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Climate Change: A Paradigm Shift for Investments?

A Review of Evidence under Climate Economics Research

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Abstract

Continuing with work of Rathee and Kapil (2013) on assessing the paradigm shift for investments due to climate change, this paper presents a review of the climate economics to add to the precious work on climate science. In its various sections the paper presents the economic treatment of climate problem as a market-failure from the perspectives of externalities and cost benefit analysis and reveals the dimensions of marginal abatement costs, and inter-generational equity. An assessment of likely total economic costs incurred due to climate change is presented to understand the scale of asset-value loss and economic risks faced by investors. We thereupon also investigate the various economic instruments that have been proposed by economists and implemented in policy for adaptation to and mitigation of climate change activity. In the penultimate section, a discussion is presented on challenges and opportunities for private investors in light of the climate economics revealed earlier in the paper. This research will add further to the work presented earlier in the series and adds another perspective of interdisciplinary dimension to the benefit of climate and economic researchers. For further action, the future researcher can build on this collective work to investigate for evidence on investable financial instruments that provide opportunities to allocate capital in the climate adaptation and mitigation related sectors.

Keywords: *Climate change, climate costs, climate economics, economic instruments, private climate investments.*

INTRODUCTION

Climate change has been recognized as one of the foremost dangers facing the planet. The global warming through the climate change generates stress on basic cornerstones of human life viz., energy, food, habitations, human health, transportation, industrial production and water availability.

Climate change thus cannot be seen as regional issue and transforms into a problem of global scale and enormity. The Earth's atmosphere, as a natural resource, has historically been treated as a common but free-for-all property (Ciriacy-Wantrup and Bishop, 1975). This free dumping backyard approach adopted in industrial and other economic activities have emitted an unprecedented amount of greenhouse gas (GHG) emissions in the air. It has now been scientifically established that there exists boundaries for the carrying capacity of GHGs in earth's atmosphere as a natural resource.

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However, clearly ignoring these natural principles and boundaries of resource exploitation, the rapid industrialization of economic activity since 1750s has now emitted more GHGs than any time during the last millennium. The natural carrying capacity of atmosphere has clearly been encroached in this treatment of atmosphere as common and free dump.

Earlier, in his landmark work, Boulding (1966) warned against the constraints to un-controlled industrialization and predicted that the improved lifestyles will ultimately face barriers of finite supplies and flows of materials and energy. Hotelling (1949) also reached a similar conclusion of limited carrying capacity of environment by applying the concept of optimal rate of natural resource productivity. Ironically, the warnings went ignored for several decades, till in earlier 1990's the scientific body – IPCC, provided strong evidence on earth's systems experiencing an unexpected rise in Global Mean Temperature (GMT) and causing a widespread climate change. The problem of climate change has thus presented the economists, a classic and most complex example of Hardin (1968)'s 'tragedy of commons'. The atmosphere as a global public good and free natural resource has been severely abused by the human activities and ultimately resulted into an enormous social cost of global scale and threatened the inter-generational resource parity.

The subsequent economic researches on climate change has concluded that the current trajectory of emissions growth is not expected to peak in the near future without considering them as negative externalities and putting a 'per unit cost on emissions'. By applying sound economic theories, climate economists have come out with several economic and financial instruments to price these emission externalities. We will attempt to identify these economic costs and climate instruments in the following sections of the paper. We begin in next section by analyzing climate economics researches in areas of GHG emissions as externalities, and then identify the economic cost evaluation methods applied in cost benefit analysis in the section thereafter. Further, we present the economic cost factors of economic costs estimates of climate as has been provided in various past researches. Thereupon in the next section, we identify the economic instruments forwarded in the work of various economists and currently being widely applied in climate policy. In the second last section, we discuss the challenges and opportunities of climate change through lens of information provided on climate economics in the previous sections. In end, we conclude the major points of this research and suggest leads for future researchers.

