ECONADAPT

The Economics of Adaptation

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Deliverable 8.3: Report: Policy recommendations, lessons learned, and guidance:

The effects of combining mitigation and adaptation policies for coastal zone protection[1]

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Executive Summary

This deliverable conducts a global analysis on the economic implications of combining a mitigation policy and adaptation in the form of coastal protection. Possible synergies and/or trade-offs between these two types of interventions are explored. The simulated mitigation efforts are drawn from the pledges countries submitted to the UNFCCC as Intended Nationally Determined Contributions (INDCs) during the last COP 21 in Paris, and are implemented in 2030. The adaptation policy consists in optimal protection against sea-level rise in 2030 for the Representative Concentration Pathway (RCP) 8.5 as a climate change scenario coupled with high sea-level rise estimates.

In a context where governments must decide among different priorities because of limited resources, the availability of financial resources to adopt adaptation measures is crucial. We quantitatively assessed the impacts of including sea level rise adaptation to address this issue. The economic assessment is conducted by means of the ICES-XPS Computable General Equilibrium (CGE) model featuring a realistic representation of the public sector. The model has also been improved with an adaptation module representing the necessary investments and recurrent expenditures related to coastal protection in the form of construction of protective barriers and the corresponding operation and maintenance costs.

In this way we can control the effects on the public budget of an increasing expenditure covering adaptation needs. The analysis concentrates on two measures: GDP and public deficit as two strategic dimensions to understand the interactions of short and long run goals in a context of mainstreaming adaptation in development policies. Firstly, GDP is regarded as an economic development indicator useful to measure economic performance. Secondly, public deficit is interpreted as a measure of governments' burdens posed on future expenditure policies. The fact that a government has scarce resources is crucial in budget planning, and increasing today's deficit is likely to affect the possibilities of the government to pursue other expensive policies in the future. This is particularly relevant in developing countries. These two variables allow us to summarise the trade-off in spending for climate change adaptation and development.

We analyse five policy scenarios considering the combination of adaptation to sea level rise, mitigation policies and a Climate Fund that also supports adaptation and mitigation measures in developing countries. The policy scenarios have been designed on the basis of the recent development in international negotiations. Mitigation efforts are those derived from the INDCs submitted for the Paris Agreement in 2015, while the institution of the Climate Fund is based on the pledge from developed countries to provide between $ 30 and $100 billion per year by 2020.

There are two key messages from this analysis. The first message regards the fact that public adaptation expenditures crowd out private activity. The second important message is directly related to the way adaptation is financed. When adaptation expenditures are financed through taxes rather than through public debt the distortionary crowding out effect of adaptation and the consequent penalization of growth is lower. Taxes have a recessive effect on private consumption, but public debt crowds out private investment. The latter effect is more harmful for economic growth and capital accumulation. Therefore, combining adaptation policies with mitigation efforts based on a carbon tax can be an appropriate strategy. In addition, developed countries can benefit from supporting developing countries in their climate change policies. The lower contraction of developing countries' economic activity can benefit developed countries either directly through lower international demand contraction, or through lower/higher relative competitive losses/gains following the implementation of mitigation objectives.

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1 Introduction

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The economic assessment is conducted by means of the ICES-XPS Computable General Equilibrium (CGE) model featuring a realistic representation of the public sector. The model has also been improved with an adaptation module representing the necessary investments and recurrent expenditures related to coastal protection in the form of construction of protective barriers and the corresponding operation and maintenance costs. A complete description of the ICES-XPS model has been presented in ECONADAPT Deliverable D8.2.3 (Bosello et al., 2016) to which the interested reader is addressed. The remainder of this document will focus on the description of the chosen scenarios and in presenting the simulation results.

2 Mitigation and adaptation in the international context

The two pillars of the response to climate change are mitigation and adaptation. Broadly speaking, while mitigation aims to reduce the causes of climate change by slowing GHG emissions, adaptation aims to reduce the impact of climate stresses on human and natural systems.

Both mitigation and adaptation interact with development activities in a dynamic cycle often characterized by significant delays. Mitigation and adaptation actions can themselves affect future development with: (i) direct benefits from avoided climate damage on development prospects, (ii) ancillary benefits of mitigation and adaptation development, (iii) direct costs of mitigation or adaptation, which might hinder development; and (iv) positive or negative spillover effects on other regions through international trade. Symmetrically, development policies may affect both adaptation and mitigation capacity. In particular, development trends as well as sector policies pursuing non-climate objectives can potentially increase or decrease greenhouse emissions.

