ECONOMY-WIDE ESTIMATES OF THE IMPLICATIONS OF CLIMATE CHANGE: SEA LEVEL RISE

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January 22, 2004

Working paper FNU-38

Abstract

The economy-wide implications of sea level rise in 2050 are estimated using a static computable general equilibrium model. Overall, general equilibrium effects increase the costs of sea level rise, but not necessarily in every sector or region. In the absence of coastal protection, economies that rely most on agriculture are hit hardest. Although energy is substituted for land, overall energy consumption falls with the shrinking economy, hurting energy exporters. With full coastal protection, GDP increases, particularly in regions that do a lot of dike building, but utility falls, least in regions that build a lot of dikes and export energy. Energy prices rise and energy consumption falls. The costs of full protection exceed the costs of losing land.

Key words

Impacts of climate change, sea level rise, computable general equilibrium

JEL Classification

C68, D58, Q25

1. Introduction

Of the many impacts of climate change, sea level rise is often seen as one of the more threatening. The impacts of sea level rise are straightforward – more coastal erosion and sea floods, unless costly adaptation is undertaken – and unambiguously negative (unless one happens to be in the dike building sector). Sea level rise could have very substantial impacts in river deltas, and may wipe out entire islands and island nations.

Therefore, sea level rise figures prominently in assessments of the impacts of climate change, and the costs of sea level rise figures equally prominently in estimates of the costs of climate change. The majority of estimates of the economic damages of global warming rely on the methodology of direct costs, that is, damage equals price times quantity. The direct cost method ignores that the quantity change – say, the amount of land lost to sea level rise – may well affect the price – say, of coastal land. Furthermore, this method ignores that changes in one market – say, the market of land – has implications for all other markets. In this paper, we estimate and compare the direct costs, the partial equilibrium effects, and the general equilibrium effects of sea level rise.

To our knowledge, two other papers have attempted this. Deke *et al.* (2002) use the DART model to estimate economy-wide implications of sea level rise.[1] However, their study is restricted to the costs of coastal protection, ignoring land losses. Deke et al. (2002) subtract the costs of coastal protection from investment. As they use a Solow-Swan growth engine, they essentially reduce the capital stock and ignore the stimulus to the engineering sector. Darwin and Tol (2001) use the FARM model. Their study is very similar to ours, but it is based on older data on national production and international trade. Furthermore, investments in coastal protection are modelled as a general loss of productive capital, whereas we model coastal protection explicitly as an investment. Although FARM has a much richer representation of land and land use than does our model, this feature was not used by Darwin and Tol (2001).

The structure of the paper is as follows. Section 2 presents our variant of the GTAP-E CGE model, called GTAP-EF. Section 3 discusses the implications of sea level rise. Section 4 discusses how these implications are brought into the CGE model. Section 5 presents the results. Section 6 concludes.

2. Model and simulations

To assess the systemic, general equilibrium effects of sea-level rise, we made an unconventional use of a multi-country world CGE model: the GTAP model (Hertel, 1996), in the version modified by Burniaux and Truong (2002), and subsequently extended by ourselves.[2]

First, we derived benchmark data-sets for the world economy at some selected future years (2010, 2030, 2050), using the methodology described in Dixon and Rimmer (2002). This entails inserting, in the model calibration data, forecasted values for some key economic variables, to identify a hypothetical general equilibrium state in the future.

Since we are working on the medium to long term, we focused primarily on the supply side: projected changes in the national endowments of labour, capital, land, natural resources, as well as variations in factor-specific and multi-factor productivity.

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[1] A third paper, Kemfert (2002), includes sea level rise in a wider range of impacts, but does not separate out the effects of sea level rise. See Roson and Tol (forthcoming).

[2] A more complete description of the modelling approach can be found in Roson (2003).

Most of these variables are “naturally exogenous” in CGE models. For example, the national labour force is usually taken as a given. In this case, we simply shocked the exogenous variable “labour stock”, changing its level from that of the initial calibration year (1997) to some future forecast year (e.g., 2030). In some other cases, we considered variables, which are normally endogenous in the model, by modifying the partition between exogenous and endogenous variables. In the model, simulated changes in primary resources and productivity induce variations in relative prices, and a structural adjustment for the entire world economic system. The model output describes the hypothetical structure of the world economy, which is implied by the selected assumptions of growth in primary factors.

We obtained estimates of the regional labour and capital stocks by running the G-Cubed model (McKibbin and Wilcoxen, 1998). This is a rather sophisticated dynamic CGE model of the world economy, with a number of notable features, such as: rational expectations intertemporal adjustment, international capital flows based on portfolio selection (with non-neutrality of money and home bias in the investments), sticky wages, endogenous economic policies, public debt management. We used output of this model in GTAP, rather than using G-Cubed directly, primarily because the latter turned out to be much easier to adapt to our purposes, in terms of sectoral and regional disaggregation and changes in the model equations.

