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Review of Costs and Methods for Climate Change Adaptation

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ABSTRACT

A number of studies have been estimated adaptation costs of climate change for both developed and developing countries. This study critically reviews adaptation costs of climate change and made a comparison of these estimations and methods. Strategic responses and proper estimates are required to fortify the nations and community resilience to the implications of adverse effects of climate change. Adaptation measures are important to limit the negative impacts of climate change even though with adaptation there will be residual damages/costs. The estimated costs are useful for the basis of discussion and allocation of the amount of investment needed for tackling climate change adaptation. The costing of adaptation should also be robust and methodologically transparent considering residual damages as this has been influential in the debate concerning funding on the issues of climate change.

Key words: Climate change adaptation, adaptation cost, costs and methods

INTRODUCTION

The impacts of climate change are affecting enormous physical property and livelihood damages, as well as economic growth and human development that may pose a serious threat to the community and nations security (UNDP, 2007; Amiri and Eslamian, 2010; Rashid *et al*., 2011; Begum *et al*., 2011b). According to the Intergovernmental Panel on Climate Change, partial estimates of the economic impact of a temperature increase of 2.5°C (a mid range value associated with a doubling of the atmospheric concentration of CO_2), without offsetting adaptive efforts, range from 0.5-2% of GDP, with higher losses in most developing countries (World Bank, 2006). In order to offset the damage of climate change, adaptation to climate change is an effective approach. Moreover, adaptation measures and its potential role in reducing climate vulnerabilities could play an important role to the global climate negotiations and fund disbursements (Kartha *et al*., 2006; Dellink *et al*., 2009; Tan *et al*., 2010) as vulnerability differs to the different locations (Begum *et al*., 2011a). Adaptation to climate change includes all adjustments behaviour or economic structure that reduces community vulnerability to climate change (Smith and Lenhart, 1996). Adaptation to these changes can be advanced faster through appropriate financing, technology and capacity building, if particular high risk and vulnerable groups are not to be significantly disadvantaged in the future (Begum and Pereira, 2011). However, adaptation plays a key role in determining the economic and social costs of climate change (Smithers and Smit, 1997;

Tobey, 1992; Kahn, 2003; Rashid and Sarkar, 2010; Ruth, 2012). Considering the importance of adaptation, some studies have attempted to assess the effectiveness of adaptation actions (De Bruin *et al*., 2009; Agrawala and Fankhauser, 2008). Therefore, adaptation measures are important to limit the negative impacts of climate change even though with adaptation there will be residual damages/costs. For this, adaptation and its costs estimation is vital to gear up the climate talk and fund disbursement with liability, compensation, equity and fairness (Paavola *et al*., 2006). Adaptation costs of climate change has been estimated by several studies such as World Bank (2006, 2010a), Stern (2006), UNDP (2007), Oxfam (2007) and UNFCCC (2007b), among other studies. Based on the above studies, this article critically reviews adaptation costs of climate change and made a comparison of these estimation and methods.

MATERIALS AND METHODS

This study is based on a comprehensive review of global and regional reports of different international organizations related to the cost estimation and its approaches to climate change adaptation. Most of these studies have been collected through a comprehensive search by using electronic and non electronic databases for six major studies namely World Bank (2006, 2010b), Stern (2006) review, UNDP (2007), Oxfam (2007) and UNFCCC (2007b). In addition, this review also made a comparison between the studies of UNFCCC (2007b) and World Bank (2010a) as well as also included some other studies in the review such as Hughes *et al*. (2010) and De Bruin *et al*. (2009).

RESULTS

Costing climate change adaptation accurately is now a challenge to the national and international organization which is essential for tackling climate change issue and getting ahead for climate negotiation as well as fund disbursement especially for the vulnerable countries or regions due to climate change. The subsequent sub-section discusses mainly six major studies related to the cost estimation and assessment of climate change adaptation.