Notwithstanding adaptation was considered an important climate change policy since the First Assess Report from the IPCC in 1991, it has gained the same importance of mitigation in climate policy circles only since 2001 when, during COP7 in Marrakesh, the United Nations Framework Convention on Climate Change (UNFCCC) adopted a comprehensive framework to capitalize adaptation needs in LDCs. Table 1 summarises the magnitude of UNFCCC's adaptation funds. The "Marrakesh funds" consisted of two distinct funds whose aim, among others, is the

[2] Watanabe et al. (2011)

monetization of adaptation measures. Subsequently, the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF) managed by the Global Environment Facility (GEF) were established in 2006 to address specifically short and long term adaptation needs in Least Developing and Small Islands and Developing States. The 2007 COP13 in Bali established the Adaptation Fund (AF) as an instrument of the Kyoto Protocol partially capitalized through a 2% share of the proceeds of certified emission reductions from projects under the Clean Development Mechanism (CDM). This share is completely independent of the willing of donor countries and it only depends on carbon price volatility.

Fund	*Pledged*	*Deposited*	*Approved*
Least Developed Countries Fund (LDCF)	$ 964 Million	99.7%	$ 795 Million
Special Climate Change Fund (SCCF-A)	$350 Million	98.3%	$ 278 Million
Adaptation Fund (AF)	$ 487 Million	99.4% of which: 39.8% from sales of CERs and 60.2% from voluntary national contributions	$ 325 Million

Source: Climate Funds Update. Updated data for November 2015.

Table 1: UNFCC Adaptation Funds and their magnitude

Another step strengthening the support to adaptation in developing countries was the establishment of international funds for adaptation needs in Less Developed Countries part of the 2009 Copenhagen Agreement. Specifically, developed countries committed to help adaptation efforts in developing economies and to mobilize financial instruments to support those investments with $30 billion for the period 2010-2012, and to gather long-term finance (public and/or private) of a further $100 billion a year by 2020.[3]

Finally, the Paris Agreement signed in December 2015 that allows each country to determine mitigation actions at national level through the INDCs, also recognizes the urgency of an adequate finance to fight climate change and to establish a concrete roadmap to achieve the Copenhagen goal to mobilize $100 billion annually by 2020.

Against this background, the EU is becoming increasingly active in assisting the most vulnerable countries in their efforts to adapt to climate change. In 2015 the EU participated for 90% of the cumulative contributions to the AF, for nearly 80% to that of the LDCF, and of the SCCF (European Commission, 2015). Moreover, at least 20% of the entire EU budget from 2014 to 2020 should be spent on climate-related actions (EC, 2013), and climate action should be integrated into all major EU policies (EC, 2011). The 20% climate-spending target applies also to spending outside the EU through development and external action instruments. This funding will be considered both for mitigation and adaptation actions according to a 50-50% distinction.

[3] Recent estimates from an OECD and CPI report (OECD, 2015) suggest that the target is more than half reached; the 2014 figures show that developed countries have mobilized $62 billion.

3 Policy scenarios

Consistently with the description of section 2, this report compares the results of combining mitigation and adaptation policies in 2030. Mitigation is represented by the INDCs submitted to the UNFCCC as reported by the "CAIT Climate Data Explorer".[4] Table 2 reports the mitigation commitments computed for the ICES-XPS regions.

Region	*Target (%)*	*Reference year*
USA	-27	2005
North Europe	-25	1990
EU	-40	1990
Rest of Europe**	-18	2007
Rest of Former Soviet Union**	3	2007
South Korea	-37	BAU
Australia	-27	2005
South Africa	-	BAU
Canada	-30	2005
Japan	-25	2013
New Zealand	-30	2005
North Africa**	-32	2007
Middle East**	56	2007
Sub Saharan Africa**	86	2007
South Asia**	11	2007
India	-33 to -35*	2005
China	-60 to -65*	2005
East Asia**	83	2007
Latin America & the Caribbean**	15	2007

*Reduction of carbon intensity of GDP

** Targets for this macro region were computed considering 2007 as the reference year.

Table 2: INDC emission targets by region

The implementation of the INDC targets of Table 2 in the ICES-XPS model varies according to the region and the nature of the target. Mitigation efforts in the EU are achieved by means of an EU-ETS with auctioning. The rest of the countries with emission reduction targets enforce a domestic carbon tax to achieve such reductions. Regions with carbon intensity of GDP targets, such as China and India, impose also a domestic carbon tax to achieve that particular type of target. We also assume that all revenues raised either with the domestic carbon tax or through the auctioning of carbon permits in the EU accrue to the government budget in order to ease the public burden derived from public adaptation investments.

For the adaptation scenarios we use the data from the DIVA model (Hinkel et al., 2014; Hinkel et al., 2013; Hinkel et al., 2012; Hinkel and Klein, 2009) for RCP 8.5 with high SLR estimates based on projections from the MIROC-ESM[5] climate model. To simplify the analysis we use only one scenario from the set presented in Deliverable 8.2.3. Figure 1 shows total adaptation costs that include the construction of protective barriers and the corresponding operation and maintenance costs for both developing (left panel) and developed regions (right panel). These are the costs included in the CGE model simulation (ICES) after being adjusted considering the total capital stock in ICES-XPS and the cost benefit ratios from the DIVA model.[6] Adaptation costs in developing countries are much higher than those in developed ones. As described in

[4] http://cait.wri.org/pledges/#/map, accessed on 06-04-2016.

