	-7537352	-21688924	0	0
EU	-43222063	-37619622	-48324941	-48324941
EEFSU	3116282	-43201505	-6079379	-6079379
JPN	-417310	-4293235	0	0
RoA1	16063980	-27747421	-68948	-68948
EEx	-31822804	11251183	-2553533	-2553533
CHIND	-484779	-2117862	97167	97167
RoW	-50746662	10366678	-5547398	-5547398



3. Assessing the general equilibrium effects: model structure and simulation strategy

4. Impact modelling in the CGE Framework

r

$$\mu_r = \frac{\Delta A_r + \Delta RT_r - \Delta D_r}{A_r + RT_r}$$

A_r A_r

D_r D_r RT_r

RT_r $RT_r = RA_r + NT_r$ RA_r

NT_r

NT_r

$\Delta RT =$

$$\lambda_{Rcr\ r} = \frac{VDP_{Rcr\ r}}{VDP_{MS\ r}}$$

VDP *Rcr*

MS

HT

$$\lambda_{HT\ r} = \frac{VDP_{HT\ r}}{VDP_{MS\ r}}$$

---

et al

$$\alpha_{MS\,r} = \mu_r \left(\lambda_{Rcr\,r} + \lambda_{HT\,r} \right)$$

if all prices and income levels would stay constant

$$\Delta E_r = \Delta E_r - \sum_r \Delta E_r \quad \frac{\Delta E_r}{\sum_r \Delta E_r}$$

$$\Delta E_r = VDP_{MS\,r} \quad \alpha_{MS\,r}$$

5. Baseline estimates for domestic tourism volumes

NT_r

RT_r

et al.

et al

et al

$$\frac{Dt}{pop} = \quad + \quad Y_i$$

$Dt_i \;\; pop_i \qquad Y_i$

i i t

$$_i = \left[\quad + \quad \frac{Y_i^t - Y_i}{Y_i} \right] \frac{pop_i^t}{pop_i} \qquad _i$$

RA_r

et al.

RT_r

	Tourist activity				Final tourist volumes (thousands)		
	1997	2010	2030	2050	2010	2030	2050
USA	3.68	4.42	6.14	8.41	1335881.67	2057637.79	2981453.75
EU	1.41	1.87	2.90	4.22	706615.45	1076790.45	1521252.63
EEFSU	0.64	0.97	1.65	2.54	393338.76	661033.54	1018918.85
JPN	0.62	0.75	1.23	2.02	94211.46	146391.17	224581.92
RoA1	2.71	3.32	4.79	6.93	235569.08	358444.43	522031.32
EEx	0.74	0.94	1.19	1.56	834140.08	1338591.05	2044761.36
CHIND	0.44	0.56	0.84	1.26	1405921.83	2378904.91	3769250.63
RoW	0.85	1.08	1.43	1.92	2259954.91	3765226.61	5793315.01

6. Simulation results

6.1. Shocked variables

	Private domestic demand for Market Services (% change)			Private households' real income (1997 Millions US $)		
	2010	**2030**	**2050**	**2010**	**2030**	**2050**
USA	0.0004	0.047	0.110	10.833	2373.6	9279.3
EU	0.0005	0.008	-0.080	13.050	373.26	-9424.3
EEFSU	0.0027	0.310	0.712	7.652	1803.9	7419.0
JPN	0.0014	0.162	0.361	18.759	4013.0	15987.2
RoA1	0.0051	0.631	1.517	24.342	5312.9	21516.3
EEx	-0.0022	-0.243	-0.530	-34.377	-6348.9	-20576.5
CHIND	0.00002	0.003	0.008	0.033	9.221	39.660
RoW	-0.0025	-0.265	-0.568	-40.292	-7536.9	-24240.7