We got estimates of land endowments and agricultural land productivity from the IMAGE model version 2.2 (IMAGE, 2001). IMAGE is an integrated assessment model, with a particular focus on the land use, reporting information on seven crop yields in 13 world regions, from 1970 to 2100. We ran this model by adopting the most conservative scenario about the climate (IPCC B1), implying minimal temperature changes.

A rather specific methodology was adopted to get estimates for the natural resources stock variables. As explained in Hertel and Tsigas (2002), values for these variables in the original GTAP data set were not obtained from official statistics, but were indirectly estimated, to make the model consistent with some industry supply elasticity values, taken from the literature. For this reason, we preferred to fix exogenously the price of the natural resources, making it variable over time in line with the GDP deflator, while allowing the model to compute endogenously the stock levels.

3. Impacts of Sea Level Rise

We evaluate the impacts of sea level rise in the eight regions of GTAP-EF (see Table I). For each region, Table 2 presents estimates of the potential dryland loss without protection. Our main source of information is the GVA (Global Vulnerability Assessment; Hoozemans *et al.*, 1993), an update of work earlier done for the Intergovernmental Panel on Climate Change (IPCC CZMS, 1990, 1991). The GVA reports impacts of sea level rise for all countries in the world.

Dryland losses are not reported in the GVA, but they are, for selected countries, by Bijlsma *et al.* (1996), Nicholls and Leatherman (1995), Nicholls *et al.* (1995) and Beniston *et al.* (1998). The GVA reports people-at-risk, which is the number of people living in the one-in-1000-year flood plain, weighted by the chance of inundation. Combining this with the GVA's coastal population densities, area-at-risk results. The exponent of the geometric mean of the ratio between area-at-risk and land loss for the 18 countries in Bijlsma *et al.* (1996) was used to derive land loss for all other countries from the GVA's area-at-risk. This procedure introduces additional uncertainty. The review of the SCOR Working Group 89 (1991) shows that land loss estimates due to climate change are not very accurate.

The GVA reports the costs of fully protecting the coast, with protection standards varying in an ad hoc but sensible way with population density and per capita income. Protection costs are given for a 1 metre sea level rise between 2000 and 2100, which is not very likely. However, costs are assumed to be linear in dike height (and so in sea level rise), and therefore readily scaled. The GVA reports the average annual investment over the century, which we annuitised.

Direct costs are calculated as the amount of land lost times its value. This is a crude estimate of welfare loss, but the method is standard in the literature (Cline, 1992; Fankhauser, 1994; Jansen *et al.*, 1991; Nicholls and Leatherman, 1995; Nicholls *et al.*, 1995; Nordhaus, 1991; 1994; Rijsberman, 1991; Titus, 1992; Titus *et al.*, 1998; Tol, 1995, 1996, 2002; Yohe, 1990; Yohe and Schlesinger, 1998; Yohe *et al.*, 1995, 1996, 1999).[3] The value of land is set at $250,000 in the USA, and varies with income density (GDP per area) using an elasticity of 0.53.[4]

4. Including Impacts in the CGE Model

To model the effects of sea-level rise, we run a set of simulation experiments, by shocking some specific variables in the model, depending on the policy scenario considered.

In the "no-protection" scenario, we assume that no defensive expenditure takes place, so that some land is lost in terms of productive potential, because of erosion, flooding and salt water intrusion. This case can be easily accommodated in the model by exogenously reducing the endowment of the primary factor "land" in all countries, in variable proportions.

In the "full-protection" scenario, on the contrary, we assumed that no land is lost because of sea-level rise, but this outcome requires some specific infrastructure investment. In practice, these measures can take the form of dike building or elevation, beach nourishment, and protection of freshwater resources. In the model, this translates into an exogenous increase of regional investment expenditure.

To fully assess the results of this simulation exercise, it is important to understand how we modified the mechanism of investment allocation in the GTAP-EF model, as well as the difference between our approach and some alternative modelling strategies.

Regional investments are endogenous variables in the GTAP framework. Furthermore, savings and investments are not equalized domestically, but only at the global scale.[5] Savings are generated because of the presence of a composite good "saving" in the utility function of each regional representative consumer. A hypothetical "world bank" then collects savings and allocates investments, realizing the equalization of regional *expected* returns.[6]

We modified this procedure in the following way. We made the regional investment variables exogenous, and we fixed their level, augmenting their calibration values by some given percentages, accounting for region-specific additional investment expenditure for coastal protection. To ensure the equalization of global saving and investment, we then allowed for an endogenous adjustment of regional savings. Assuming that all regional investments increase by the same percentage (reflecting the GTAP assumption of perfect international

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[3] Turner *et al.* (1995) use the discounted flow of GDP per square kilometre as an indicator for land value. Broadus (1996) also uses this approach.