[5] Watanabe et al. (2011)

[6] For a description of the data adjustment process refer to section 3 of Deliverable D8.2.3 "Modelling Planned Adaptation for Coastal Zone Protection in a General Equilibrium Framework" (Bosello et al., 2016).

deliverable 8.2.3, public investments in adaptation to protect coastal zones are financed through the emission of adaptation bonds.

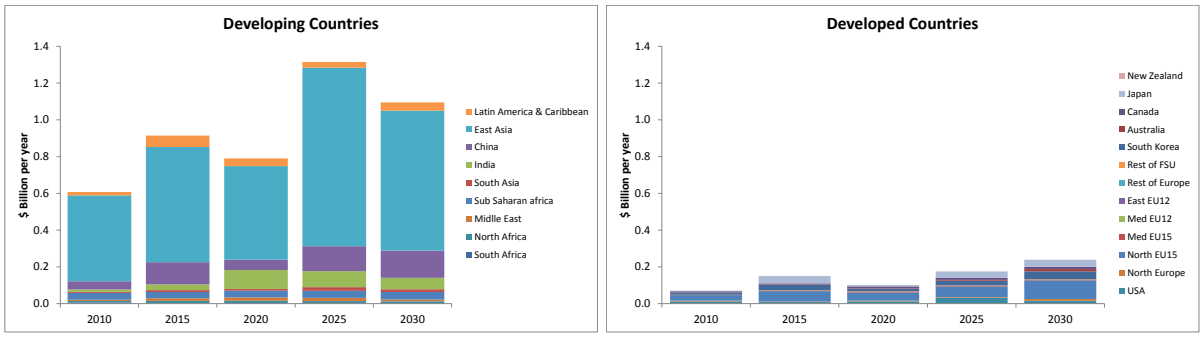

Figure 1: Coastal protection costs ($ billion)

In addition to the policy combining mitigation and adaptation, we simulate the establishment of a ***Climate Fund*** by Developed Countries contributing for a total of $30 billion per year from 2010 to 2012, and then increasing gradually to $100 billion per year by 2020. Afterwards the total amount of the fund remains at $100 billion per year until 2030. Contributions to the fund are proportional to GDP. Donor regions are USA, North Europe, EU27, South Korea, Australia, Canada, Japan, and New Zealand. Developing countries receive these funds following a criterion that is inversely proportional to their GDP. This means that regions with lower GDP will receive a higher share of the climate fund. The beneficiary regions are Africa, Middle East, Asia, Latin America and the Caribbean. Only two regions neither contribute to the climate fund nor benefit from it: Rest of Europe and Rest of Former Soviet Union.

Then, the following policy scenarios are considered:

Reference: is the SSP2 "Middle of the Road" scenario (O'Neill et al., 2014) for population and GDP projections from the OECD version.[7] This is a no-policy scenario that does not include any impact from SLR.

Mitigation scenario: simulates the INDCs for 2030 as stated during 2015 COP 21 in Paris (see Table 2).

Mitigation + Climate Fund scenario: The same as the mitigation scenario, but Developed countries establish a Climate Fund that will support developing countries for a total of $30 billion per year from 2010 to 2012 up to $100 billion per year from 2020 to 2030.

Adaptation scenario: it features public intervention to protect coastal zones against SLR as prescribed by the DIVA model (see Figure 1) financed with adaptation bonds.

Mitigation + Adaptation scenario: Combining the adaptation and the INDCs mitigation scenarios.

Mitigation + Adaptation + Climate Fund scenario: The same as the previous scenario but including the Climate Fund instituted by developed countries.

[7] The benchmark scenario is described in Deliverable 8.1: Report on the ICES and the GEM-E3 model benchmark scenario for the subsequent analysis.

4 Simulation results

In what follows, the analysis disregards the costs and benefits of adaptation (coastal protection), amply discussed in the ECONADAPT Deliverable D8.2.3 (Bosello et al., 2016) and centres the attention on how the indirect effects of adaptation may change in the presence of a contextual mitigation policy. Two main indicators are considered: changes in Gross Domestic Product (GDP) to capture effects on growth, and public deficit to measure the impacts on public budgets.

The GDP costs of implementing the INDCs by 2030 are shown in Table 3. Compared with the reference scenario, these vary between -5.7% for East EU12 and 1.8 % for South Korea, in developed countries, while in developing countries they vary between -12.% for North Africa to 4% for Middle East (column a). Therefore, some regions belonging both to the developed and the developing world can ultimately experience GDP gains implementing their INDCs. This is a combination of particularly loose decarbonisation goals, once compared with the baseline trends, and relatively stringent targets from other parties. This originates carbon/economic leakage effects.