ECONOMICS OF CLIMATE CHANGE

The role of economists in climate change policy have been direct through the calculations of social and private marginal cost-benefits, design of viable market-based instruments, evaluation among economic rationale of action versus action later (Nordhaus, 1991; 1994). We will discuss all these approaches over the coming section.

EMISSIONS AS ENVIRONMENTAL EXTERNALITIES

Externalities are the unaccounted fallouts of an activity on parties external to it. As a result, the activity itself may turn up inefficient in resource usage and further the mitigation of fallouts can be a costly affair for the external parties. The concept of externality has been under academic scrutiny for around a hundred years. Externality was conceived as a negative or positive influence on a third party for which no price is attached in the decision of the users. In the earliest attempt, Pigou's (1924) theory of welfare economics provided guidance on a market mechanism of pricing the negative externalities. The Pigouvian theory introduced the concept of identifying a marginal social cost of polluting emissions by any economic activity and argued to impose a tax of equivalent amount on the polluter.

On similar terms, the environmental externalities especially pollution damage fit into this structure. Emissions are the negative effects on third party that create unaccounted costs and restrict the society as whole to achieve Pareto optimality from common resources. The growth in economic activity over last 150 years has been as a result of improvement in human capability to extract and consume more physical resources. The process however is not complete without generating externalities through physical transformation of matter and energy in gaseous emissions as waste. Waste gases are emitted as a result of chemical transformation of material and energy utilized in the activity. Emissions have long distance diffusive effects and carry intertemporal stay in atmosphere. This vintage and diffusive effect makes it more difficult to recapture and mitigate the effects of emissions on climate cycle. In materials balancing approach, Ayres and Kneese (1969) demonstrated that economic systems will continue to suffer from negative externalities if environmental systems have limited carrying capacity but economic activity caused waste is persistent in nature.

Externality as a case of market failure and cost-benefit analysis

In cases where market-oriented economic systems fail to attach costs of externalities to the emitters, the costs of fallout will be borne by society and hence the concerned economic system would turn suboptimal in maximizing human well-being. After earlier years of neglect, the subsequent suggestions justified a public policy intervention to internalize this environmental externality, wherein the third-party effects of emissions were required to be included in the internal costs of polluters. Several economic instruments and approaches have been forwarded by economists over the period of time to internalise the price of these negative externalities.

Taking cues from materials balance principle, Boulding (1966) justified that without technological intervention the carrying capacity of nature as reservoir of pollution would be limited. The welfare economics approach of resource endowments integrated externalities as crucial factors for deriving social optima and system efficiency. This acknowledgement of externalities further ensured the requirement of significant intervention for achieving optimality. One adopted change is the economic valuation of ecosystem as capital assets, which have led to innovative financial instruments and institutional arrangements (Daily, 2000).

Coase (1960), on the other hand, took social cost approach and produced two potential solutions for addressing externality problem – one targeted at the polluter and the other involving the sufferer. The distributional burdens of economic costs varied under these two approaches but it was argued that they carry equivalent efficiency weights. The first approach – polluter pays - argues to impose a charge - including an economic instrument such as taxes or a regulatory restriction, on the activity of polluter. The second solution - sufferer compensates - involves compensation of the polluter by the sufferer, to either stop / restrict the polluting activity or adopting costly measures to mitigate the pollution at source level. The sufferer compensates principle has specific relevance in cases wherein the polluter is a low-income agent and he has high switching costs in moving away from the activity. This free market approach requires government to serve as a facilitator for framing the rules for Coaseian bargains among polluter and sufferer.