[4] This elasticity is estimated using data for the states of the USA; data are taken from US DoC (1992, 1993).

[5] The condition equalizing global saving and investment is the redundant equation in the Walras general equilibrium system.

[6] The interested reader may find a complete description of the investments allocation mechanism in Hertel (1996). Here, it is sufficient to say that this mechanism attains a compromise between a neo-classical arbitrage and a home-biased asset allocation.

mobility of capital), we asked the model to calculate the implied changes in the shares of national income devoted to savings.

Clearly, since global investment increases, so do global and hence domestic savings. To save more, each representative consumer has to consume less, thereby reducing her immediate utility. However, there is no direct link between consumption levels and additional investment expenditure. This is because domestic saving and investment are not equalized, meaning that each economy can run a foreign debt. If a region would be especially vulnerable to the sea-level rise, it would require relatively more defensive expenditure. Part of this spending would then be financed through foreign capital inflows.

Our methodology significantly differs from the one adopted by Darwin and Tol (2001) and Deke *et al.* (2002) who also perform a simulation experiment on capital investment for coastal protection. Darwin and Tol model defensive expenditure simply by assuming that some fraction of the capital, used in the production of goods and services, is converted to unproductive defensive infrastructure. The hypothesis of capital conversion is clearly unrealistic in the short run, but could be justified as an approximation of a long-run equilibrium in which defensive investment completely offsets productive investment, although there is no specific reason to believe that this offset would be one-for-one. Deke *et al.* (2002) subtracts investments in coastal protection from overall investment, without building up a “coastal protection capital” or even creating a demand for dike building. Our approach is different, and provides the advantage of accounting for the multiplicative effects of changes in the demand structure. For example, our model generates higher growth rates for the construction industry wherever new infrastructure is built.

5. Results

In this section, simulation results for the year 2050 are reported and commented, in terms of variation from the no-climate-change baseline equilibrium. Results for other reference years are qualitatively similar.

No protection scenario

Table I shows the effects of sea level rise for the no-protection scenario, based on a uniform increase of 25 cm.

The fraction of land lost is quite small in all regions. The highest losses affect Oil Exporter Countries (EEx), loosing 0.18% of their dry land, followed by Japan (JPN) and the Rest of the World (RoW), both with a 0.15% loss. The value of the land lost is large in absolute terms, but quite small if compared to GDP (EEx has the biggest value: 0.1% of GDP). Generally, developing regions – CHIND and RoW – experience direct losses higher than those of developed countries, because their economies are more agricultural. The high loss in EEx is partly due to their losses of energy exports (see below).

GDP falls in all regions, especially in CHIND (-0.030%), EEx (-0.021%) and RoW (-0.017%).[7] Two aspects are worth noticing: first, general equilibrium effects influence the cost distribution. GDP losses for the Former Soviet Union (EEFSU), the Rest of Annex 1 (RoA1), EEx and RoW are lower than the direct cost of the lost land, whereas the opposite occurs to USA, EU, JPN and CHIND; in the case JPN, the GDP losses are even 10 times as large as the

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[7] Note that the change in the *net* domestic product is the sum of the change the *gross* domestic product and the direct costs of land loss. This implies that, overall, the direct cost method underestimates the true costs of land loss, a point also noted by Darwin and Tol (2001).

direct costs. Second, there is no direct relationship between the environmental impact and the economic impact. For instance, JPN exhibits the second highest amount of land lost, but the second smallest loss of GDP. CHIND, on the contrary, has the third smallest relative amount of land lost, but the highest cost in terms of GDP. This highlights the importance of conducting a general equilibrium analysis in this context, as substitution effects and international trade work as impact buffers or multipliers.

Since land is an essential factor in agriculture, agricultural industries bear the biggest impact of the loss of land, as can be seen in terms of higher prices and lower production levels (Table II).

The regional impacts are illustrated in Table III. In general, lower GDP losses are associated with investment inflows, so it is important to clarify the role played here by the investments.

Land loss is a direct resource shortfall, that is, a negative economic shock, which reduces income and consumption levels. The value of primary resources tends to fall, with the exception of the resource "land", which is getting scarcer.

The international allocation of investments is driven by the relative price of the capital in each country. The higher the capital return, the higher the share of international investments flowing into a country, with implications in terms of regional GDP variations, since investment is one component of GDP.

