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Research article

Long-term economic impacts of coastal floods in Europe: a probabilistic analysis

Ignazio Mongelli*, Michalis Vousdoukas, Luc Feyen, Antonio Soria and Juan-Carlos Ciscar

EU Commission - Joint Research Centre; Unit C6 - Economics of Climate Change, Energy and Transport, Sevilla, Spain

* Correspondence: Email: Ignazio.Mongelli@ec.europa.eu; Tel: +34954488425; Fax: +34954488235.

SI1 Direct coastal impacts

The direct physical impacts associated to inundations are estimated in four steps. First, estimate present and future extreme sea levels along Europe's coastlines based on state-of-the-art projections of sea level rise, waves, storm surges and tides for a high emission (RCP8.5) pathway. Second, delineate the land areas inundated when extreme sea levels overtop current coastal protection and derive the corresponding flood inundation depth using 2-D hydraulic modelling14; third, overlay the inundation maps with exposure information on population and land use; fourth, translate this into direct flood losses using functions that relate the depth of inundation with economic damage to the assets inundated, and into the number of people flooded, taking into account gridded socio-economic projections.

The coastal flood risk analysis is based on the model LISCOAST (large-scale integrated sea-level and coastal assessment tool). The modular framework has been developed to assess weather-related impacts in coastal areas in present and future climates. It combines state-of-the-art large-scale modelling tools and datasets to quantify hazard, exposure and vulnerability and compute consequent risks. In order to reflect the large uncertainty that underlies the extent, frequency and timing of the sea level rise related inundations, in this study we use a set of Monte Carlo projections of the extreme sea level rise events (ESL) obtained with the combination of a GCM ensemble, with probabilistic distribution of extreme wind, atmospheric pressure and maximum tidal level (see [13] for further information).

SI2 Data and calibration of the model

Three main data sources have been used to calibrate the model: the ECFIN Ageing Report 2021 (AR), the Penn World Table 10.0 (PWT) and the World Development Indicator of the World Bank. The model's parameters, i.e. the saving rate, the depreciation rate etc., have been calibrated at country level in order to reflect cross country heterogeneity as much as possible, considering the stylized nature of the model used. Country specific saving rates and depreciation rates reflect, to some extent, the different level of economic structural resilience. For instance, a country with a high saving rate is characterized with a higher prudent attitude, which makes that country more resilient and with a better recovery capacity compared to a country with a lower saving rate, i.e. where current consumption is preferred to future one.

Furthermore, as the depreciation rate reflects the composition and type of capital assets, economies with a higher depreciation rate invest in short-lived assets (computers and software are more prone to obsolesce and physical deterioration) that require larger volume of investments, compared to an economy with a lower depreciation rate, whose functioning is more based on long-lived assets (infrastructure and building). While for EU countries, which have relatively small structural differences among them, this type of cross-country heterogeneity could be a reasonable proxy for economic resilience, it could be a less reliable one for developing economies. In that case, a low aggregate depreciation rate would reflect that certain type of assets are more expensive and also that there is a shortage of the complementary human capital, which makes those economies even less resilient.

The baseline replicates the GDP projections of the AR 2021 and assumes the growth rates for labour as reported in the AR 2021. The basic features of the model are very similar to the one used to generate the baseline GDP projections of the ECFIN Ageing Report, which represents an advantage for the calibration of the parameters. In particular, while labour input is projected to fall for most countries, both for the on-going demographic shift and also for a reduction of the average number of hours worked, productivity is expected to be the main if not the only source of growth for EU countries. The AR2021 assumes that labour productivity will grow during the next decades in part exogenously, for an increase of total factor productivity, and in part because of capital deepening, i.e. increase of the amount of physical assets per worker. We therefore calibrate our model in such a way that these particular assumptions are reflected in the parameters. We calibrate our model and choose the parameters such that the sum of squared errors between the model solution and the projected data of the AR2021 is minimised. The calibration is based on a nonlinear optimisation procedure and for this reason is quite dependant on the initial guess for the estimated parameters. We therefore implement a random selection for the initial guess of the parameters, which allows a sufficient exploration of the parameter space. All model's parameters, except for the output elasticity, are allowed to vary. However, we preserve the information about the saving and the depreciation rates, i.e. the parameters s and d, which we have from the official statistics, by using a smaller range for the initial guesses for these parameters compared to the others. The calibration mainly focus on the estimation of the parameters b and c of Eq 8, where for the exogenous growth rate g we keep it exogenous and corresponding to the growth rate of the AR2021.