Environmental impacts are generally accounted for in the statements of costs and benefits as part of investment appraisal process. The welfare economics approach for non-marginal changes arising from a project calls for their inclusion in a cost-benefit appraisal. However, environmental changes are usually construed as intangibles and accounting these non-marketed goods remained a challenge. Two popular theoretical approaches for estimation of non-marketed goods are revealed preference and stated preference methods. In a revealed preference approach individual's price, preferences for a non-marketed resource are revealed through transactions from other markets. Adopting a revealed preference approach, Hotelling (1949) forwarded travel cost method in context of calculating recreational values of public parks. Thereby, consumer surplus is estimated from the demand curve constructed out of differential costs faced by visitors to reach the park. The price or recreational value of the site can be captured by the time and travel costs incurred by people. The willingness to pay for accessing the site could be an estimation of the frequency of trips at differential costs. This willingness to pay for an environmental and intangible resource served as analogous to the price discovery and demand curve of a marketed good. Travel cost methods have since been used in various exhaustive ways for the valuation of intangibles (Ward and Beal, 2000). However, there are several challenges in efficacy of the travel cost methods such as evaluating a fair value for opportunity cost of time, the exclusion of non-users, quality of resource, and a statistical case of sampling bias.

The hedonic pricing method is also commonly applied to price an environmental service. Under it, the implicit value of an environmental activity is drawn through the association of its attributes to the observed prices of a differentiated market resource (Rosen, 1974). The most popular case is of emission's effect on residential property prices (Ridker and Henning, 1967). Property prices are capital goods that derive their value among others from the rental charge originating from the asset. The rental charge in turn is dependent on other factor flows. Hence, in a regression known as hedonic price function, the environmental attributes, particularly the air quality can be taken as one of the independent variable contributing to the price of property. Thus knowing the value of property and implicit price for air quality can be drawn.

COST-BENEFIT ANALYSIS APPROACH FOR ASSESSING THE CLIMATE PROBLEM

Marginal Abatement Costs

Marginal abatement cost (MAC) curve is a measure for assessing the economic options for reducing emissions in a time bound frame. MAC can be defined as the cost of removing an additional unit of emissions from the atmosphere. Subsequently, the area under the MAC curve gives the sum of marginal costs known as total abatement cost. A MAC curve for CO_2 emissions plots CO_2 prices for emission permits or the stipulated tax amount for CO_2 taxes, on one axis, and on the other axis it plots the required emission reductions. As shown in figure 1 below, MAC plotting involves simulation runs of the models over various price-quantity scenarios. For multiple GHGs, MAC plotting is conducted through their benchmarking on global warming potential (GWP). MACs are generally applied as the primary tool to evaluate the benefits of abatement actions. MACs are also used to draw reduced-form inferences to examine the situations where solving complex models is comparatively difficult. Ellerman and Decaux (1998), for example, have applied MACs to compare the abatement levels among different regions and the scope of emission trading therein. However, MAC outcomes remain challenged by their intertemporal stability as growth in technological opportunities and resources or variation in other related conditions may change the curves over time Morris et al (2008). Still, these are considered as valuable forecasting and cost-benefit tools for emissions trading and permit prices. A popular reference of marginal abatement cost curves for cost assessment of various measures is McKinsey MAC curves for forecasted GHG emission scenarios (McKinsey, 2009).

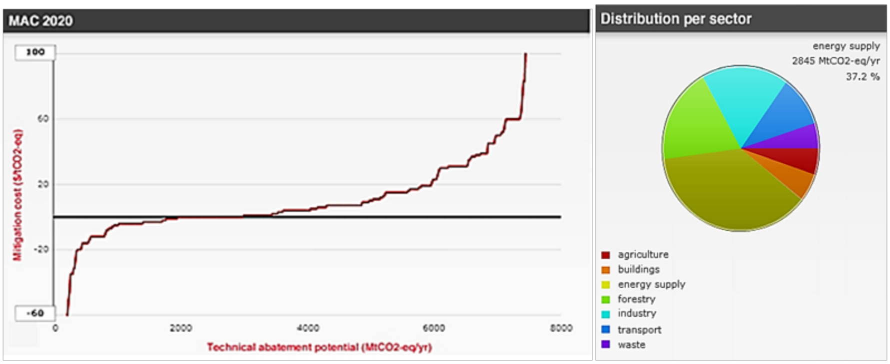

Figure 1: Marginal Abatement Cost Curve for Non-Annex 1 Countries (Source: The Energy Research Centre of the Netherlands (ECN), 2012)