In turn, changes in the price of capital services are determined by two overlapping, and opposite, effects. On one hand, the negative shock lowers the value of national resources, including capital. On the other hand, economies try to substitute land with capital. Capital supply is fixed in the short run, though, and the higher demand for capital translates into higher capital returns.

The fall in the relative price of capital services is particularly strong in EEx, CHIND and RoW. This explains why regional GDP decreases relatively more than private consumption in these regions (as can be seen through the changes in the households utility index).

International trade also matters, through its effects on the terms of trade. In particular, two main effects are at work here: higher world prices for agriculture benefit net-exporters of agricultural goods (USA, RoA1, EEx), whereas lower prices for oil, gas, coal, oil products, electricity, energy intensive industries harm the net-exporters of energy products (EEx, EEFSU).

Labour, capital and *energy* substitute the land loss. At the same time, overall economic activity falls. In the OECD regions, the former effect dominates. The growth in market services raises the consumption of oil products, mainly by the transportation industries. Consequently, CO_2 emissions increase, despite the fall in GDP. In developing regions, the latter effect dominates; the decrease of GDP is associated with a decrease in CO_2 emissions. carbon dioxide emissions rise.

Total protection scenario

In the protection scenario, there is no negative economic shock, since –by assumption– the stock of land resources is fully preserved. However, the structure of final demand changes, because investment increases and household consumption decreases.

Table IV shows the additional expenditure for the various regions. Figures are relatively small in terms of GDP, but substantially higher than the value of land lost: the highest values are for

RoA1 (0.80% of GDP) and EEFSU (0.33% of GDP), the lowest for USA (0.01% of GDP).[8] The high value for RoA1 results from a combination of length of coast exposed and high protection cost, particularly in Canada, Australia and New Zealand. To meet this extra demand for investment, all regions increase uniformly (+ 1.9%) their savings, reducing at the same time private consumption, especially in CHIND (- 0.96%), JPN (- 0.56%) and RoW (- 0.35%). The impact on regional GDP is mixed: EU and JPN experience small losses (- 0.02% and - 0.01%, respectively), while all other regions gain slightly. EU and JPN attract little additional investment and are hit hard by the price increase of fossil fuels; USA also attracts little investment, but suffers less from the energy price increase.

Regional impacts are determined by the interplay of demand effects and changes in the terms of trade (see Table VI). Because of the need to finance defensive infrastructure, the most vulnerable regions (RoA1, EEFSU) experience net investment inflows, stimulating a regional GDP growth. Note that this additional GDP does not offset the costs of dike building; GDP net of coastal protection is lower for all regions compared to the case without climate change.

Changes in the terms of trade are mainly driven by increases in the world price of energy products (see Table V), benefiting energy exporting countries (EEx, EEFSU), and leading to a worldwide decrease of CO_2 emissions.

Variations in regional GDP are not particularly informative for a comparison of the two scenarios, but changes in aggregate private consumption (household utility index) provide a rough estimate of the welfare impact in the two cases. From this perspective, there are significant differences in both aggregate and distributional effects. See Figure I.

At an aggregate level, effects are stronger, and globally an order of magnitude more negative, in the total protection scenario than in the no protection case. This seems to suggest that it would be better, economically speaking, to avoid a full protection policy. This would not be entirely correct, however, since results shown here only hold for the short run.

There are also quite substantial distributional effects in the total protection scenario. Asian regions – JPN and CHIND – are especially worse off in these circumstances. EEFSU is the only region getting short term utility gains, because it receives the second highest influx of investments in coastal protection, stimulating regional GDP and income, and because it benefits from the increased value of energy exports. The utility loss of RoAx1 is relatively small, because it receives so much investment for coastal protection.

Another way of comparing no protection and full protection is to look at the loss of GDP plus the direct costs of land loss versus the loss of GDP plus the investment costs for coastal protection. Figure II does just that. The total protection case is, roughly, a factor 50 more expensive. Furthermore, whereas EEx and ROW are hit hardest in the no protection case, EEFSU and RoAx1 are in the total protection case.

6. Discussion and Conclusion

We estimate the economy-wide effects of sea level rise using a global computable general equilibrium model with eight regions. We do so for the year 2050, assuming a 25 cm sea level rise. Other scenarios are of course possible, but would not lead to a greater qualitative insight. We distinguish two scenarios for adaptation. In the first, coast are unprotected and lands are lost to the sea. In the second scenario, coasts are fully protected. Reality will lie somewhere in

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[8] Indeed, using cost-benefit analysis, Fankhauser (1994) and Yohe *et al.* (1994) find that it is optimal to protect some but not all coasts.

between. Compared to earlier studies, our treatment of the impact of sea level rise is more complete, and our treatment of investments in coastal protection is more realistic.

