The economics of adaptation to climate change environmental sciences essay

The methodology used for the global estimate of cost of adaptation and the country case studies has been briefly elaborated in this section and is also depicted in Figure 3. 1. For the global estimates, gives an estimate of adaptation costs covering eight sectors (infrastructure, coastal zones, water supply, agriculture, fisheries, human health, forestry and ecosystem services, and extreme weather events). Adaptation costs are defined as the cost of actions attempting to restore pre-climate change welfare standards whose marginal benefits exceed marginal costs (World Bank, 2010a). The study has considered only planned adaptation while accepting that autonomous adaptation is also an important component. Country level data sets were used to generate this information. For the global track, country-level data set were used. The climate projections sets are consistent for most sectors and there are projections of the development trajectories without climate change using GDP and population projections. This is then used to estimate the social and economic costs of adaptation (World Bank 2010). For the country case studies, a bottom-up approach was taken which was done by engaging national experts, discussions with local stakeholders and using local databases. Here, the impacts of climate change and costs of adaptation were estimated only for the major economic sectors for each country. Vulnerability assessments and and develop adaptation strategies accordingly. Analysis was conducted to integrate the sectoral analyses and pinpoint cross sectoral effects (World Bank 2010). For the purpose of this research, the country case studies have been perused but not described and only the global estimates have been discussed. Time Frame and Discount Rate. The adaptation costs were calculated for the period 2010-2050. This time period was chosen to make more precise estimates because the projections of climate change and its effects on the economy become all the more uncertain after this period (World Bank 2010). A zero discount rate for this study was considered for this study because of the inability of the sectoral models to choose the optimal timing of the investments. This is because of the complex nature of the sectors at the global level. The costs have been expressed in 2005 constant prices. Baselines. An econometric analysis was carried out to come up with projections equations for average infrastructure demand in 2050. The climate variables used for this purpose were the population and inverse population weighted means of; (a) annual average temperature in degree Celsius; (b)total annual precipitation; (c) temperature range (the difference between the average maximum temperature in the hottest month and the average minimum temperature in the coldest month) and (d) the precipitation range (Hughes, Chinowsky and Strzepek, The Costs of Adapting to Climate Change for Infrastrcuture 2010). There is limited availability of independent projections of the variables to 2050 that can be used. For the purpose of this study the other variables considered are the total population, urbanisation, age structure of

Figure 3. 1. Steps for calculatings costs of adaptation of infrastructure

Using projections equations with no climate change estimate Qijt+1 , ΔQijt = Qijt+1 - QijtBaseline projections = ΔQijt x Cijt1. Construct baseline projections of infrastructure investmentProjections of climate variables as averages for 20 years - 2010, 2030 and 20502. Add alternative climate scenariosSame as step1, but using alternative climate variables in the projection equations3. Project infrastructure quantities under the alternative climate scenarios. ΔCijt is calculated for alternative climate scenarios for each period t in country j for infrstructure type i4. Apply the dose-response relationship to estimate changes in unit costs for alternative climate scenarios. Yields Delta-P costs5. Estimate the change in total investment costs for the baseline projectionsYields Delta-Q costsEstimate the change in investment costs due to the difference between the baseline infrastructure quantities and the alternative climate scenario quantities. Source: (World Bank 2010)population, growth in income (GDP per capita measured at PPP[1]), crude birth rate, infant mortality and some geographical features which would be country-fixed effects[2]. A consistent set of future population and GDP projections were used to develop baselines across sectors which reflects the A2 SRES scenario. The GDP trajectory is based on the average of the GDP growth projections of the three major integrated models of global emissions - ; (a)Climate Framework for Uncertainty, Negotiation, and Distribution(FUND), (b) PAGE2002 and (c) Regional dynamic Integrated model of Climate and the Economy (RICE99) and - growth projections used by the International Energy Agency (IEA) and the Energy Information Administration of the United States Department of Energy to forecast energy demand. This is done in order to ensure consistency with the emissions projections. 2005 is treated as base year for all estimates and the World Development Indicators published in 2008 is the source for most data. Climate Scenarios and Global Climate Models. The Community Climate System Model 3 (CCSM3) of the National Centre for Atmospheric Research (NCAR) and Mk 3. 0 model of the Commonwealth Scientific and Industrial Research Organization (CSIRO) were used for modelling climate change. The projections for these two models were created at a 0. 5 by 0. 5 spatial degree scale and a monthly time scale. This was done by applying the predictions through 2050 to the historical climate baseline obtained from the University of East Anglia Climate Research Unit’s Global Climate Database time series 2. 1.