6.2. Trade

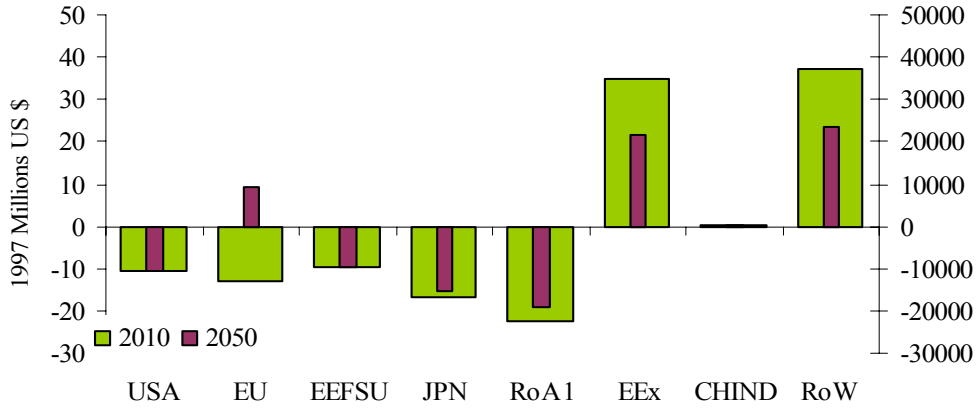


Figure 2. Net exports in 2010 (wide, light bars; left axis) and in 2050 (narrow, dark bars; right axis).

6.3 Gross Domestic Product

In general variations in the GDP (Figure 3) follow the shocks' pattern. However, in terms of magnitude, the relative ranking of our initial shocks does not always coincide with the relative ranking of GDP changes. This is a consequence of setting our analysis in a general equilibrium framework, where trade and substitution effects can dampen or amplify the impact of initial shocks.

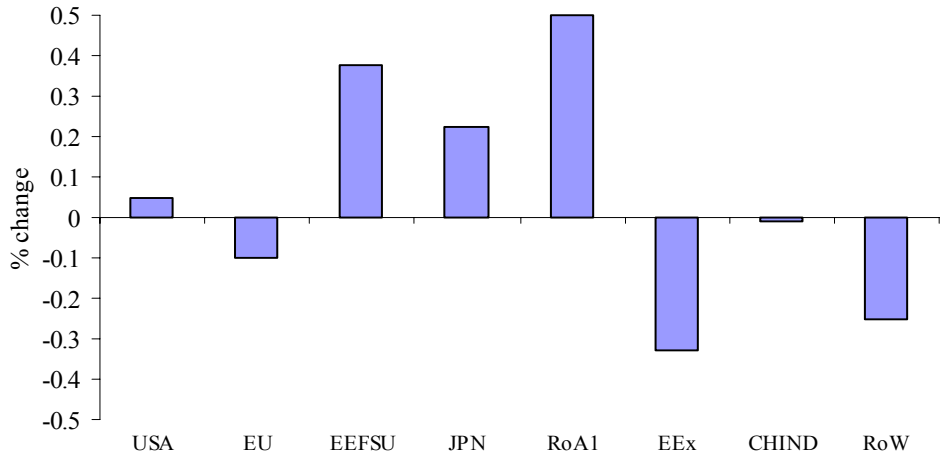


Figure 3. GDP percentage changes with respect to the baseline in 2050.

6.4. Primary factors and industrial output

Demand for primary factors is linked to final demand. As services use neither land nor natural resources, but relies on capital and labour in very similar shares, relative demand for these factors grows in those regions experiencing positive shocks, and vice versa.

Supply of primary factors is fixed in the short run. When demand for services increases, prices of labour and capital also increase (Figure 4). On the other hand, the price of other primary resources falls, despite the fact that positive shocks are associated with more expenditure generated by foreign tourists. As it has already been pointed out, the increased return on capital also triggers the multiplicative effect on foreign investment.