The World Bank estimated the fraction of current investment flows that is climate sensitive and then used a 'mark up' factor that reflects the cost of 'climate-proofing' investments for adapting to climate change (UNFCCC, 2007b). The World Bank (2006) assumed that 2-10% of Gross Domestic Investment (GDI) monetarily $1500 billion per year at the time, 10% of foreign direct investment (FDI, $160 billion) and 40% of official development assistance (ODA, $100 billion) would be sensitive to climate change. The assumed mark-up to climate-proof these investments was 10-20%. It is found that only the ODA figure had some empirical grounding (UNFCCC, 2007b). This estimation has taken into account a wide range of adaptation cost which is summarized in Table 1.

Table 1: World bank estimates of adaptation cost

Factors consideration	Investment flow (US$ billion)	Of which climate sensitive (%)	Extra cost of climate proofing (%)	Adaptation cost (US$ billion)
Gross domestic investment	1,500	2-10	10-20	3-30
Foreign direct investment	160	10		2-3
Official development assistance	100	40		4-8
Total				9-41

World Bank (2006)

Table 2: Stern review estimates of adaptation cost

Factors consideration	Investment flow (US$ billion)	Of which climate sensitive (%)	Extra cost of climate proofing (%)	Adaptation costs (US$ billion)
Gross domestic investment	1,500	2-10	5-20	2-30
Foreign direct investment	160	10		1-3
Official development assistance	100	20		1-4
Total				4-37

Stern (2006)

Table 3: UNDP estimates of adaptation cost

Factors consideration	Investment flow (US$ billion)	Of which climate sensitive (%)	Extra cost of climate proofing (%)	Adaptation costs (US$ billion)
Gross domestic investment	2,724	2-10	5-20	3-54
Foreign direct investment	281	10		1-6
Official development assistance	107	17-33		1-7
Additional adaptation				42
Total				86-109*

*The minimum level of "climate proofing" (the first three cost items) was arbitrarily set at $44 billion, UNDP (2007)

Compare to the World Bank studies, the prominent document on climate change issues, Stern Review has reduced the mark-up for climate-proofing from 10-20% to 5-20% and the share of climate sensitive ODA from 40-20% which is shown in Table 2. It seems that the Stern review has also adopted similar approach like World Bank but made no further adjustments to the method. The changes in assumptions were not explained, other than to say that they were derived through discussions with the World Bank (UNFCCC, 2007a).

The United Nation Development Programme (UNDP) has estimated costs for climate proofing development investments and infrastructure to be at least US$44 billion annually by 2015 followed by the World Bank's methodology and using 2005 data. It is remarkable that this study has included the costs of adapting poverty reduction strategies i.e. $40 billion a year and strengthening disaster response systems i.e., $2 billion a year which shows $42 billion of new additional adaptation finance (Table 3). Overall, the range of total adaptation cost becomes US$86-109 billion a year by 2015 which requires a huge amount of money to be invested.

The international confederation of aid and development, Oxfam has also estimated the broad financing requirements for community-based adaptation and the cost of implementing NAPA (National Adaptation Programme of Action) style program. This study has measured an alternative cost of adaptation at least to an amount of $50 billion a year. This estimation was based on scaling up the current costs of community-based projects, scaling up the most urgent immediate needs (based on existing NAPA estimates) and identifying other hidden costs (Oxfam, 2007). Table 4 shows the Oxfam estimates of adaptation costs. The result across these different parameters is an estimate of just the most immediate and urgent projects for all LDCs costing $1-2 bn. This study has extrapolated from LDC costs to all developing countries, on the same basis (scaling up by population, GDP and land-use area). The result is an estimate ranging from $7.7 bn (when population is used as the scaling parameter) to $33.1 bn (when GDP is used instead). This indicative range of $8-33 bn (the total, not annual, cost of these projects) would cover the most urgent and immediate priorities across developing countries.