Inter-generational socio-economic liability and resource equity

Amidst the debates, on one side there were suggestions including investing in improvement of socio-economic profiles of vulnerable regions, which will enable them to adapt to such changes themselves and will provide higher comparative intergenerational benefits (Cooper, 2000). On the other hand, other economists preferred, under uncertainty, acting now in preservation of an environmental asset is better given the seeming irreversibility of the costs attached. A conserved asset in the future will provide the choice on whether to preserve it further or not. Then only it will be assisted with better information available through the benefits from its existence. In an otherwise case, there is no chance of reconsideration when we have better information (Arrow and Fisher, 1974).

Debated Discount Rates

One of the most debated areas of climate economics has been the choice of discount rates for assessing the future climate changes cost-benefits (Nordhaus and Yang, 1996). The variation in discount rate automatically leads to different valuation of the expected future outcomes of climate related stress on World GDP. Predictably, intertemporal actions and the stringency of policy and economic choices also vary for different outcomes. On one hand, the positivist support application of market rates as the discount rate for future costs. On the other side, ethicists favor the intergenerational responsibility approach of maintaining the sustainability of global commons for future generations and hence lower discount rates.

TOTAL ECONOMIC COSTS ESTIMATES OF CLIMATE CHANGE

Given the enormous scale of climate change challenge, it is believed that large-scale investments are urgently required to build climate resilience, mitigate GHG emissions and support sustainable development across the countries (United Nations, 2010). Past researches have attempted to investigate the future economic costs of impending climate change and the amount of required investments for meeting the challenge. Figure 2 (Field et al., 2014) estimates the probable causality among likely temperature deviations and the loss of economic welfare.

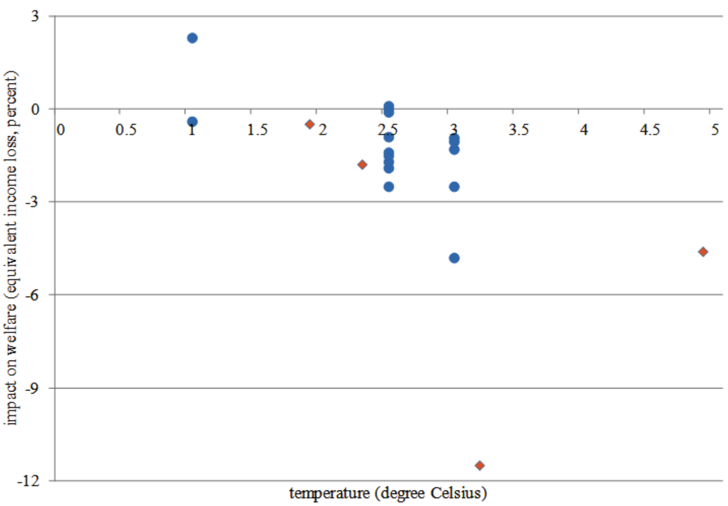

Figure: 2 Estimates of the total economic impact of climate change at various levels (Source: Field et al (2014))

The precise estimates are still unclear on the actual costs suffered by global economies per year. A list of conservative estimates is depicted in the table 1. Such is the magnitude and scope of problem that a consensus on these numbers is still evolving, as new climate information is revealed and higher investment amounts are being proposed. The conservative estimates are projecting the direct annual costs suffered globally due to climate change are in the range of $50-100 billion.

Table 1: Annual Cost Estimates of Climate Change *(Source: Agrawala & Fankhauser, 2008)*

Research Source	Publication year	Estimated Average Annual economic costs (USD billion)
World Bank	2006	9-41
Stern	2006	4-37
Oxfam	2007	>50
UNDP	2007	86-109

Agrawala & Fankhauser (2008) in their conclusion of a survey of cost estimates commented that the existing estimates of adaptation costs by various researches are preliminary and incomplete. They identify that studies need to broaden the geographical and sectoral scope and depth of various climate impacts and observe that there are still several relevant costs, which require to be incorporated within the existing and the extrapolated climate scenarios. Similarly, to address the overall challenges and preparing for a changing climate, researchers have mentioned amounts in the range of $500 billion (see figure 2).