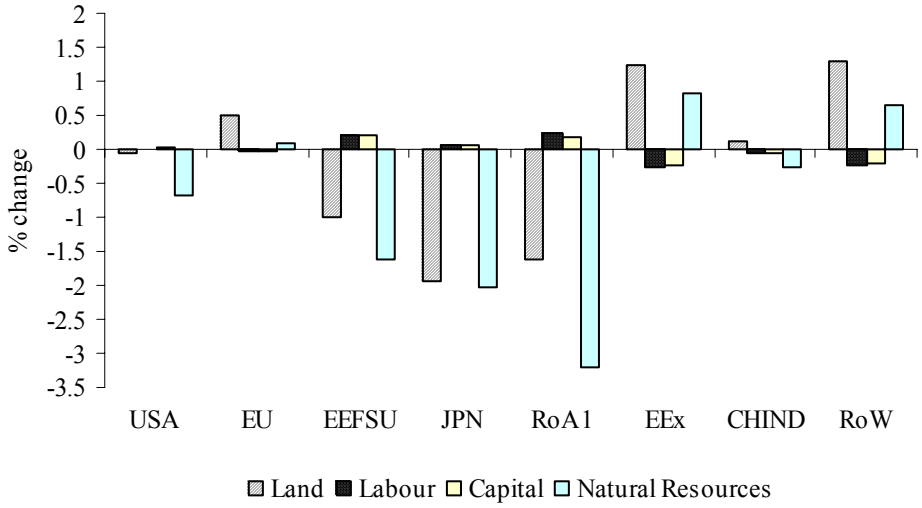


Figure 4. Real primary factors' prices. Change with respect to the baseline, 2050[10].

[10] Again, factor price changes are analogous but smaller in most regions in 2010 and 2030. The main exception is the EU in 2010 and in 2030, where changes have signs opposite to those observed and 2050 (as a direct consequence of the change of shocks' signs).

Table 4 shows variations in industrial production levels for 2050. Comparing it with Figure 4, it can be noticed that decreases (increases) in land prices are generally associated with decreases (increases) in production levels for some agricultural industries. Also, decreases (increases) in prices of natural resources are associated with decreases (increases) in the output of energy production industries, such as coal and oil.

	USA	EU	EEFSU	JPN	RoA1	EEx	CHIND	RoW
Rice	-0.007	0.102	-0.487	-0.439	-0.759	0.355	0.014	0.299
Wheat	-0.078	-0.021	-0.149	0.298	0.300	0.146	-0.021	0.122
Cereals	0.035	0.074	0.031	0.168	0.149	-0.011	0.042	-0.080
Vegetables & Fruits	0.065	0.088	0.027	-0.045	0.057	0.100	0.016	0.100
Animals	-0.090	0.040	-0.165	-0.287	-0.460	0.139	-0.013	0.151
Forestry	-0.211	0.024	-0.396	-0.375	-0.751	0.217	-0.020	0.169
Fishing	-0.177	0.049	-0.490	-0.396	-0.721	0.312	-0.040	0.325
Coal	-0.084	0.061	-0.333	-0.443	-0.868	0.280	-0.004	0.202
Oil	-0.096	-0.040	-0.406	-0.488	-0.501	0.148	-0.041	0.089
Gas	-0.095	0.168	-0.604	-1.034	-0.951	0.480	-0.125	0.341
Oil Products	0.042	0.120	-0.268	-0.314	-0.808	0.098	0.018	0.113
Electricity	-0.099	0.125	-0.465	-0.498	-1.940	0.208	-0.025	0.314
Water	-0.058	0.074	-0.217	-0.399	-0.372	0.178	0.010	0.194
Energy Intensive Industries	-0.143	0.154	-0.720	-0.470	-1.610	0.423	-0.017	0.406
Other Industries	-0.089	0.099	-0.535	-0.476	-1.445	0.407	0.012	0.324
Market Services	0.062	-0.038	0.376	0.204	0.764	-0.288	-0.013	-0.223
Non-Market Services	-0.081	-0.011	-0.091	-0.180	-0.619	-0.015	0.028	-0.034

Table 4. Percentage changes in industrial output with respect to the baseline in 2050.