On balance, the general equilibrium effects add to the direct costs of land loss or investments in coastal protection. This is because the loss of land or investment deflates the entire economy. The distribution of the general equilibrium effect is very different from the distribution of land losses or coastal protection, and the distributional effects of land losses and coastal protection also differ substantially.

For the scenario without coastal protection, the general equilibrium effects are strongest in economies that rely most on agriculture. Although energy is substituted for the loss of land, the price of energy demand falls with the shrinking economy, hurting the energy exporters.

For the other scenario, GDP generally expands as we force the model to additionally invest in coastal protection. These investments are financed by the global capital market. As a result, utility falls, least in those regions with most dike building, and utility falls most in Asia.

This paper shows that the economy-wide, indirect effects of the impacts of climate change are, first, substantial compared to the direct effects and, second, distributed differently. The direct cost method still dominates the climate change impact literature (Smith et al., 2001). As such, this paper adds to our knowledge.

On the other hand, more research needs to be done. First, sea level rise is only one of the many impacts of climate change. In two companion papers, we look at health and tourism. Second, we use a static CGE, limiting the analysis to the short term effects. Fankhauser and Tol (2003) study the impact of climate change in one-sector growth models, also finding that the indirect economic effects may be just as important as the direct costs. Third, the shocks imposed are relatively crude; the allocation of land is underdeveloped in GTAP, so that adaptation is limited; investment in coastal protection does not crowd out other investment; and the trade-off between coastal protection and land loss is not made. Fourth, although we find that carbon dioxide emissions change, we do not feed this back into the climate scenario. All this is postponed for future research.

Acknowledgements

We had useful discussions about the topics of this paper with Andrea Bigano, Carlo Carraro, Sam Fankhauser, Marzio Galeotti, Andrea Galvan, Claudia Kemfert, Hans Kremers, Katrin Rehdanz and Kerstin Ronneberger. 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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Tab. I: No protection scenario: main economic indicators

	Land lost (% change w.r.t. baseline)	Land lost in km^2	Value of land lost		GDP (% change w.r.t. baseline)	Household utility index (% change w.r.t. baseline)	CO$_2$ Emissions (% change w.r.t. baseline)
			1997 million US$	% of GDP			
USA	-0.055	5000	102	0.0002	-0.002	-0.005	0.010
EU	-0.032	1015	187	0.0010	-0.001	-0.005	0.012
EEFSU	-0.018	4257	611	0.0100	-0.002	-0.006	0.005
JPN	-0.153	575	20	0.0001	-0.001	0.003	0.035
RoA1	-0.006	1065	221	0.0030	0.000	0.008	0.015
EEx	-0.184	31847	15556	0.1010	-0.021	-0.015	-0.008
CHIND	-0.083	10200	324	0.0030	-0.030	-0.062	-0.024
RoW	-0.151	71314	13897	0.0600	-0.017	-0.014	-0.012

Tab. II: No protection scenario: price and production levels by industry

	Price index for world supply (% change w.r.t. baseline)	Quantity index for world supply (% change w.r.t. baseline)
Rice	0.484	-0.054
Wheat	0.314	-0.040
CerCrops	0.389	-0.042
VegFruits	0.360	-0.058
Animals	0.329	-0.045
Forestry	-0.102	-0.017
Fishing	-0.057	-0.020
Coal	-0.068	-0.012
Oil	-0.081	0.004
Gas	-0.066	0.001
Oil_Pcts	-0.075	0.004
Electricity	-0.058	-0.007
En.Int_in	-0.042	-0.013
Oth_ind	0.044	-0.033
MServ	-0.040	0.003
NMServ	-0.040	0.007

Tab. III: No protection scenario: industrial output and price of primary factors by region