3. 2. 2 Methodology to estimate costs of adaptation for infrastructure

Costs for infrastructure adaptation have formed a major chunk of total adaptation costs as seen in previous estimates for total adaptation. In this study the infrastructure has been given a broad definition and includes transport (especially roads, rail, and ports), electricity, water and sanitation, communications, urban and social infrastructure, urban drainage, urban housing, health and educational facilities and general public buildings (Hughes, Chinowsky, & Strzepek, 2010; World Bank 2010). For this sector the design standard updates and the maintenance and operations are the adaptation measure considered while calculating the costs. For the purpose of estimation, the study defines an efficient level of provision of infrastructure which would be reached if the " country had invested up to the point at which the marginal benefits of additional infrastructure just cover the marginal costs—both capital and maintenance—of increasing the stock of infrastructure" (Hughes, Chinowsky and Strzepek, The Costs of Adapting to Climate Change for Infrastrcuture 2010). It considers the development deficit is different from adaptation deficit. The various equations involved in the calculation of the costs of adaptation are elaborated below. The basic equation of total value of investment in infrastructure type i in a country j and period t is depicted as; $Iijt = Cijt(Qijt+1 – Qijt + Rijt)$ --------(1)Where Cijt is the unit cost of investment and Rijt is the quantity of existing infrastructure of type i to be replaced during the period. When the change in total costs have to be calculated with respect to relevant climate variables it is done in terms of total differential of the above equation that either would effect the unit costs or efficient levels of provision of infrastructure. Thus it would be written as$\Delta Iijt = \Delta C (Qijt+1 - Qijt + Rijt) + (C +\Delta C) (Qijt+1 - Qijt + Rijt)$--------- (2)The stocks of various kinds of infrastructure are projected over 2010 under the development baseline without climate change. The additional costs of constructing, operating and maintaining these baseline levels of infrastructure services under the new climatic conditions as projected by the CCSM3 and Mk 3. 0 global climate models are computed as adaptation costs. These are referred to as the delta-P[3]cost of adaptation and focuses on price and cost changes for fixed quantities of infrastructure. Thus the delta-P component calculates the costs of " climate-proofing"[4]the baseline projections of infrastructure assuming no climate change with estimates of the percentage changes in the unit costs of constructing, operating, and maintaining infrastructure as a consequence of climate change. The delta-Q costs are more difficult to estimate because they deal with change in infrastructure requirements due to impacts of climate change and according to the study there are lot uncertainty associated with this and also a need for extensive research. Thus in the final EACC report on delta-P costs of adaptation are included in the finals costs of adaptation. The econometric analysis was thus conducted with the purpose of determining the how a given climate affects the demand for infrastructure and not how change in climate would lead to change in the demand. The results suggest that demand for some types of infrastructure is impacted by different climate variables along with significant interactions with income per capita and urbanization. Dose Response Values. Infrastructure specific dose-response relationships were developed between climate variables (dose) and unit costs of construction and maintenance (response) which were used for estimation of the costs of adaptation through 2050. Tables 3. 1 and 3. 2 give the dose response relationships that have been calculated for different kinds of infrastructure. There were two kinds of methodologies followed while estimating code updates for constructions cost. The building code methodology[5]was centred on the proposition that a major building code update would lead to a 0. 8 per cent increase in construction costs of buildings and paved roads which would be required for every 10cm increase in annual precipitation. Code updates for paved roads related for first one degree rise would be . 29 per cent followed by the a . 29 per cent rise every three degree rise in maximum of monthly maximum temperatures. The direct response[6]methodology was used for bridges and unpaved roads. In this method the changes in construction costs are directly associated with the specific alterations in climate or infrastructure design specifications. Thus for unpaved roads, the construction costs would increase by 0. 8 per cent for every 1 per cent increase in monthly maximum temperature. For bridges, there is a 3. 13 per cent costs for each one foot increase in clearance[7].