ECONOMIC INSTRUMENTS FOR CLIMATE CHANGE

Economists have suggested control of externalities through putting price on externalities and adoption of economic instruments such as taxes, subsidies and marketable permits (Nordhaus and Yohe, 1983; Taschini, 2010). A comprehensive of list below in table 2 mentions the key economic instruments that have been introduced to tackle climate change. Broadly, they fall in the categories of fiscal or monetary (e.g. subsidies, price supports, and taxes), market based instruments (tradable licenses, permits or quotas), and financial instruments for risk hedging.

Table 2: Economic Instruments for climate change *(Source: Author's own)*

Category	Instrument	Asset value impact (+ve/-ve)	Industries
Subsidies	Grants	+ve	Renewable Energy Clean Technology
	Tax Rebates	+ve	Water and Irrigation technologies
	Price supports / Pre-purchase agreements	+ve	Agricultural equipments and fertilizer; storage and warehousing infrastructure

Category	Instrument	Asset value impact (+ve/-ve)	Industries
Taxes and fees	Carbon Taxes	-ve	GHG emission-intensive manufacturing industries; energy production - fossil fuels; high emission transportation
Tradable Licenses, permits, or quotas	Tradable units	+ve (low-carbon activity) / -ve (high-carbon activity)	Renewable Energy Certificates
			Water Markets
	Project based offsets		Carbon Markets
Financial Instruments	Soft loans	+ve	Low-carbon activities in all major sectors
	Insurance	-ve (Hedging costs)	all sectors; specially agriculture, manufacturing industries in Coastal
	Catastrophe bonds		
	Weather derivatives		

The success of these instruments to control the climate change problem has been judged with mixed responses so far. For climate mitigation specifically, the approach adopted is to set price on per tonne emissions of GHGs in any activity and through this added cost, gradually incentivize users towards low-emission activities. As restrictive fiscal and 'market-based' instruments of pricing – there is wider application of 'Carbon Taxes' and 'Carbon Trading'. Similare to various other aspects of climate change, the merits and demerits of these two economic instruments have also been long under debate. 'Carbon taxes' are "price-based" market instruments that are expected to de-motivate emitters activity through the added cost of tax (Nordhaus, 2007). As carbon emissions vary by fuel (e.g. higher in coal with respect to natural gas), over the period of time, the added costs decrease the demand and consupmtion of higher emitting fuels. Taxes, simulatenously raise revenues for government to fund long-term emission control systems. Though, carbon tax spreads cost among a larger base and is easy to implement and monitor but it distributes the costs evenly among all the emitters inspite of credible differences in cost of mitgation for respective operations. In cumulative and system wide assessment, taxes lead to higher economic costs. Additionaly, covering all the GHGs within a single tax regime is difficult to operate. If taxes are not applied in all regions uniformly then competitiveness of industries suffer due to 'carbon leakage' i.e. production shifts to non-tax regimes due to cost-advantage.