6.4. CO_2 emissions

Figure 5 displays the impact on the yearly amount of CO_2 emissions. In our simulations, variations in CO_2 emissions are quite small. However, recall that we excluded transportation industries from the set of tourism activities.

Interestingly, emissions generally move in the opposite direction of GDP and demand shocks. This means that the industry mix drives the effect: when more tourists arrive, consumption patterns change towards relatively cleaner industries.

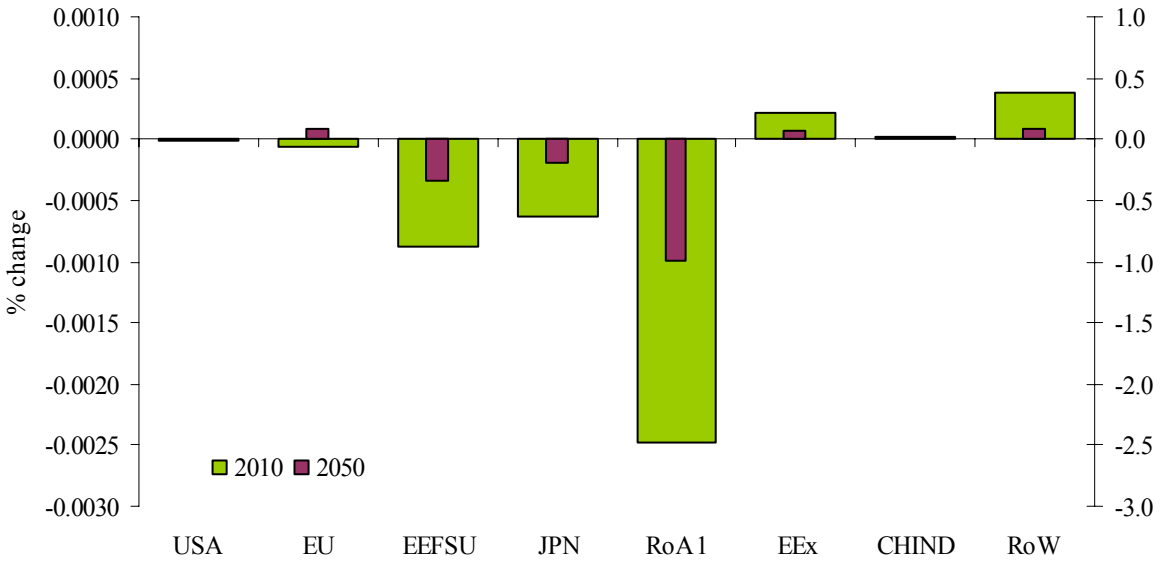


Figure 5. CO_2 emissions. Changes with respect to the baselines in 2010 (wide, light bars; left axis) and in 2050 (narrow, dark bars; right axis).