Table 3. 1 Description of Dose Response for constructions

Precipitation Dose ResponseTemperature Dose ResponseWind Dose ResponseMethodologyBridges3. 13% with each one-foot increase in clearance. Not estimated. Impact likely to be minimalNot estimated. Impact likely to be minimalDirect ResponsePaved Roads0. 8% increase per km for every 10 cm rise in annual precipitation0. 29% for first 1 degree Celsius rise maximum of monthly maximum temperature values and later with every 3 degree increaseNot estimated. Impact likely to be minimalBuilding CodeUnpaved Roads0. 8 % increase incosts per km for each 1 % increase in maximum precipitation. Not estimated. Impact likely to be minimalNot estimated. Impact likely to be minimalDirect ResponseTransmission PolesNot estimated. Impact likely to be minimalNot estimated. Impact likely to be minimal0. 8% increase for every 15 mile per hour increase in maximum of the maximum monthly wind speedsBuilding CodeBuildings0. 8% increase in costs per square foot for every 10cm increase in annual precipitation0. 22% change in costs per square feet for every 0. 5 degree Celsius change in annual average temperatureNot estimated. Impact likely to be minimalBuilding CodeSource (Chinowsky, Price and Neuman, 2010)The estimation of dose response for maintenance was also done using two different methodologies. These have been depicted in Table 3. 2. The avoided lifespan decrement method was used for evaluating the relationship between climate stressors and maintenance costs. This is based on estimating the costs of preventing lifespan reduction due to effects of climate change. There are two basic steps; (a) estimation of the reduction in lifespan due to a unit change in climate stress[8]and (b) the cost of preventing such a reduction in life span.[9]

Table 3. 2 Description of Dose Response for maintenance

Precipitation Dose ResponseTemperature Dose ResponseMethodologyPaved Roads - ExistingChange in annual maintenance costs per km per 10 cm change in annual rainfall projected during lifetimeChange in annual maintenance costs per km per 1 degreechange Celsius in maximum of monthly maximum temperatureprojected during lifespan. Avoided Lifetime DecrementPaved Roads –NewPaved roads constructed after 2010 would have no maintenance impact if designed for changes in climateexpected during their lifetimeUnpaved RoadsIncrease by 0. 8% with every 1 per cent increase in the maximumof the maximum monthly precipitation values projectedfor any given year. Not estimated. Impact likely to be minimalDirect ResponseRailroadsNot estimated. Impact likely to be minimal0. 14% increase with every 1 decre increase in maximum of monthly maximum temperatureDirect ResponseBuildings – ExistingChange in annual maintenance costs persquare foot per 10 cm change in annualrainfallChange in annual maintenance costs per square foot per1 degree change Celsius in annual average temperatureAvoided Lifespan DecrementBuildings - NewBuildings constructed after 2010 would have no maintenance impact if designed for changes in climate expected during their lifetime. Source: (Chinowsky, Price and Neuman, 2010)Direct response methodology was used to calculate the dose-response values for the costs of maintenance for railroads and unpaved roads which is similar to the method discussed earlier for the construction costs of unpaved roads and bridges.

Results and Analysis

According to the final report of the EACC study (World Bank 2010) on global estimates the average cost estimates for infrastructure adaptation for developing countries as a whole are between $14 to $ 30 billion per year. The EACC report has not considered a deep analysis of CSIRO scenario because of the low costs that are predicted by it and thus this section would also focus on the NCAR scenario for future analysis. In the report on infrastructure (Hughes, Chinowsky and Strzepek, The Costs of Adapting to Climate Change for Infrastrcuture 2010), the costs of adaptation for infrastructure from 2010-50 was presented classified by economic categories and infrastructure sectors for the whole world which has been shown in Table 5. It is seen that the total adaptation costs per year for infrastructure in the world till 2050 comes to only $ 43 billion USD which is just 1 per cent of the total baseline investments projected for the same period. The adaptation costs as a percentage of baseline costs are the lowest for high income countries at 0. 79 per cent while for the low income countries it is 1. 69 per cent.