Region	**Scenario**				
	INDCs (a)	***INDCs + Climate Fund (b)***	***Adaptation (c)***	***INDCs + Adaptation (d)***	***INDCs + Adaptation + Climate Fund (e)***
USA	-0.54	-0.50	-0.04	-0.58	-0.54
North Europe	-5.39	-5.33	-0.45	-5.81	-5.75
North EU15	-1.34	-1.29	-0.02	-1.38	-1.33
Mediterranean EU15	-1.11	-1.05	-0.01	-1.14	-1.08
Mediterranean EU12	-4.36	-4.30	0.02	-4.38	-4.32
East EU12	-5.69	-5.63	-0.01	-5.73	-5.66
Rest of Europe	4.05	4.13	-0.01	4.01	4.10
Rest of Former Soviet Union	-5.79	-5.75	-0.02	-5.82	-5.78
South Korea	1.81	1.91	0.04	1.77	1.87
Australia	-1.44	-1.38	-0.08	-1.57	-1.51
South Africa	2.81	2.93	-0.09	2.76	2.88
Canada	-1.63	-1.57	-0.06	-1.72	-1.65
Japan	0.22	0.28	-0.02	0.19	0.25
New Zealand	-0.24	-0.17	-0.04	-0.30	-0.23
North Africa	-12.72	-12.64	-0.05	-12.76	-12.68
Middle East	4.28	4.37	-0.06	4.23	4.32
Sub Saharan Africa	1.88	1.97	-0.03	1.83	1.92
South Asia	-7.71	-7.67	-0.09	-7.78	-7.74
India	3.80	3.87	-0.13	3.70	3.77
China	0.55	0.61	-0.07	0.48	0.54
East Asia	1.49	1.56	-0.34	1.16	1.23
Latin America & the Caribbean	0.39	0.48	-0.05	0.33	0.42

Table 3. GDP: % change respect to the reference scenario in 2030

Impacts on GDP of implementing coastal protection are much lower than those of mitigation policies (column c), but anyway negative. Accordingly, when combined, mitigation and adaptation increase GDP losses respect to mitigation or adaptation alone (column d). The introduction of the Climate Fund changes the picture slightly, but in a qualitatively interesting way. When it is introduced as an accompanying measure both to mitigation, and to mitigation and adaptation policies, it decreases GDP costs not only in recipient countries, as expected, but also in donor countries (columns b and e). This result depends upon two factors. The first and more straightforward one is that developed countries can benefit from the lower contraction of economic activity in developing countries. But there is also a more subtle mechanism. When receiving the funding, economic activity in developing countries increases (slightly), emissions are higher (slightly) and the carbon tax needed to achieve the respective

INDCs is higher (slightly). This favours the relative competitiveness of developed countries goods and services in international markets.

The impacts on public deficits go in the opposite direction as shown by Table 4. That is: the implementation of INDCs by means of taxes or auctioned permits raises significant revenues that help reducing public deficits (column a). With the implementation of the climate fund, developed countries use part of these revenues to support developing countries. Therefore, the deficit reduction in developed countries is lower with the climate fund than without it (column b). Anyway, the amount of the fund is quite small compared with the total revenues originated by the mitigation action. Consequently, substantive resources remain available to developed countries for their deficit reduction. On the contrary, adaptation expenditure increases public deficits (see column c) thus when it is combined with the INDCs, the reduction of the deficit is lower (column d). The climate fund further decreases resources for deficit reduction in developed countries in favour of developing countries (columns b and e).

Region	Scenario				
	INDCs Mitigation (a)	*INDCs + Climate Fund (b)*	*Adaptation (c)*	*INDCs + Adaptation (d)*	*INDCs + Adaptation + Climate Fund (e)*
USA	-289.5	-262.7	2.0	-287.1	-260.3
North Europe	-9.7	-7.8	1.5	-8.1	-6.2
North EU15	-106.9	-91.7	2.2	-104.6	-89.4
Mediterranean EU15	-112.2	-102.1	0.5	-111.6	-101.5
Mediterranean EU12	-2.9	-2.7	0.0	-2.8	-2.7
East EU12	-56.9	-55.1	0.1	-56.7	-54.9
Rest of Europe	-4.0	-4.0	0.0	-3.9	-4.0
Rest of Former Soviet Union	-59.5	-59.9	0.2	-59.4	-59.7
South Korea	-33.4	-30.4	0.8	-32.5	-29.4
Australia	-8.2	-6.1	0.8	-7.3	-5.3
South Africa	-8.7	-23.6	0.2	-8.5	-23.4
Canada	-35.3	-32.3	0.6	-34.6	-31.5
Japan	-43.9	-38.2	0.9	-42.9	-37.2
New Zealand	-4.1	-3.8	0.1	-4.0	-3.7
North Africa	-42.3	-60.1	0.6	-41.8	-59.6
Middle East	-99.0	-114.3	1.1	-97.6	-113.0
Sub Saharan Africa	-27.3	-38.3	1.3	-25.9	-36.9
South Asia	-30.6	-39.8	0.5	-30.0	-39.3
India	-31.3	-46.8	3.2	-27.6	-43.1
China	-276.1	-289.8	4.9	-271.4	-285.1
East Asia	-42.4	-56.8	20.2	-20.8	-35.2
Latin America & the Caribbean	-126.3	-142.7	2.3	-123.7	-140.1