6.5. Welfare

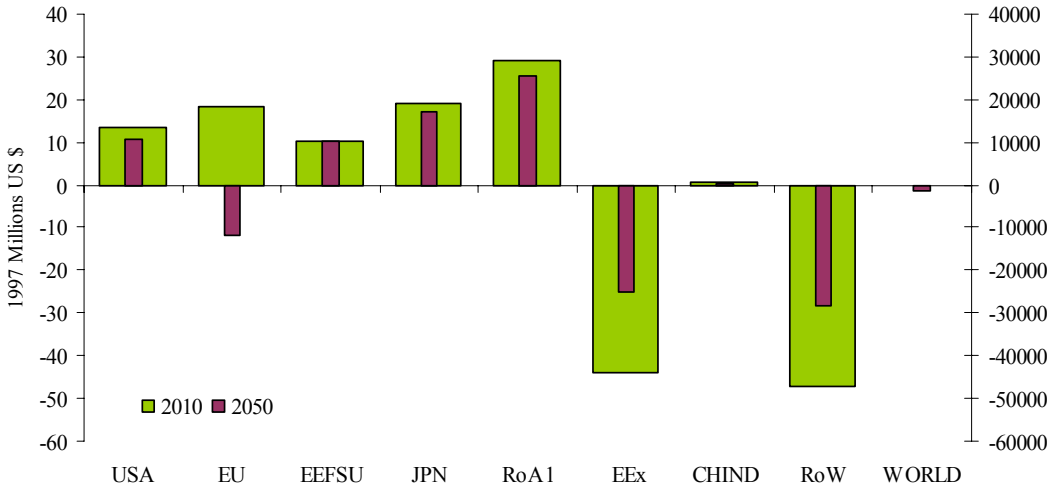


Figure 6: Equivalent variation in 2010 (wide, light bars; left axis) and in 2050 (narrow, dark bars; right axis).

Figure 6 illustrates the effects on income equivalent variations (a welfare index[11]). Total (world) welfare constantly decreases during the three periods[12]. At the regional level, welfare impacts have the same sign as income and demand shocks.

The main winners are the countries whose climate is currently too cold to attract many tourists, such as the former Soviet Union's countries and Canada (which is inside the Rest of Annex 1 group). Also, USA and Japan gain substantially. The EU enjoys a tiny welfare gain in 2010 and 2030, but suffers substantial losses in 2050. Welfare losses are mainly borne by the Rest of the World macro-region, which gathers the poorest countries and, incidentally, those that are also more exposed to other negative climate change effects (relevant for the tourism industry), such as sea-level rise (Bosello *et al.*, 2004a).

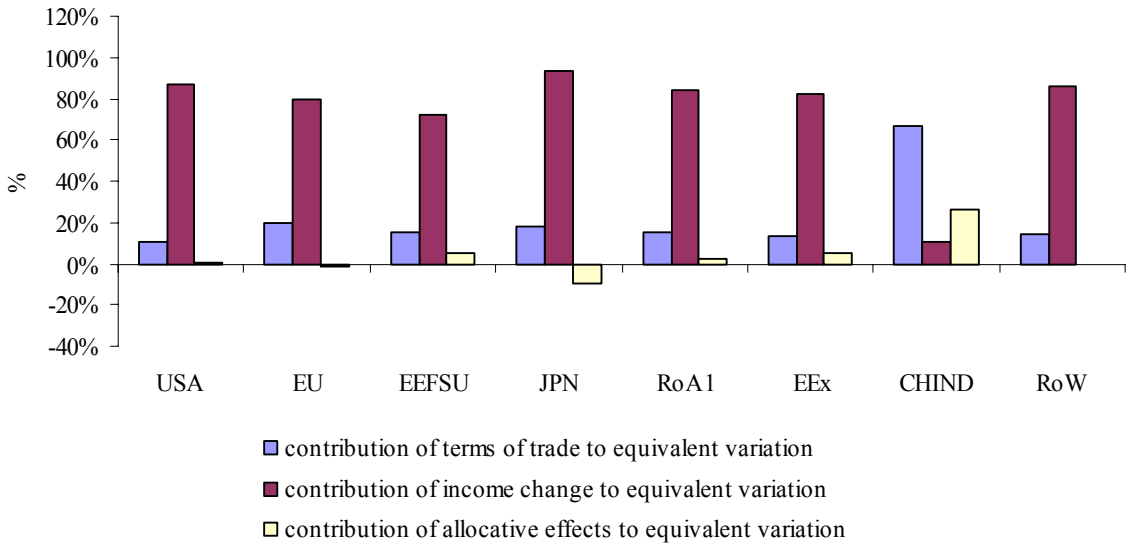


Figure 7. Welfare decomposition of equivalent variation (2050).

[11] EV measures the amount of income variation, at constant prices (1997 US$), which would have been equivalent to the simulation outcome, in terms of utility of the representative consumer.

Following Hanslow (2000), and Huff and Hertel (2000), we decompose the welfare changes in a series of components. As Figure 7 shows, most of the change in welfare is due to income variations, with the exception of China and India [CHIND], where allocative and trade effects prevail. This suggests that, for most regions, the main structural effect is due to the additional spending generated by foreign tourists.