Industry Output (% change w.r.t. baseline)								
	USA	EU	EEFSU	JPN	RoA1	EEx	CHIND	RoW
Rice	-0.020	0.040	-0.013	-0.019	0.056	-0.086	-0.028	-0.073
Wheat	-0.051	-0.022	0.008	-0.259	0.043	-0.080	-0.033	-0.076
CerCrops	-0.020	0.037	0.060	-0.069	0.103	-0.116	-0.025	-0.083
VegFruits	-0.029	0.031	0.036	-0.078	0.087	-0.128	-0.050	-0.078
Animals	-0.026	-0.016	0.020	-0.035	0.022	-0.094	-0.077	-0.079
Forestry	-0.041	-0.024	-0.026	-0.031	-0.024	-0.015	-0.001	-0.011
Fishing	-0.007	-0.012	-0.017	-0.019	-0.033	-0.015	-0.036	-0.016
Coal	-0.009	-0.013	-0.008	-0.091	-0.058	0.016	-0.007	-0.012
Oil	-0.011	-0.024	-0.008	-0.064	-0.033	0.013	0.019	0.000
Gas	0.003	-0.036	-0.005	-0.042	-0.048	0.036	0.022	-0.014
Oil_Pcts	0.014	0.013	0.009	0.017	0.024	0.002	-0.034	-0.006
Electricity	0.001	-0.010	0.003	-0.010	-0.023	-0.007	-0.025	-0.006
En_Int_ind	-0.013	-0.015	-0.007	-0.040	-0.051	0.006	-0.003	-0.005
Oth_ind	-0.021	-0.017	-0.019	-0.010	-0.009	-0.083	-0.035	-0.071
Mserv	0.003	0.001	0.000	0.005	0.002	0.010	-0.036	0.011
NMServ	0.003	0.003	0.005	0.003	0.010	0.009	0.060	0.014
Investment	0.008	0.008	-0.013	0.031	0.022	-0.066	-0.172	-0.043
Price of primary factors (% change w.r.t. baseline)								
Land	0.534	0.514	0.532	1.019	0.607	0.804	0.467	0.802
Labor	-0.051	-0.051	-0.059	-0.002	-0.026	-0.123	-0.196	-0.108
Capital	-0.051	-0.048	-0.061	-0.001	-0.025	-0.127	-0.212	-0.112

Tab. IV: Total protection scenario: main economic indicators

Region	Coastal protection expenditure		Investment induced by coastal protection (% change w.r.t. baseline)	GDP (% change w.r.t. baseline)	Household utility index (% change w.r.t. baseline)	CO_2 Emissions (% change w.r.t. baseline)
	1997 million US$	% of GDP				
USA	5153	0.010	0.151	0.001	-0.206	-0.069
EU	11213	0.025	0.302	-0.022	-0.296	-0.160
EEFSU	23076	0.332	3.179	0.049	0.033	-0.133
JPN	7595	0.032	0.242	-0.009	-0.605	-0.344
RoA1	71496	0.799	9.422	0.103	-0.009	-0.130
EEx	363856	0.185	2.235	0.015	-0.223	-0.069
CHIND	11747	0.106	1.254	0.003	-0.889	-0.116
RoW	38808	0.148	1.817	0.009	-0.310	-0.115

Tab. V: Total protection scenario: price and production levels by industry

	Price index for world supply (% change w.r.t. baseline)	Quantity index for world supply (% change w.r.t. baseline)
Rice	0.011	0.094
Wheat	0.051	0.025
CerCrops	0.085	0.022
VegFruits	-0.103	-0.043
Animals	0.022	-0.011
Forestry	-0.064	-0.177
Fishing	0.038	-0.052
Coal	0.122	-0.109
Oil	0.080	-0.143
Gas	0.283	-0.180
Oil_Pcts	0.056	-0.154
Electricity	0.034	-0.080
EnInt_in	0.024	-0.002
Oth_ind	-0.002	0.136
MServ	-0.015	0.013
NMserv	-0.016	-0.102

Tab. VI: Total protection scenario: industrial output and price of primary factors by region

Industry Output (% change w.r.t. baseline)								
	USA	**EU**	**EEFSU**	**JPN**	**RoA1**	**EEx**	**CHIND**	**RoW**
Rice	0.061	-0.140	-0.160	0.595	-0.560	-0.073	0.165	-0.031
Wheat	0.045	0.045	-0.073	-0.378	0.161	-0.061	0.097	-0.015
CerCrops	-0.007	-0.017	-0.095	-0.061	-0.021	0.025	0.164	0.030
VegFruits	-0.030	-0.060	-0.082	-0.185	-0.095	-0.045	-0.037	-0.025
Animals	0.140	0.104	-0.074	0.399	-0.478	-0.029	-0.207	-0.027
Forestry	0.091	0.112	-0.287	0.209	-0.783	-0.141	-0.273	-0.160
Fishing	0.157	0.049	-0.166	0.454	-0.854	-0.099	-0.207	-0.096
Coal	0.097	0.113	-0.244	0.876	-1.236	-0.059	0.019	0.016
Oil	0.063	0.120	-0.374	0.387	-0.691	-0.102	-0.092	-0.056
Gas	0.231	0.556	-0.419	0.177	-1.234	-0.071	0.020	-0.060
Oil_Pcts	-0.121	-0.114	-0.136	-0.251	0.139	-0.101	-0.413	-0.158
Electricity	0.056	0.088	-0.249	0.042	-1.204	-0.119	-0.116	-0.109
En_Int_ind	0.259	0.269	-0.823	0.573	-2.470	-0.204	0.084	-0.132
Oth_ind	0.227	0.199	-0.177	0.655	-1.364	-0.104	0.336	-0.027
MServ	-0.043	-0.055	0.257	-0.177	0.725	0.132	0.019	0.078
NMserv	-0.093	-0.074	-0.004	-0.117	-0.092	-0.121	-0.382	-0.116
Price of primary factors (% change w.r.t. baseline)								
Land	0.499	0.356	-0.359	2.098	-1.467	-0.101	-0.713	-0.071
Labor	-0.154	-0.090	0.833	-0.536	1.376	0.251	0.111	0.130
Capital	-0.144	-0.103	0.806	-0.528	1.275	0.253	0.156	0.140