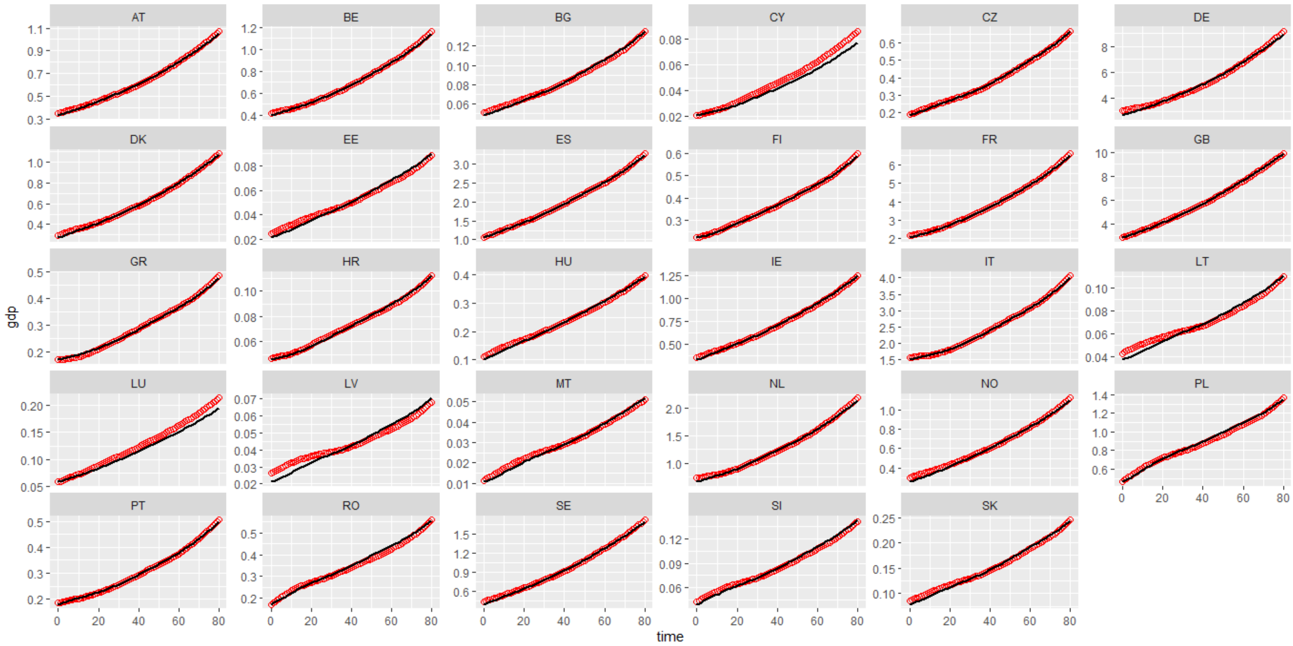

Figure S1. Comparison of the GDP projection of the AR2021 and the GDP projected by the calibrated model.

Figure S1. offers a visual comparison of the projections of GDP from the AR2021 and the GDP projected by the calibrated model.

Table S1. calibrated parameters for the European countries analysed in the study: d (depreciation rate), s (saving rates), b and c (parameters for the endogenous growth of productivity).

	d	s	b	c	sse
BE	0.044	0.231	0.003	0.643	0.005
BG	0.059	0.206	0.000	0.251	0.000
CY	0.034	0.145	0.001	0.286	0.002
DE	0.037	0.251	0.002	0.595	1.589
DK	0.049	0.283	0.002	0.595	0.008
EE	0.049	0.253	0.000	0.028	0.000
ES	0.041	0.191	0.003	0.598	0.007
FI	0.043	0.193	0.004	0.638	0.001
FR	0.043	0.204	0.003	0.604	0.094
GB	0.037	0.124	0.004	0.609	0.118
GR	0.029	0.104	0.006	0.624	0.004
HR	0.050	0.205	0.002	0.463	0.000
IE	0.077	0.265	0.004	0.597	0.008
IT	0.038	0.185	0.004	0.617	0.031
LT	0.046	0.173	0.000	0.002	0.001
LV	0.033	0.217	0.000	0.029	0.001
MT	0.063	0.231	0.003	0.573	0.000
NL	0.051	0.275	0.002	0.630	0.045
NO	0.041	0.332	0.002	0.614	0.035
PL	0.055	0.161	0.002	0.564	0.037
PT	0.030	0.161	0.003	0.602	0.001
RO	0.066	0.221	0.000	0.014	0.005
SE	0.047	0.267	0.002	0.649	0.020
SI	0.046	0.216	0.002	0.478	0.001

SI3 Results at country level

Results are presented as the average of the period 2071 to 2100, which we refer to as end of century.

Table S2. Welfare and GDP impacts at country level projected at the end of the century, i.e. average of the years 2071–2100.

	Welfare (% w.r.t. reference)		GDP (% w.r.t. reference)	
	mean	95% CI	mean	95% CI
Cyprus	6.76	5.86 – 7.9	5.12	2.99 – 7.5
Greece	3.57	2.60 – 4.9	2.69	1.00 – 4.68
Croatia	2.20	1.42 – 2.77	1.52	0.55 – 2.48
Denmark	2.01	1.38 – 2.75	0.98	0.29 – 1.84
Ireland	0.97	0.81 – 1.16	0.56	0.17 – 0.99
Nederland	0.79	0.00 – 2.63	0.29	0.00 – 1.12
France	0.74	0.60 – 0.91	0.46	0.17 – 0.78
Lithuania	0.57	0.38 – 0.78	0.38	0.12 – 0.68
Great Britain	0.55	0.39 – 0.75	0.42	0.19 – 0.7
Italy	0.50	0.40 – 0.62	0.33	0.12 – 0.57
Sweden	0.38	0.27 – 0.52	0.23	0.11 – 0.38
Belgium	0.37	0.05 – 1.14	0.27	0.02 – 0.91
Romania	0.37	0.28 – 0.46	0.18	0.02 – 0.37
Spain	0.33	0.20 – 0.46	0.23	0.07 – 0.41
Slovenia	0.23	0.15 – 0.34	0.13	–0.01 – 0.3
Finland	0.23	0.11 – 0.41	0.13	0.03 – 0.29
Portugal	0.22	0.11 – 0.34	0.15	0.01 – 0.32
Latvia	0.22	0.09 – 0.34	0.14	0.01 – 0.28
Germany	0.16	0.06 – 0.33	0.10	0.03 – 0.23
Estonia	0.15	0.10 – 0.19	0.07	–0.01 – 0.16
Poland	0.14	0.08 – 0.2	0.08	–0.01 – 0.19
Malta	0.03	0.02 – 0.04	0.02	0.00 – 0.03
Bulgaria	0.02	–0.08 – 0.12	–0.02	–0.14 – 0.09