7. Conclusion

Climate change will affect many aspects of our lives, and holiday habits are among the ones most sensitive to variations in climate. This implies that a very important service sector, the tourism industry, will be directly affected, and this may have important economic consequences.

This paper is a first attempt at evaluating these impacts within a general equilibrium framework, and establishes two things. Firstly, we show that tourism has impacts throughout the economy. This implies that economic studies, focusing on the tourism industry only, miss important effects. Secondly, we estimate the economy-wide impacts of changes in international tourism induced by climate change. Impacts on domestic demand and household income spread to the rest of the economy through substitution with other goods and services, and through induced effects on primary factors demand and prices. Also, changes in the rate of return of capital influence investment flows, which affects income and welfare.

[12] In this setting, climate conditions do not have any direct impact on utility. As stated previously, the shocks are neutral in the aggregate, as they only imply a redistribution of resources. Yet, Figure 6 highlights that this redistribution generates small welfare losses.

Despite the crude resolution of our analysis, which hides many climate-change-induced shifts in tourist destination choices, we find that climate change may affect GDP by –0.3% to +0.5% in 2050. Economic impact estimates of climate change are generally in the order of –1% to +2% of GDP for a warming associated with a doubling of the atmospheric concentration of carbon dioxide (Smith *et al.*, 2001), which is typically put at a later date than 2050. As these studies exclude tourism, this implies that regional economic impacts may have been underestimated by more than 20%. The global economic impact of a climate-change-induced change in tourism is quite small, and approximately zero in 2010. In 2050, climate change will ultimately lead to a non-negligible global loss.

Net losers are Western Europe, energy exporting countries, and the rest of the world. The Mediterranean, currently the world's prime tourism destination, would become substantially less attractive to tourists. The "Rest of the World" region contains the Caribbean, the second most popular destination, which would also become too hot to be pleasant. The "Rest of the World" also comprises tropical countries, which are not so popular today and would become even less popular under global warming. Energy exporting countries lose out because energy demand falls. China and India are hardly affected. North America, Australasia, Japan, Eastern Europe and the former Soviet Union are positively affected by climate change.

This study has a number of limitations, each of which implies substantial research beyond the current paper. We already mentioned the coarse spatial disaggregation of the computable general equilibrium model. In particular, finer disaggregation could highlight that climate impacts in Europe will be very different between northern countries and southern countries.

We only consider the direct effects of climate change on tourism. We ignore the effects of sea level rise, which may erode beaches or at least require substantial beach nourishment, and which may submerge entire islands, particularly popular atolls (Bosello *et al.*, 2004a). In the aggregate, we likely underestimated the costs of climate change on tourism. Disaggregate effects may be more subtle. Remaining atolls may be able to extract a scarcity rent, perhaps even witness a temporary surge in popularity under the cynical slogan "come visit before it is too late". We also overlooked other indirect effects of climate change, such as those on the water cycle, perhaps misrepresenting ski-tourism, and those on the spread of diseases (Bosello *et al.*, 2004b), perhaps further deterring tourists. On the economic side, the structure of the CGE does not allow us to estimate the effects of tourism travel, but only the effects of tourism expenditure in the destination country. Finally, our exercise is based on a rather ad-hoc scenario, in which all climate change effects occur suddenly and unexpectedly in a given reference year. In reality, climate change and its impacts are phenomena which evolve over time, and so do the expectations and the adaptive behaviour of economic agents. All these issues are deferred to future research.

Such research is worthwhile. We show that there is a substantial bias in previous studies of the economic impacts of climate change, and therewith a bias in the recommendations of cost-benefit analyses on greenhouse gas emission reduction. We also show that the economic ramifications of climate-change-induced tourism shifts are substantial.