'Carbon trading', on the other hand, is a 'quantity-based' market approach whereby it provides flexibility in mitigating the targeted 'quantity' of emissions at least marginal costs. In the lon-term, the emissions doesn't show a locational behavior and due to their mobility carry a global nature of impact. Carbon trading particularly operates on this concept and prescribes to reducing emissions on the behalf of high marginal cost entities in industiries and geogrpahies where the marginal cost of mitigation is minimum. The value and quanitifed amount of reduced emissions, in one entity on behalf of other, is transacted under a trading system of 'cap-and-trade'. Generally, the studies favor carbon trading systems over carbon taxes for their environmental performance, cost effectiveness, and distributional equity in costs among the players (Stavins, 2008). The international negotiations have also recognised the merit in the least marginal cost of abatement advantage provided under the trading systems and susbequently have adopted emissions trading as the choice policy tool for global treaties (Grubb, 2003). Kyoto Protocol (KP) is also designed on similar market-based based principles and economic instruments. The emission trading systems under KP allows leveraging least cost advantages through three mechanisms – International Emission Trading (IET), Clean Development Mechanism (CDM) and Joint Implementation. The market-based economic approaches allow a system-wide reduction in total cost of compliance with emission reduction related targets. Since the adoption of KP in 2005, market participants and covered business entities have responded positively to these market based measures and substantial volume growth in emission reduction trade was observed during the first seven years (World Bank, 2005 - 11) . In general, the trading systems that use permits have found more favor among both economists and policymakers (Montgomery, 1972; Tietenberg, 1985; Hahn and Hester, 1989; Stavins 1995; Ellerman, 2003; Stavins, 2008). However, the debate over permits being a better measure than carbon taxes is still from over, in particular the economists have not been able to reach consensus on the comparative benefits over long term (Nordhaus, 2007; Cooper, 2008).

DISCUSSION – CHALLENGES AND OPPORTUNITIES FOR INVESTORS

Amid the alternations in natural worldview and socio-economic conditions due to climate change the arising economic costs have a critical dimension and scope for investment community to adjust (for example, see in table 3). The rise in frequency of natural calamities has increased the private and public insurance costs manifold, put the stakeholder value at risk for invested assets and raised long-term challenges to the profitability in mainstream asset classes and sectors. Insurers and reinsurance industry, for example are the frontline industries that would need to carry out readjustment to the assessment of event related risk measurement frameworks and valuation of claim sizes evolving therein. The unexpected nature and suddenness associated with natural shocks makes it even more difficult to account for the expected property damage size and costs precisely.

Table 3: Driver, Effects, and Economic Risks and Opportunities of Climate Change *(Source: Author's own)*

Driver	Effect	Economic Risks	Opportunities
Climate Forcings	Increase in GMT, Feedback effect speeding up	Rise in insurance costs, reconstruction costs, adaptation costs	Adaptation projects, innovative financial instruments,
Long-lived GHGs	Feedback effects (+ve or -ve), GHG effect increases, Heat trappings and Climate forcings increase	Rise in insurance costs, reconstruction costs, adaptation costs; climate tax and liabilities on manufacturing, energy and transportation industry investments	climate friendly clean technology, energy efficient products and services
Anthropogenic Emissions	Increase in atmospheric GHGs, Increase in Climate Forcings	Marginal Abatement Costs, Regulatory costs – emission taxes, emission permits, energy efficiency standards and usage guidelines	Mitigation and abatement projects, innovative financial instruments,
Climate Impacts	Extreme Weather Changes, Tipping Points, Socio-economic implications	Human and physical capital risks, replacement costs, insurance costs, revenue and operational stress	Adaptation projects in the areas of water conservation, agriculture production, and costal area protections

Emissions Scenarios	Higher GMT ranges, Socio-economic repercussions, rise in frequent extreme weather conditions, Positive feedback effects, Tipping point occurrence rapidity	Rapid rise in Human and physical capital costs, replacement costs, insurance costs, revenue and operational stress	Mitigation and Adaptation projects
Low Carbon Solutions	Rapid investments and commercialisation of technological innovations	High carbon intensity projects under regulatory and competitive stress, regulation costs, Technology and innovation investment costs	Mitigation projects

Role of private investments in climate adaptation and mitigation

The cost of impact and the requirements for long-term investments also have varying degree of spread among the developing and developed economies. Developing countries, particularly the ones located in southern hemisphere are expected to be the worst sufferers and at the same time the high-growth economies among these are also likely to contribute Greenhouse Gases (GHGs) at an incremental rate. As highlighted in table 4 below, it is estimated that during the current decade, annually around $300 billion will be required by these countries for adaptation to climate change and mitigation of GHGs emission factors. In the subsequent decade, 2020-30, these investments will escalate to $500 billion. Simultaneously, along with the climate change control, the inter-connected theme of global energy supply is also investment intensive. To adapt under a 2 degree Celsius global warming scenario, IEA (2012) estimates that for low-carbon energy technologies alone a total of USD 36 trillion dollar would be needed till 2050 - annually USD 500 billion till 2020, and USD 1 trillion from 2020 till 2050.