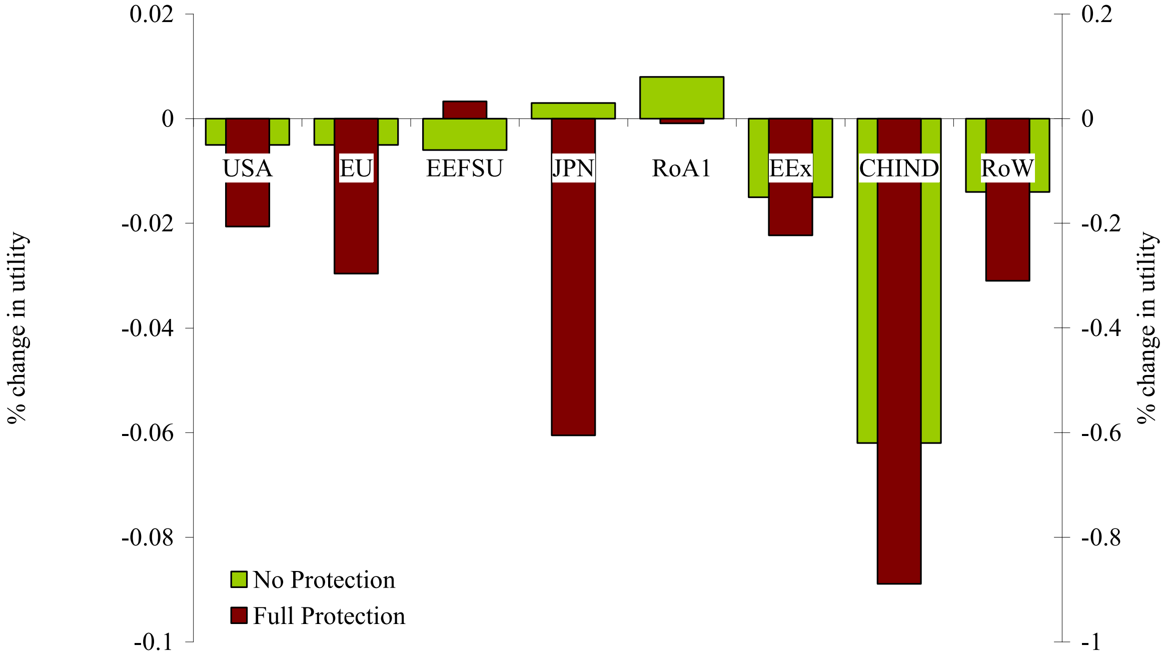

Figure I. The change in household utility index with respect to the baseline for the case without protection (wide, light bars; left axis) and the case with full protection (narrow, dark bars; right axis).