Table 4: Estimates of the cost of urgent and immediate adaptation needed, scaled up from the 13 NAPA budgets

	Parameters		
Grouping	Population (millions)	GDP ($ bn)	Land use (km^2)
NAPA 13 submitted	217.8	83.49	349,320
All LDCs	741	257.3	2,262,910
All developing countries	5094	8347	15,178,410
Scaling up from NAPA budgets (NAPA-13: $330 m)			
Scaling up for All LDCs	$1.1 bn	$1.0 bn	$2.2 bn
Scaling up for All developing countries	$7.7 bn	$33.1 bn	$14.4 bn

Oxfam (2007)

Table 5: UNFCCC estimates of additional annual investment for adaptation

	Adaptation cost (billion US$)		
Sectors	Developed countries	Developing countries	Global adaptation cost (billion US$)
Agriculture	7	7	14
Water	2	9	11
Human health	Not estimated	5	5
Coastal zones	7	4	11
Infrastructure	6-88	2-41	8-130
Total	22-105	27-66	49-171

UNFCCC (2007a, b)

The United Nation Framework Convention on Climate Change (UNFCCC) estimates are based on six commissioned studies which have provided estimates of the cost of adaptation for the year 2030. A special feature of UNFCCC estimates is that it has divided the adaptation cost for both the developed and developing countries by sectors. This assessment has estimated the global investment flows which range from USD 50 to USD 170 billion per year by 2030, of which USD 27 to USD 66 billion per year was anticipated from developing countries which is demonstrated in Table 5.

The Economics of Adaptation to Climate Change (EACC) study of World Bank has defined adaptation costs as the cost of actions attempting to restore pre-climate change welfare standards whose marginal benefits exceed marginal costs (World Bank, 2010a). Because welfare would not be fully restored, there would be residual damage from climate change after allowing for adaptation (Hughes *et al*., 2010). To estimate the costs of adaption, World Bank (2010b) study compares the world with and without climate change that shows a projection of the world future by 2050 by making a comparison between now and future. EACC team used the projected world without climate change as baseline. Climate scenarios were chosen to capture as large as possible a range of model predictions although model predictions do not diverge much in projected temperatures increases by 2050, precipitation changes vary substantially across models. For this reason, model extremes were captured by using the model scenarios that yielded extremes of dry and wet climate projections, although, catastrophic events were not captured (World Bank, 2010a). This study estimated 75-100 billion US$ to cover the adaptation cost per year for the period of 2010-2050 which is presented in Table 6.

In comparison of the studies between World Bank (2010a) and UNFCCC (2007b) that evident the upper end of UNFCCC (2007b) estimate is closer to the World Bank (2010b) estimate. There

Table 6: Total annual costs of adaptation for all sectors by region (2010-50)

	Cost of adaptation (billion US$)	
Region	NCAR wettest scenario	CSIRO driest scenario
East Asia and Pacific	28.7	21.8
Europe and Central Asia	10.5	6.5
Latin America and Caribbean	22.5	18.8
Middle East and North Africa	4.1	3.7
South Asia	17.1	19.4
Sub-Saharan Africa	18.9	18.1
Total	101.8	88.3

World Bank (2010a, b)

Table 7: Comparison of adaptation cost estimates between UNFCCC and EACC by sector (billion US$)

	EACC study (World Bank, 2010a, b)		
Sector	NCAR (wet) scenario	CSIRO (dry) scenario	UNFCCC (2007a, b)
Infrastructure	29.5	13.5	2-41
Coastal zones	30.1	29.6	5
Water supply and flood protection	13.7	19.2	9
Agriculture, forestry, fisheries	7.6	7.3	7
Human health	2.0	1.6	5
Extreme weather events	6.7	6.5	-
Total	89.6	77.7	28-67

NCAR: National Centre for Atmospheric Research, CSIRO: Commonwealth Scientific and Industrial Research Climate

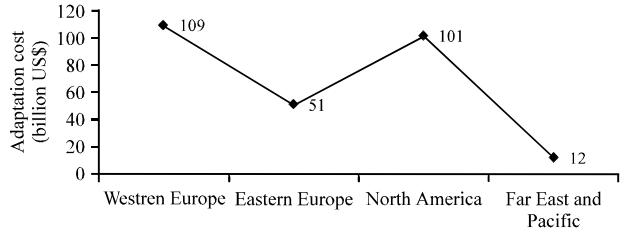

Fig. 1: Cost of adaptation for OECD countries by NCAR scenario (2010-50) (Hughes *et al*., 2010)

is not much methodological difference in using a consistent set of climate models to link impacts to adaptation costs but the major difference found is about six-fold increase in the cost of coastal zone management and defense of the World Bank study compared to the UNFCCC as shown in Table 7.