At present, the developed countries have formally agreed to provide an annual assistance of $100 billion by 2020 towards addressing the adaptation and mitigation challenges among developing countries. Even then, the investment gap is of huge scale and enormity. Additionally, public finances of the developing countries are already stressed by the existing poverty alleviation, health, education and livelihood sustenance related immediate matters of local concern.

Table 4: Average Annual level of Investments required

Author	Publication year	Average Annual level of investments required (USD billion)	
		2010-2020	2030
International Institute for Applied Systems Analysis	2009	63-165	264
International Energy Agency	2008	565	565
McKinsey & Company	2009	300	563
Potsdam Institute for Climate Impact Research	2009	NA	384

Given the long-term and large size requirements of investments for tackling the climate change, a major policy puzzle has been how to arrange this finance? Two possible financing channels are a) the public funds that are raised through tax-receipts and other revenue collections by the national governments, and b) the private capital that comprises of the funds available with individual and institutional investors for capital appreciation and wealth creation. Among the two, the first resource, public funds are already constrained by various macroeconomic and poverty-alleviation related priorities. On the other hand the second pool of funds i.e., the private investment capital with its size and supply is also a possible alternative that can provide a sustainable resource of climate investment supply.

However, the climate negotiations within the context of the United Nations Framework Convention on Climate Change (UNFCCC) have been debating since early days and now have reached a stalemate, mainly over – who and why should fund these investments? Noticeably, at the Copenhagen conference of UN in 2009, developed countries agreed to contribute $100 billion per year by 2020 to support climate adaptation and mitigation activities in the developing countries. On one end, $ 100 billion was a highly insufficient amount given the scale of climate problem, still, mobilizing even this large scale of annual investments from public funds looked very difficult. As is evidenced in the money contributed so far, it is clear that in this post financial-crises period when many governments are still struggling with fiscal and budgetary constraints, they will be unwilling to fulfill this commitment. One possible solution for this is to instead mobilize large private capital into the climate investments. However, this requires firstly, an extensive understanding of the private investment landscape and its investment motivations, secondly, creating an enabling policy environment to facilitate private participation, and lastly, funding through incentives or investments, that gap which can make these investments attractive for private investors.

CONCLUSION

The research synthesizes the work in climate economics to discuss the economic perspective of climate change problem and how it may affect the investor behavior and their investment decisions. The emerging understanding on scale and scope of climate change problem is also supported by studies in climate economics where it has been declared a serious case of market failure and externality of uncontrolled industrial activity in the past few centuries. Marginal abatement costs and naturally endowed rights to intergenerational resource equity are the two main concepts that the economists have applied to examine the various dimensions of climate change and provide economic policy solutions to manage it. The direct annual economic cost estimates of the likely climate change vary to a great deal between the researchers and range between $5 billion and $110 billion. However, these forecasts are only in regard of the disaster related direct climate change costs. The studies predict as high as a five percent of annual global GDP income loss when indirect costs are also accounted under the total long term cost estimations. To address this problem, major categories of economic instruments suggested by the economists include subsidies, taxes and fees, tradable licenses, permits and quotes, and a list of financial instruments to hedge against the likely losses. Overall, the work presented in climate economics reveal that new kind of climate related economic costs would be incurred by various mainstream assets – particularly in the sectors of agriculture, energy, fisheries, forestry, health, manufacturing industries, transportation, tourism, and water. In addition, the estimates of annual investments required for addressing the climate change problem has been put at various levels of $500 billion to over a $ 1 trillion in just the energy sector. In summary, the various economic costs and liable economic instruments will on one side stress the investment opportunities in several leading asset classes. On the other end, the huge amount of investments required and the incentivising economic instruments introduced by policymakers will also widen the investment universe of private investors.

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