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Appendix

A Concise Description of GTAP-EF Model Structure

The GTAP model is a standard CGE static model, distributed with the GTAP database of the world economy (www.gtap.org).
The model structure is fully described in Hertel (1996), where the interested reader can also find various simulation examples. Over the years, the model structure has slightly changed, often because of finer industrial disaggregation levels achieved in subsequent versions of the database.
Burniaux and Truong (2002) developed a special variant of the model, called GTAP-E, best suited for the analysis of energy markets and environmental policies. Basically, the main changes in the basic structure are:
- energy factors are taken out from the set of intermediate inputs, allowing for more substitution possibilities, and are inserted in a nested level of substitution with capital;
- database and model are extended to account for CO_2 emissions, related to energy consumption.
The model described in this paper (GTAP-EF) is a further refinement of GTAP-E, in which more industries are considered. In addition, some model equations have been changed in specific simulation experiments. This appendix provides a concise description of the model structure.
As in all CGE models, GTAP-EF makes use of the Walrasian perfect competition paradigm to simulate adjustment processes, although the inclusion of some elements of imperfect competition is also possible.
Industries are modelled through a representative firm, minimizing costs while taking prices are given. In turn, output prices are given by average production costs. The production functions are specified via a series of nested CES functions, with nesting as displayed in the tree diagram of figure A.1.
Notice that domestic and foreign inputs are not perfect substitutes, according to the so-called "Armington assumption", which accounts for product heterogeneity.
In general, inputs grouped together are more easily substitutable among themselves than with other elements outside the nest. For example, imports can more easily be substituted in terms of foreign production source, rather than between domestic production and one specific foreign country of origin. Analogously, composite energy inputs are more substitutable with capital than with other factors.

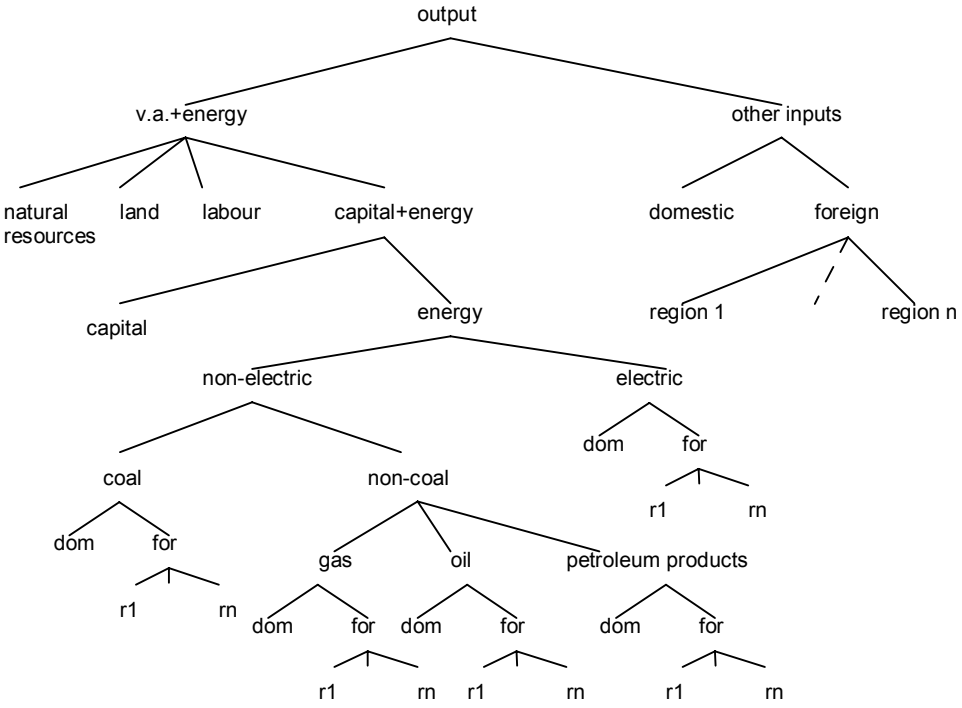

Figure A.1. Nested tree structure for industrial production processes.