Table 4. Public deficit: absolute changes respect to the reference scenario ($ billion) in 2030

As can be noticed from Table 3 and Table 4, figures in column (d) reporting respectively the GDP costs and deficit impacts of mitigation and adaptation, do not coincide with the sum of column (a), mitigation alone, and (c), adaptation alone. This is due to the presence of interaction effects that the model captures. Accordingly, to isolate effect of adaptation on GDP and public deficit when mitigation (the INDCs) is present, we subtract column (a) from column (d) in Table 3 and Table 4. Similarly, to disentangle the effect of establishing a Climate Fund when mitigation is present it is necessary to subtract column (a) from column (e) in Table 3 and Table 4.

Table 5 shows the isolated effects of adaptation on GDP and deficit for the three cases of interest, namely when adaptation is the only policy implemented (columns f and i coinciding with column c in Table 3 and Table 4); when adaptation is coupled with mitigation (columns g and j); and when adaptation and the climate fund are coupled with mitigation (columns h and k).

It is interesting to note (left panel of **Table 5**) that adaptation in the presence of mitigation (i.e. the INDCs) could produce a lower penalization of GDP than adaptation implemented alone (or

looking at Table 3 that adaptation and mitigation implemented jointly cost slightly less than the sum of mitigation and adaptation costs when implemented in isolation). Examples are North Europe, South Africa, North Africa, Middle East and Asia. These results are particularly insightful considering the potential advantages that the increased mitigation would bring to the economic system in terms of lower climate change damages, and in particular to adaptation that could accordingly be lower, are not part of the assessment. The beneficial interaction of mitigation and adaptation can be explained by the revenues that mitigation actions raise. These accrue to the public budget; decrease the need by the public sector to borrow money from the private sector to finance coastal protection expenditure; decrease thus the crowding out of public current expenditure on private investment, and, eventually, decrease the penalization on the capital accumulation process.

The right panel of **Table 5** shows that adaptation implemented with mitigation tends to produce a higher deficit than adaptation alone (or, looking at Table 4, that deficit reduction when adaptation and mitigation are implemented jointly is lower than the deficit reduction obtained summing deficits produced by mitigation and adaptation when implemented in isolation). In this case, it is adaptation that influences negatively the revenues that mitigation action can raise. More specifically, adaptation expenditure depresses slightly more GDP, compared to the situation in which mitigation is alone. Lower GDP implies lower emissions and thus lower taxes needed to achieve the emission reduction target stated by the INDCs. This outcome, which is unquestionably good news in term of reduced mitigation policy costs, means however that lower revenues are available to cut public deficits.

The further introduction of the Climate Fund improves the GDP results almost everywhere, increasing deficit in developed countries and reducing it in developing countries.

Region	***Effects on GDP (% change from reference)***			***Effects on Public Deficit ($ billion)***		
	Adaptation only (f) = (c)	***Adaptation with INDCs (g) = (d) – (a)***	***Adaptation + Fund with INDCS (h) = (e) – (a)***	***Adaptation only (i) = (c)***	***Adaptation with INDCs (j) = (d) – (a)***	***Adaptation + Fund with INDCS (k) = (e) – (a)***
USA	-0.04	-0.04	0.00	2.00	2.34	29.16
North Europe	-0.45	-0.42	-0.37	1.55	1.59	3.46
North EU15	-0.02	-0.04	0.01	2.21	2.32	17.57
Mediterranean EU15	-0.01	-0.03	0.03	0.50	0.63	10.70
Mediterranean EU12	0.02	-0.03	0.03	0.01	0.01	0.14
East EU12	-0.01	-0.03	0.04	0.12	0.15	1.94
Rest of Europe	-0.01	-0.04	0.05	0.02	0.03	-0.02
Rest of Former Soviet Union	-0.02	-0.02	0.02	0.23	0.20	-0.12
South Korea	0.04	-0.04	0.05	0.81	0.93	3.97
Australia	-0.08	-0.13	-0.07	0.80	0.83	2.87
South Africa	-0.09	-0.05	0.08	0.17	0.18	-14.67
Canada	-0.06	-0.08	-0.02	0.65	0.72	3.75
Japan	-0.02	-0.03	0.03	0.89	1.00	6.70
New Zealand	-0.04	-0.06	0.01	0.08	0.09	0.39
North Africa	-0.05	-0.04	0.04	0.57	0.50	-17.32
Middle East	-0.06	-0.05	0.04	1.08	1.34	-14.00
Sub Saharan Africa	-0.03	-0.05	0.04	1.34	1.40	-9.59
South Asia	-0.09	-0.07	-0.03	0.53	0.54	-8.70
India	-0.13	-0.10	-0.03	3.24	3.65	-11.87
China	-0.07	-0.06	0.00	4.88	4.76	-8.92
East Asia	-0.34	-0.32	-0.25	20.20	21.62	7.18
Latin America & the Caribbean	-0.05	-0.06	0.03	2.33	2.63	-13.78