Table 3. 4: Delta-P costs of adaptation by different infrastructure types and country class (2010-2050) (US $ Billion per year at 2005 prices and no discounting)

NCAR scenarioType of costsLow IncomeLower Middle IncomeUpper Middle IncomeHigh IncomeTotalPower and TelephonesAdaptation0[10]1012Baseline13217392304701Water and SewersAdaptation00001Baseline11915495193562RoadsAdaptation321712Baseline675660215398Other TransportAdaptation00416Baseline8188631142Health and SchoolsAdaptation01012Baseline3612192302551Urban InfrastructureAdaptation862520Baseline2872192098411555Total CostsAdaptation11981543Baseline64974063418873910Source: Adapted from Hughes, Chinowsky, & Strzepek, 2010As can be seen in figure 3. 2

adaptation costs for urban infrastructure forms the major part of total costs at 47 per cent followed by roads at 28 per cent. But if we examine the adaptation costs as percentage of baseline costs it can be seen that the highest costs are for other transport at 4. 2 per cent followed by roads at 3 per cent. The results also state that the adaptation costs are going to be the highest for the high income countries at $ 15 billion USD.

Figure 3. 2 Sectoral composition of adaptation costs

Source: Adapted from Hughes, Chinowsky, & Strzepek, 2010Figure 3. 3 shows the how adaptation costs are distributed among low income, lower middle income, higher middle income and high income countries. It was be seen that the high income countries would have to bear the highest adaptation costs approximately 35 per cent of the total adaptation costs.

Figure 3. 3 The distribution of adaptation costs per year across country class

Table 3. 5 shows us the estimates of annual delta-P costs for infrastructure for developing countries in different regions till 2050. As mentioned earlier the costs of adaptation can be seen to be considerably higher for the NCAR scenario which is also considerably wetter. It can also be seen that in NCAR scenario the East Asia and Pacific region has the highest cost of infrastructure adaptation followed by South Asia while all the other regions do not show much variations. In the CSIRO scenario however the annual average costs are not much different for South Asia and East Asia and Pacific regions.

Table 3. 5: Estimates of Annual Delta-P costs for infrastructure

($ Billions at 2005 constant prices, no discounting)

YearEast Asia and PacificEurope and Central AsiaLatin America andCaribbeanMiddle Eastand North AfricaSouth AsiaSub-SaharanAfricaTotalNational Centre for Atmospheric Research (NCAR), wettest scenario2010-196. 81. 51. 80. 93. 81. 115. 92020-299. 51. 92. 81. 26. 62. 324. 32030-3911. 34. 43. 91. 58. 73. 933. 72040-4914. 85. 35. 41. 810. 76. 144. 1Average10. 63. 33. 51. 47. 53. 429. 5Commonwealth Scientific and Industrial Research Organization (CSIRO), driest scenario2010-193. 10. 71. 30. 61. 40. 77. 82020-293. 31. 11. 60. 51. 51. 09. 02030-394. 31. 51. 80. 93. 91. 714. 12040-495. 62. 11. 21. 49. 12. 622. 9Average4. 11. 41. 70. 94. 01. 513. 5Source: (World Bank 2010)If we compare the estimates of the costs of adaptation falls in the middle level of the estimates of the UNFCCC range. The lower end of the World Bank estimate is pushed up because of a more detailed coverage of infrastructure and also due looking at different types of infrastructure to differentiate costs and risk. The World Bank estimates are pushed down because adaptation is measures against a consistently projected development baseline and a smaller multiplier is used on baseline investments. In the next section, the dose response methodology is applied to the investments on roads in the 12th five year plan directly to come out with an indicative approximate of the costs that would be required to make them climate resilient.