A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour, capital). Capital and labour are perfectly mobile domestically but immobile internationally. Land and natural resources, on the other hand, are industry-specific.
This income is used to finance the expenditure of three classes of expenditure: aggregate household consumption, public consumption and savings (figure A.2). The expenditure shares are generally fixed, which amounts to say that the top-level utility function has a Cobb-Douglas specification. Also notice that savings generate utility, and this can be interpreted as a reduced form of intertemporal utility.
Public consumption is split in a series of alternative consumption items, again according to a Cobb-Douglas specification. However, almost all expenditure is actually concentrated in one specific industry: Non-market Services.
Private consumption is analogously split in a series of alternative composite Armington aggregates. However, the functional specification used at this level is the Constant Difference in Elasticities form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods.
In the GTAP model and its variants, two industries are treated in a special way and are not related to any country.
International transport is a world industry, which produces the transportation services associated with the movement of goods between origin and destination regions, thereby determining the cost margin between f.o.b. and c.i.f. prices. Transport services are produced by means of factors submitted by all countries, in variable proportions.

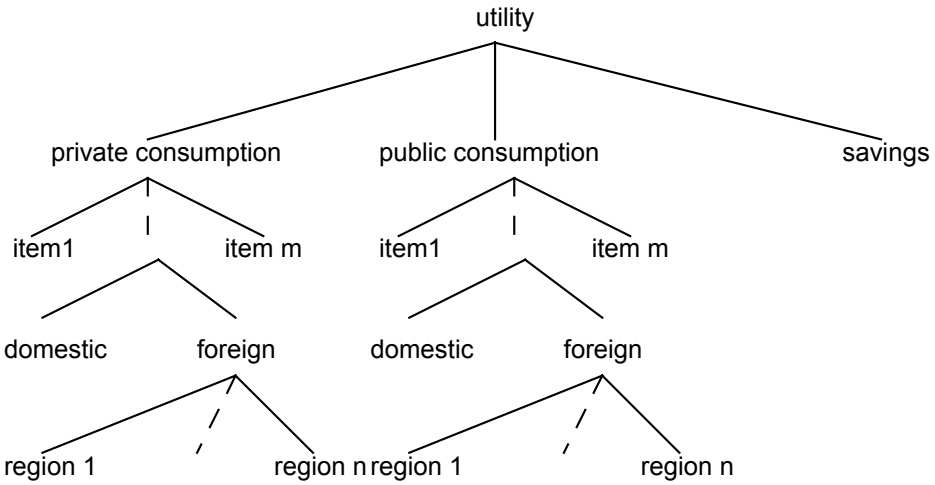

Figure A.2. Nested tree structure for final demand.

In a similar way, a hypothetical world bank collects savings from all regions and allocates investments so as to achieve equality of expected future rates of return. Expected returns are linked to current returns and are defined through the following equation:

$$r_s^e = r_s^c \left(\frac{ke_s}{kb_s} \right)^{-\rho}$$

where: r is the rate of return in region s (superscript e stands for expected, c for current), kb is the capital stock level at the beginning of the year, ke is the capital stock at the end of the year, after depreciation and new investment have taken place. ρ is an elasticity parameter, possibly varying by region.
Future returns are determined, through a kind of adaptive expectations, from current returns, where it is also recognized that higher future stocks will lower future returns. The value assigned to the parameter ρ determines the actual degree of capital mobility in international markets.
Since the world bank sets investments so as to equalize expected returns, an international investment portfolio is created, where regional shares are sensitive to relative current returns on capital.
In this way, savings and investments are equalized at the international but not at the regional level. Because of accounting identities, any financial imbalance mirrors a trade deficit or surplus in each region.

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(lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
(lx) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002
(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
(lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002
(lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
(lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
(lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003
(lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL) , Venice, August 28-29, 2003
(lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003
(lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003
(lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference “The Future of Climate Policy”, Cagliari, Italy, 27-28 March 2003
(lxx) This paper was presented at the 9th Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

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