Note: (a), (c), (d), (e) refers to column in Table 4

Table 5: Isolated effect of adaptation on GDP and public deficit in 2030

For further clarity, Figure 2 and Figure 3, referring to developing and developed regions respectively, translate in the two dimensions of GDP and public deficit. These figures show the comparison of the effects of implementing coastal protection in combination with mitigation (arrows' starting point in the figures), and of implementing coastal protection plus the Climate

Fund in combination with mitigation (arrows' ending point in the figures), with those related to coastal protection alone (axis origin in the figures). It can be noted first that coastal protection, when coupled with mitigation is less costly in terms of GDP and deficit decreasing for China and North Africa. Then, moving counter clockwise (top-right quadrant): East Asia, India, and Middle East may experience low GDP costs, but a worsening of deficit; Sub Saharan Africa, Latin America and the Caribbean, may experience higher GDP costs and deficits. In Figure 3, developed countries can experience slightly higher GDP costs, with almost null effects on public deficits.

The introduction of the fund is clearly beneficial for the recipient i.e. developing countries. All of them move "south east", implying that GDP costs and deficits are both decreasing (see Figure 2). What is interesting to note is that developed countries, even though experiencing a deficit increase, as part of their financial resources are channelled out, may at the same time experience lower GDP costs (see Figure 3).