Hughes *et al*. (2010) estimated adaptation costs of OECD countries by region for water sector according to NCAR scenario. Figure 1 shows that OECD countries in Western Europe and Far East and Pacific need highest and lowest cost i.e., US$109 billion and US$12 billion for climate change adaptation while Eastern Europe and North American countries needs US$51 billion and US$101 billion, respectively. This means that there is also a huge amount to be needed for the North American OECD countries for adapting to climate change.

De Bruin *et al*. (2009) used Integrated Assessment Models (IAMs) to capture both costs and benefits of climate change adaptation and also provide a consistent framework to investigate

Table 8: Undiscounted climate change costs during 2005-2105 (trillions US$)

Cost type	Total cost
Adaptation costs	10.5
Mitigation costs	16.5
Residual damages	139.3

De Bruin *et al.* (2009)

"optimal" balances between investments in climate change mitigation, climate change adaptation and accepting (future) climate change damages. By using the Dynamic Integrated model for Climate and the Economy (DICE) and its regional sister-model Regional Integrated model for Climate Change and the Economy (RICE), De Bruin *et al.* (2009) has estimated global adaptation cost $10.5 trillion while mitigation cost and residual damage estimated 16.5 and $139.3 trillion, respectively for the period of 2005-2105 as shown in Table 8. Other studies have showed that estimates for global annual damages due to climate change are US$ 300-350 billion which translated to about 1% of the Gross Global Income (GGI) (Fankhauser and Tol, 1996; Tol *et al.*, 2004).

REVIEW: MEASURING METHODS OF ADAPTATION COST

Adaptation measures are important to limit the negative impacts of climate change even though with adaptation there will be residual damages/costs. Most of the studies (World Bank, 2006; Stern, 2006; UNDP, 2007) have measured the possible costs which are needed for enhancing the resilience of climate change. The UNDP (2007) has added costs of strengthening social protection programmes and disaster response while the Oxfam (2007) study adopted a different approach, scaling up estimates based on both the NAPAs and NGO programmes. It is also noted that UNFCCC (2007a) adopted a more detailed approach, disaggregating the analysis by sector and world region whereas World Bank (2010a, b) estimated sectoral cost of adaptation by comparing the world with and without climate change.

In line with UNFCCC (2009), this review also found that there are broadly two major categories of global studies or assessments of adaptation costing such as (1) Investment and Financial Flow (I and FF) analyses and other similar aggregated assessments and (2) Economic Integrated Assessment Models (IAMs). Most of the studies used an aggregate approach and built around some form of (I and FF) approach. I and FF analyses with an estimate of the level of 'climate sensitive' investment in each country and applied a 'mark-up' to account for the additional costs of climate change. These studies exclude benefits of adaptation and do not work within a full economic framework (UNFCCC, 2009). The IAMs used an explicit economic framework to assess the global costs and benefits of adaptation over long time-scales, including comparison against mitigation. It should be noted that De Bruin *et al.* (2009) estimated adaptation cost with mitigation and residual damage by using Integrated Assessment Models. The approach of IAMs also have some limitations such as use relatively high discount rate for future climate change impact, assign monetary value of human lives and ecosystems through speculative judgments or incomplete information and exaggerate mitigation cost (Ackerman *et al.*, 2009). Table 9 summarizes the approaches or methods and highlighted features of the above discussed studies/assessments.

Table 9: Approaches of the global/regional studies of adaptation cost

Method	Highlighted features of adaptation costing	References
I and FF	Climate-proofing' investments	World Bank (2006)
I and FF	Climate sensitive investment	Stern (2006)
I and FF	Climate-proofing investment plus cost of adapting poverty reduction and strengthening disaster response	UNDP (2007)
I and FF	World Bank plus cost of NAPAs and (NGO) programmes	Oxfam (2007)
I and FF	Five sectors and separate cost for developed and developing countries in 2030	UNFCCC (2007a, b)
I and FF	Six sectors and regional estimates from 2010-2050	World Bank (2010a, b)
IAM	Cost-benefit of adaptation	Hope (2009) (Parry, 2009)
I and FF	OECD water sector	Hughes *et al.* (2010)
IAM	Adaptation cost, mitigation cost and residual damage	De Bruin *et al.* (2009)

