Modelling Planned Adaptation for Coastal Zone Protection in a General Equilibrium Framework

Climate change impact on coastal zones, and sea-level rise (SLR) in particular, are utmost concerning since a large fraction of population and economic activities are already located in these areas (World Bank, 2010). Moreover, future projections suggest that in the 21st century damages will increase significantly both because of socioeconomic development bringing more population and capital at risk; and because of increasing SLR trends linked to global warming processes. However, there is a high degree of uncertainty on the magnitude of SLR, thus on damages, and on the adaptation investments needed to lower those impacts.

A particular dimension of SLR impacts is their potential stress on public budgets. This issue was initially introduced, in broader terms, by Heller (2003) indicating climate change as one of the major threats posed on public budgets in future decades (together with demographic changes and globalization). On the one hand, countries heavily dependent on few climate sensitive productive sectors may face significant revenue reductions. On the other hand, public spending may increase to contrast or prevent for instance intensified incidence of vector borne diseases, stress on infrastructures or population movements. The importance (and sign) of these fiscal impacts will vary across countries, but they are likely to be mostly adverse precisely where vulnerabilities to climate change are greatest (IMF, 2008).

Adaptation in particular, will require increased public expenditure, both on climate related public goods (such as information acquisition and dissemination on likely extreme events) and to protect public and private assets at risk like transportation systems, water and health systems. Eventually, adaptation could reduce or increase the stress on public budgets depending on its effectiveness, the structure of the tax system, the size of adaptation investment, and the funding sources available (Osberghaus and Reif, 2010).

This paper aims to assess the costs of SLR impacts and adaptation using a Computable General Equilibrium (CGE) model extended with a detailed description of the public sector. The final goal is to account not only for the GDP effects of adaptation, but also for the impacts on public finance. More specifically, we assume that adaptation expenditure is not financed through new taxes but issuing government bonds. Future projections of SLR damages are generated by the Dynamic Interactive Vulnerability Assessment (DIVA) modelling framework (Hinkel et al, 2013, 2014; Vafeidis et al. 2008). DIVA is a socio-economically driven geo-bio-physical model which projects the impacts and costs of sea-level rise, and subsequent adaptation for a range of scenarios. Outputs from two climate models (MIROC and NorESM) and the SSP2 socioeconomic scenario were used as drivers for the DIVA model for RCP2.6 and RCP8.5 scenarios. Final impacts depend on adaptation measures that in the model take the form of dike building and upgrading existing ones. The DIVA assessment is of partial equilibrium in nature as it cannot capture explicitly the intersectoral and international economic impacts triggered by se-level rise, nor their rebounds on the sectors and countries initially impacted. This is however possible with CGE models that quantify the impacts on the value of production and ultimately on GDP accounting for all those interactions. It is thus particularly interesting to compare the consistency of the projections of a partial equilibrium assessment such as in the DIVA model, with that of a general equilibrium assessment tool.

CGE models consider market-driven adaptation by construction (i.e. the functioning of autonomous mechanisms – primarily, demand and supply reactions to endogenous changes in relative prices) which characterizes instantaneous resource allocation across two market equilibria in response to exogenous economic shocks. There are few examples of modelling planned adaptation to sea level rise using a static CGE model with investments carried out by the public sector. In the case of SLR in particular, coastal protection expenditures mainly consist of huge infrastructure expenditures which are primarily financed by public funds. For instance, CEPS and ZEW (2010) establish that more than 95% of investments against SLR in Europe are publicly financed. Nicholls et al. (2010) suggest that much of the costs for adaptation to SLR falls on government finance while only a minority of adaptation could be funded by private investments (i.e. port and harbour upgrade). Within this background, the paper implements public planned expenditure for coastal protection inclusive of investments and maintenance costs in a recursive dynamic CGE model. It further develops a more realistic description of the public sector behaviour to better capture coastal protection expenditure effects on public finance.

The analysis is developed comparing a reference scenario against two climate change scenarios based on RCP 2.6 and RCP 8.5 considering projections within a time frame from 2007 to 2050:
1. Reference scenario: following the SSP2 “Middle of the Road” scenario for GDP growth and population projections and does not include any impact from SLR.
2. No additional adaptation scenario: Including SLR impacts to represent a counter factual scenario with adaptation frozen at 1995 protection levels.
3. Additional adaptation scenario: Taking into account public intervention to protect coastal zones against SLR as prescribed by the DIVA model, thus including residual damages.

Public finance outcomes strictly depend on the closure rule choice in the public sector. For the counterfactual analysis in the adaptation scenarios we suppose that the governments in each country respect their reference scenario level of consumption.

Comparing impacts on regional GDP for RCP2.6 and RCP8.5 in 2050 with and without adaptation, the ‘No additional adaptation’ scenario features a generalized GDP loss in all regions for both RCPs. The magnitude of losses is strictly dependent on the size of impacts on capital, land and labor productivity. The most affected countries are East Asian Countries, North Europe and South Asia.
Adaptation has the ability to reduce GDP losses from SLR, which is more pronounced in regions like Asian, Sub Saharan, Middle East and North Africa countries, where SLR has more impacts. The positive result of adaptation is the compounded effect of two mechanisms directly and indirectly related with the impacts of SLR. The first one regards the avoided direct impacts (loss of labor productivity, land and capital). In this case, the avoided capital losses are the main drivers of the benefits, due to their key role in determining growth in a recursive dynamic model. The second mechanism is the public deficit effect.

Without adaptation, all regions increase their public deficits, or reduce their surpluses, respect to the reference scenario. Public deficit worsening, when SLR impacts occur, is mainly driven by the reduction in tax revenues. This is strictly dependent on the tax system structure in each country and by the interaction between input taxes, affected by the negative effects on primary factors, and output taxes affected by the decline in production and therefore in GDP.

A higher deficit deteriorates public finance therefore the government borrows from household savings, which eventually reduces also the available resources for private investments. Since lower impacts of SLR translate into lower deficits, then the government borrows less from households which would allow for an increased capital accumulation in the long-run. Furthermore, lower deficits imply lower debt accumulation, and consequently a lower debt service. This also permits more resources devoted to growth.

A particularly interesting aspect to consider is the evolution along the time path (until 2050) of the deficit comparing the two adaptation scenarios. In most countries, public deficits are higher when adaptation investments are being put in place and become lower only in the long run. This is a direct consequence of the long-run nature of SLR impacts that are more damaging for GDP and also deteriorate the ability to raise tax revenues in the longer term.

All in all, at least in the case of SLR impact, support to adaptation in deficit spending is not necessarily bad for GDP growth, and might trigger positive effects on public finance sustainability. This highlights a potentially interesting policy insight: adaptation expenditure can enable virtuous processes even though initially financed with debt.

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