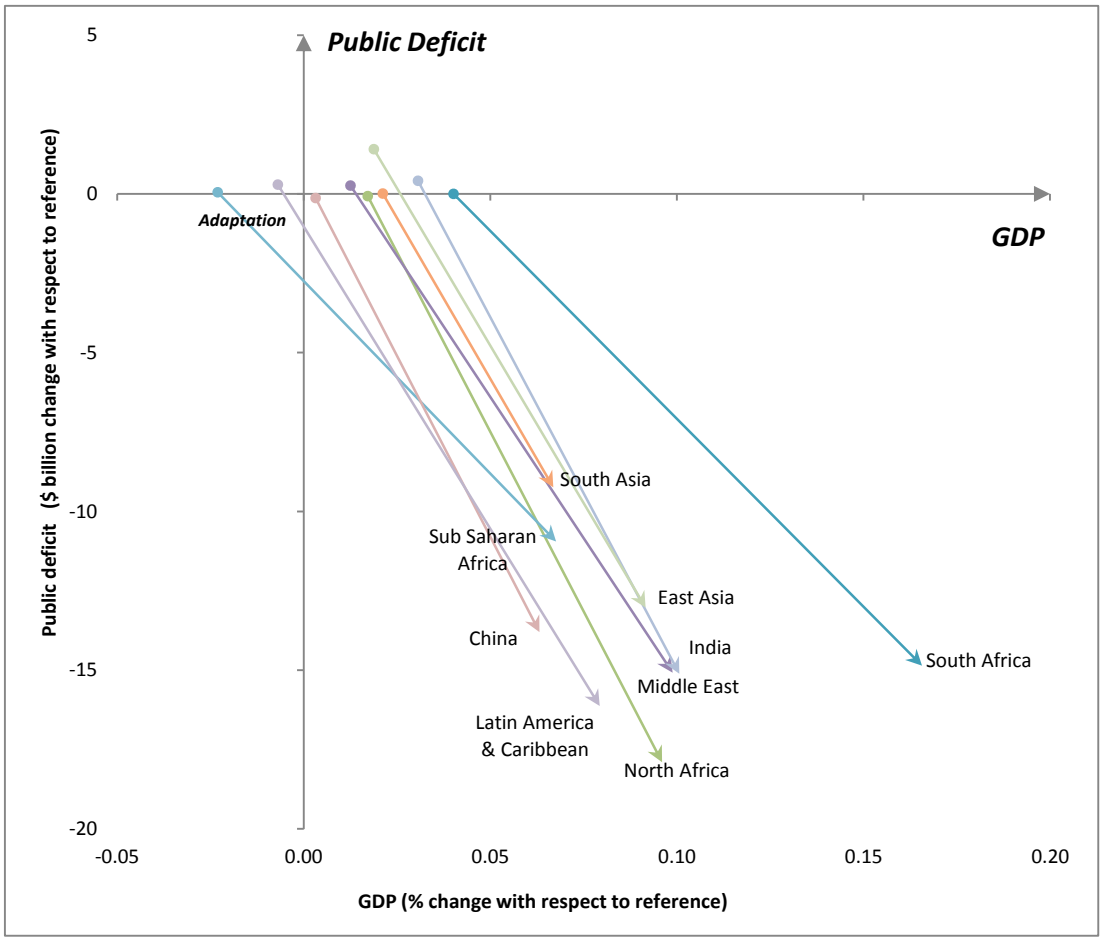

Figure 2: Developing regions in 2030: additional effect of mitigation on GDP cost and public deficit associated to adaptation and adaptation + Climate Fund

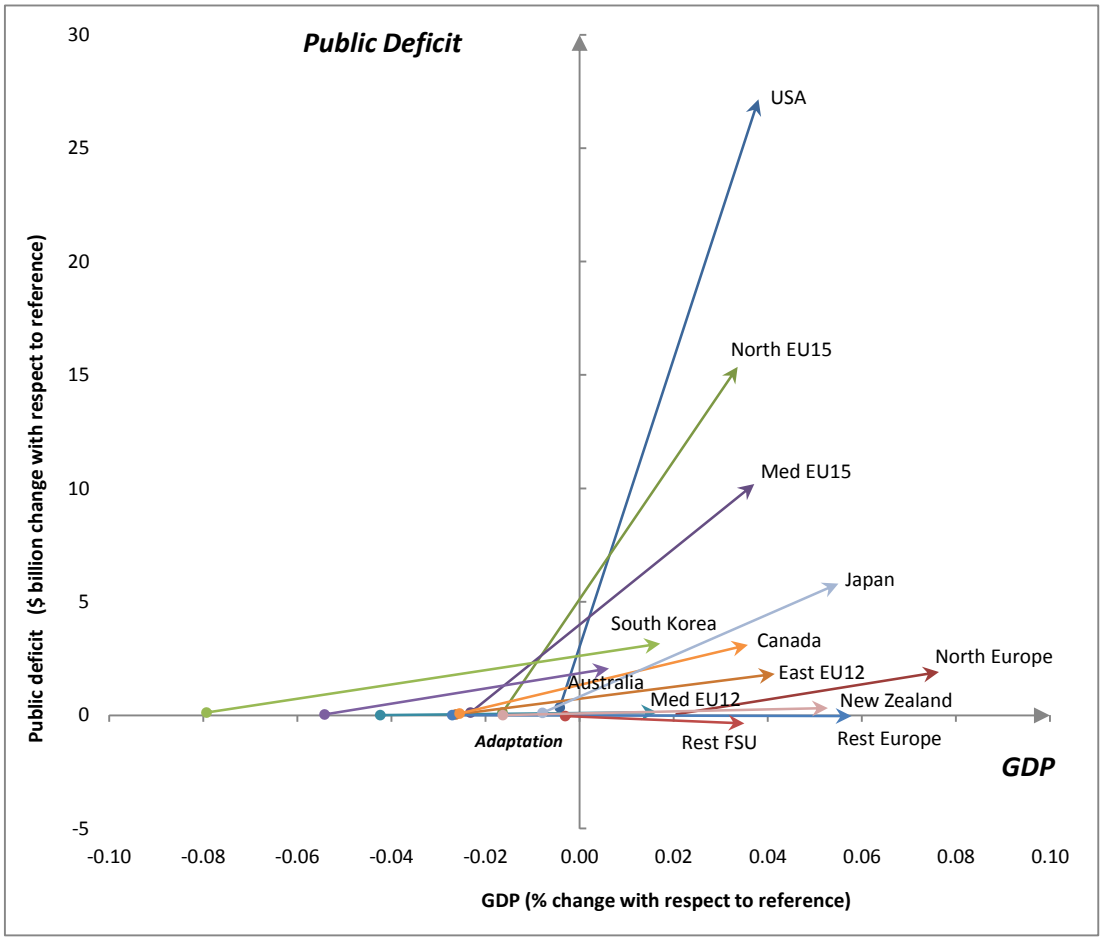

Figure 3: Developed regions in 2030: additional effect of mitigation on GDP cost and public deficit associated to adaptation and adaptation + Climate Fund

In summary, there are two key messages from the analysis conducted. Firstly, public adaptation expenditure crowds out private activity. Secondly, this distortionary effect, and the penalization of growth is however (slightly) lower if adaptation expenditure is financed through taxes rather than through public debt. Indeed the first (taxes) reduces private consumption, the second (public debt) crowds out private investment. The latter effect is more noxious for capital accumulation processes and growth. In this sense, coupling adaptation with carbon tax based mitigation can be a good strategy. A potential negative outcome of the coupling is however a lower public deficit reduction stemming directly from the lower taxes needed to achieve the desired mitigation goals.