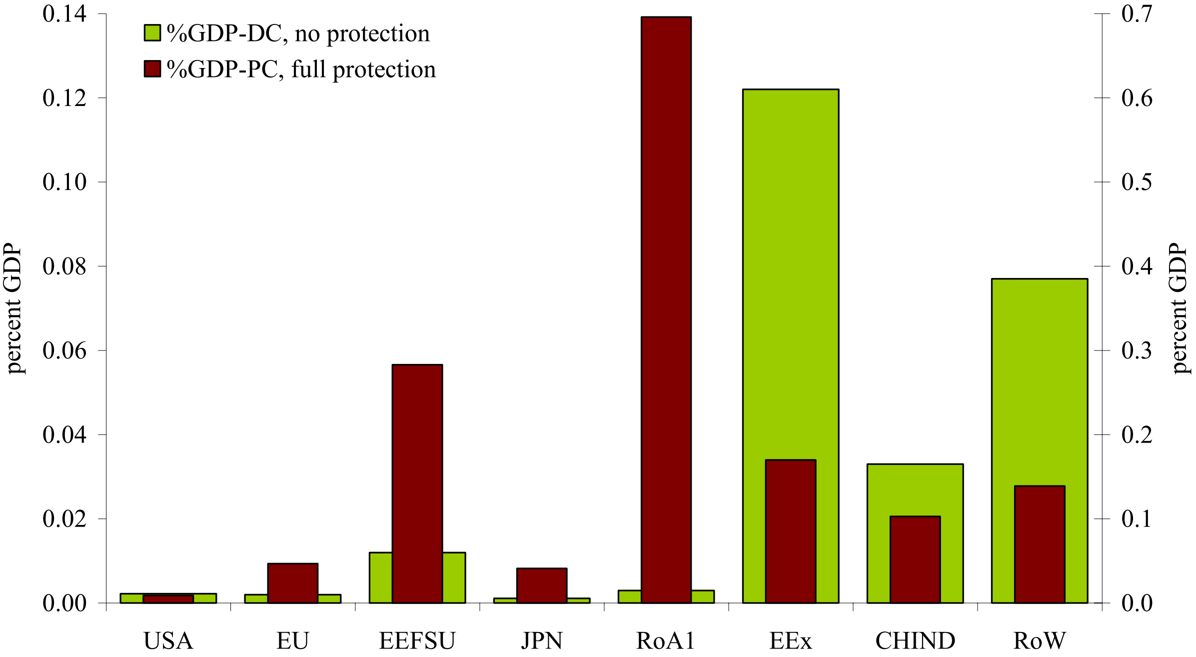

Figure II. The costs of land loss plus the induced changes in GDP for the case without coastal protection (wide, light bars; left axis) and the coastal protection costs plus the changes in GDP for the case with full protection (narrow, dark bars; right axis); everything is expressed as percentage of baseline GDP.

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Centre for Marine and Climate Research, Hamburg University, Hamburg

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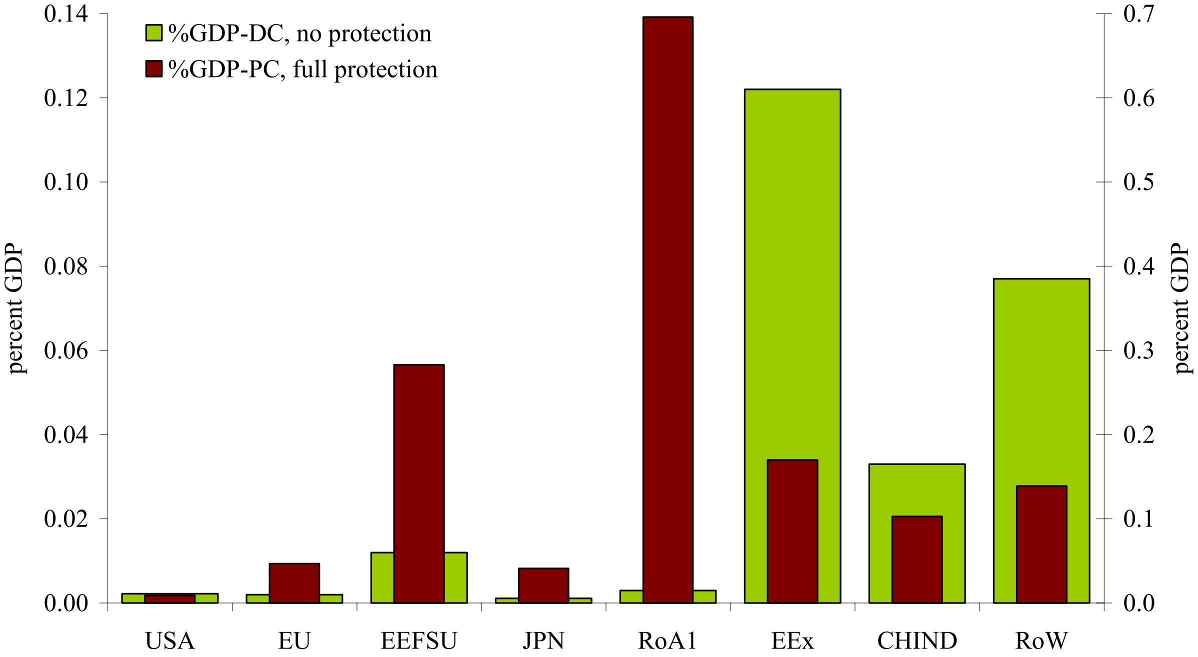

Figure II. The costs of land loss plus the induced changes in GDP for the case without coastal protection (wide, light bars; left axis) and the coastal protection costs plus the changes in GDP for the case with full protection (narrow, dark bars; right axis); everything is expressed as percentage of baseline GDP.