DISCUSSION

The above studies show a wide range of adaptation cost, with the lowest at $4 billion and the highest at over $100 billion. Most of the studies estimated only the costs of adaptation but there is lack of estimation on the adaptation benefits or residual damages. It is also observed a limited empirical fact or information about the share of climate-sensitive investments and the mark-ups required to 'climate-proof' which are likely to be situation-specific (Parry *et al.*, 2009). The studies which have been reviewed in this article are useful and obviously remarkable in the literatures on costing of climate change within some limitations. Table 10 presents a brief summary of the above estimated costs of climate change adaptation.

Figure 2 shows an increasing trend of both lower and upper bound adaptation cost for the respective years. This exponential line provides an indication of higher adaptation cost needed over the time period. The estimation and its method of the above studies might influence by the datasets, assumptions and time frames and also between developed and developing countries (World Bank, 2010a). Therefore, there is need for more research to find a common and standard method for adaptation cost estimation especially for developing countries (UNFCCC, 2007a; Parry *et al.*, 2009; World Bank, 2010b; Begum *et al.*, 2011a, b).

This article reviewed a range of international level studies that can provide an insight to conduct national and local level study on the costing of climate change adaptation. In addition to this, it is noticed that some of the international level studies also have been derived from national and local level studies (UNFCCC, 2007a; World Bank, 2010a). However, the cost estimation or assessment is useful for the basis of discussion and allocation of the amount of investment needed for tackling climate change adaptation. Strategic responses and proper estimates are required to fortify the nations and community resilience to the implications of adverse effects of climate change because without proper estimation of adaptation cost, it is very difficult to maintain equity, fairness in distribution of climate fund (Paavolaa and Adger, 2006; UNFCCC, 2009). The costing of adaptation should be robust and methodologically transparent considering residual damages as this has been influential in the debate concerning funding on the issues of climate change (UNFCCC, 2007a). There is also need for national and local level studies on costs of climate change adaptation considering residual damage by providing a detailed and robust assessment of costing climate change adaptation for policy and decision making. This article can be useful for future studies in relation to climate change adaptation at the national and local level.

Table 10: Estimates of the annual costs of adaptation for developing countries (billions US$)

Costs	Time frame	Comments	References
9-41	2010	Cost of climate-proofing FDI, GDI and ODA flows	World Bank (2006)
4-37	2010	Update with slight modification of World Bank	Stern (2006)
At least 50	2010	Based on World Bank, plus costs from NAPAs and NGO projects	Oxfam (2007)
86-109	2005-2015	World Bank, plus costing of PRS targets and better disaster response	UNDP (2007)
27-66	2030	Sectoral estimates of additional investment and financial flows needed for adaptation	UNFCCC (2007a, b)
70-100	2010-2050	Estimates adaptation costs by using with and without climate change	World Bank (2010a)

FDI: Foreign direct investment, GDI: Gross domestic investment, ODA: Official development assistance, NAPA: National adaptation programme of Action, PRS: Poverty reduction strategy, Modified from Agrawala and Fankhauser (2008)

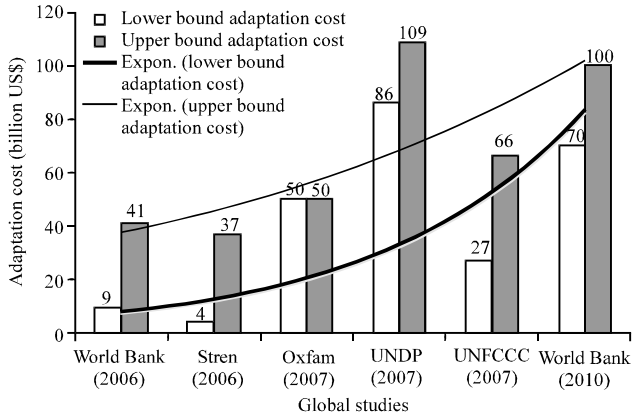

Fig. 2: Adaptation cost of climate change by the global studies (World Bank, 2006, 2010a; Stern, 2006; Oxfam, 2007; UNDP, 2007; UNFCCC, 2007a, b)

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