Supporting developing countries in their climate change policies can be also in the self-interest of developed countries. They can indeed benefit from the lower contraction of developing countries economic activity either directly, through lower demand contraction, but also through lower/higher relative competitive losses/gains following the implementation of mitigation objectives.

5 Conclusions

The present work uses a CGE model with an extended representation of the public sector to assess the effects on GDP and public budget of interacting adaptation, mitigation, and international support for climate change policies from developed to developing countries.

SLR impacts and Adaptation expenditures are those related to coastal protection for 2030 as derived from the DIVA model in the Representative Concentration Pathway (RCP) 8.5 coupled with high sea-level rise estimates based on projections from the MIROC-ESM climate model. Mitigation efforts are those foreseen for 2030 according to the INDCs submitted to the 2015 COP 21 in Paris, while the Climate Fund is based on the pledge by developed countries to provide between $ 30 and $100 billion per year by 2020 to developing regions for mitigation and adaptation activities.

The analysis highlights that adaptation and mitigation implemented jointly could entail slightly lower GDP costs than the sum of mitigation and adaptation GDP costs when implemented in isolation. This positive interaction effect is explained by the revenues that mitigation actions implemented with taxes or auctioned permits raise. These revenues accrue to the public budget; decrease the need by the public sector to borrow money from the private sector to finance coastal protection expenditures; decrease thus the crowding out of public current expenditure on private investment, and, eventually, decrease the penalization on the capital accumulation process. Conversely, deficit reduction when adaptation and mitigation are implemented jointly is lower than the deficit reduction obtained summing deficits produced by mitigation and adaptation when implemented in isolation. In this case, it is adaptation that influences negatively the revenues that mitigation actions can raise. More specifically, adaptation expenditure depresses slightly more GDP, compared to the situation in which mitigation is alone. Lower GDP implies lower emissions and thus lower taxes are needed to achieve the emission reduction target stated by the INDCs. This outcome, which is unquestionably good news in term of reduced mitigation policy costs, means however that lower revenues are available to cut public deficits.

The introduction of the Climate Fund is clearly beneficial for the recipients i.e. developing countries. All of them decrease both GDP costs and deficits. What is interesting to note is that developed countries, even though experiencing a deficit increase, as part of their financial resources are channelled out, may at the same time experience lower GDP costs. This result depends upon two factors. The first and more straightforward is that developed countries can benefit from the lower contraction of economic activity in developing countries. But there is also a more subtle mechanism. When receiving the funding, economic activity in developing countries increases (slightly), emissions are higher (slightly) and the carbon tax needed to achieve the respective INDCs is higher (slightly). This favours the relative competitiveness of developed countries goods and services in international markets.

All in all, there are two key messages from the analysis conducted. The first message regards the fact that public adaptation expenditure crowds out private activity. The second key message is related to the way adaptation is financed. Indeed, the distortionary crowding out effect of adaptation and the consequent penalization of growth is lower when adaptation expenditures are financed through taxes rather than through public debt. While taxes have a recessive effect on private consumption, public debt crowds out private investment. The latter effect is more noxious for economic growth and capital accumulation. In this sense, coupling adaptation with mitigation efforts based on a carbon tax can be an appropriate strategy. Developed countries can benefit from supporting developing countries in their climate change policies. The lower contraction of developing countries' economic activity can benefit developed countries either directly through lower demand contraction internationally, but also through lower/higher relative competitive losses/gains following the implementation of mitigation objectives.

Remarks on the macroeconomic assessment of adaptation

Finally, it is worth proposing some remarks on the methodology potentially applicable to adaptation modelling, starting from the experience characterizing the macroeconomic assessments performed within the ECONADAPT project. In the end it has been shown that it is possible to include adaptation in top-down models and analyse it with a top-down perspective once adaptation expenditure, the sectors recipient of this expenditure, and the actors sourcing this expenditure are clearly identified. This allows moving beyond the "adaptation measure" scale to consider broader aspects linked to adaptation strategies like impacts on public budgets, overall GDP performances, and international spillovers. In principle there are no limits to the sectors, or adaptation types that this methodology could address. This however requires a sufficient amount of data that, with the exception of few domains like those analysed in ECONADAPT, are not yet available.

If this is a limitation now, it also offers a great opportunity to foster collaboration between the macroeconomic and the "bottom-up" modelling communities along with local planners for a comprehensive and consistent multi-dimensional assessment of adaptation. In particular, it would be useful to foster the generation of data for adaptation assessment, extend data sharing and result dissemination, eventually establish modelling communities on adaptation developing modelling comparison exercises following experiences similar to AgMiP or ISI-MIP initiatives. This would contribute to greatly reduce the cost of information gathering, increase the cross validation of models and model results, and allow a more rapid development of the modelling tools themselves.

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