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After Paris: Fiscal, Macroeconomic, and Financial Implications of Climate Change

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EXECUTIVE SUMMARY

The December 2015 Paris Agreement lays the foundation for meaningful progress on addressing climate change—now the focus must turn to the practical policy implementation issues. Against this background, this paper takes stock of the wide-ranging implications for fiscal, financial, and macroeconomic policies of coming to grips with climate change.

Most immediate, and key, is the need to recognize and exploit the potential role of fiscal policies in implementing the mitigation pledges submitted by 186 countries in the context of the Paris Agreement. At the heart of the climate change problem is an externality: firms and households are not charged for the environmental consequences of their greenhouse gases from fossil fuels and other sources. This means that establishing a proper charge on emissions—that is, removing the implicit subsidy from the failure to charge for environmental costs—has a central role.

Also critical are establishing a clear pathway to meeting complementary commitments on climate finance, effective adaptation, and ensuring financial markets play a full and constructive role. Fiscal policies are key to efficiently mobilizing both public and private sources of finance, while the need to adapt economies to climate change raises issues that have implications for the design of national tax and spending systems (for example, strengthening fiscal buffers and upgrading infrastructure in response to natural disaster risks). There is also a growing need to enhance the contribution of the financial sector to addressing climate challenges, by facilitating clean investments and pooling climate-related risks.

For reducing carbon emissions ('mitigation'), carbon pricing (through taxes or trading systems designed to behave like taxes) should be front and center. These are potentially the most effective mitigation instruments, are straightforward to administer (for example, building off fuel excises already commonplace in most countries), raise (especially timely) revenues for lowering debt or other taxes, and establish the price signals that are central for redirecting technological change towards low-emission investments. The challenges lie in gauging appropriate price paths and dealing with the adverse effects on vulnerable households and firms, and the consequent political sensitivities.

Moving ahead unilaterally with carbon pricing is likely to be in many countries' own interests, because of the domestic (non-climate) benefits of doing so, most notably fewer deaths from exposure to local air pollution. As national pricing schemes emerge, a natural way to enhance these efforts and address concerns regarding lost competitiveness would be through international carbon price floor arrangements, analogous to those developed to counter some cases of international competition over mobile tax bases.

For climate finance, carbon pricing in developing countries would establish price signals needed to attract private flows for mitigation. Substantial amounts could also be raised from charges on international aviation and maritime fuels. These fuels are a growing source of emissions, are underpriced, and charges would exploit a tax base not naturally belonging to national governments.

For adaptation, specific measures to strengthen resilience to climate change will depend on a country's specific circumstances and vulnerabilities. Policies should be worthwhile across a range of scenarios for (uncertain) local climate effects and are particularly important for low-income countries and small states prone to climate-related natural disasters.

In financial markets, increased disclosure of firms' carbon footprints, prudential requirements for the insurance sector, and appropriate stress testing for climate risks will help ensure financial stability during the transition to a low-carbon economy. Analyses of how firms' asset values could be impacted by de-carbonization are needed to efficiently allocate investments across carbon-intensive and other sectors. Strengthening countries' regulatory oversight is also needed to ensure sound and resilient institutions and well-functioning financial markets for providing instruments to manage climate risks. Besides promoting green financial instruments, catastrophe bonds and similar hedging instruments can transfer climate-damage risks to those who are better able to bear them.

I. INTRODUCTION

1. **The landmark December 2015 Paris Agreement on climate change provides a framework for meaningful progress on climate mitigation**. 186 countries submitted emission reduction pledges, covering 96 percent of global emissions, and parties agreed on procedures for evaluating progress on, and updating these pledges. Without mitigation, global temperatures are projected to rise by about 3–4ºC over pre-industrial levels by 2100, but with risks of more catastrophic warming (Box 1). Many developing countries (those, for example, that are coastal or highly agriculture-dependent) are especially vulnerable to climate impacts. The success of the Paris Agreement will require sizable reductions in energy-related carbon dioxide (CO_2) in large emitters, including in developing economies. The key practical issue is what policies are best suited for making progress on these mitigation pledges—economic analysis provides especially useful guidance on this.

2. **The central problem is that no single firm or household has a significant effect on climate, yet collectively there is a huge effect—so pricing is necessary to force the factoring of climate effects into individual-level decisions**. This pricing aligns private and social costs, thereby promoting cleaner and less energy use, and encouraging innovation toward these ends.

3. **The Paris Agreement also reiterates and modestly extends previous commitments on finance, but without specifics**. Advanced economies are strongly urged to scale up their efforts with a concrete roadmap to achieve the goal of providing $100 billion a year in finance to support adaptation and mitigation in developing countries by 2020; subsequently, by 2025, the Parties to the Paris Agreement are expected to set a new collective, quantified goal from a floor of $100 billion

per year. This commitment is seen as a pre-requisite for developing countries moving forward on mitigation pledges though the allocation of finance remains contentious. The importance of compensation for climate disasters ('loss and damage') was recognized in the Paris Agreement, but it does not provide a basis for compensation liability for bad weather events in developing economies.

Box 1. Global Climate Change: Trends and Science

Atmospheric carbon dioxide (CO_2) concentrations increased from pre-industrial levels of 280 parts per million (ppm) to current levels of about 400 ppm. This increase mainly reflects fossil fuel CO_2 emissions (half of which enter the atmosphere where they remain, on average, for about 100 years), the annual flow of which increased from 2 billion (metric) tons in 1900 to 32 billion in 2013. Without mitigation, emissions are projected to approximately triple from current levels by 2100, raising atmospheric concentrations to about 700–900 ppm (though such forecasts are highly uncertain). Developing countries account for nearly three-fifths of global CO_2 emissions and essentially all of the rapid growth in projected future emissions. Land-use changes (mainly deforestation) add another 5 billion tons of CO_2, though their projected growth is slower than that of fossil fuels. Non-CO_2 greenhouse gasses (GHGs) (such as methane and nitrogen oxides) increase current CO_2-equivalent atmospheric concentrations to about 440 ppm. Ice core data indicate that concentrations have not exceeded 300 ppm in the last 800,000 years.

Globally-averaged surface temperature has risen by about 0.8°C since 1900, mostly from rising GHG concentrations. If CO_2 equivalent concentrations were stabilized at 450, 550, and 650 ppm, mean projected warming over pre-industrial levels would be 2.0, 2.9, and 3.6°C, respectively, once the climate system reaches equilibrium (which takes several decades due to gradual heat diffusion in the oceans). Mean projected warming in the absence of mitigation is expected to reach about 3–4°C by 2100. Actual warming may be substantially greater (or less) than projections due to poorly understood feedbacks in the climate system.

Physical risks include: changed precipitation patterns, shifting deserts and monsoons, sea level rise (up to several meters if ice sheets melt), more intense and frequent extreme weather, destruction of the marine food chain from ocean acidification, and changes in ocean circulation.

Sources: IEA (2014), IPCC (2014).

4. **Adaptation to climate change reduces the severity of impacts and, being in countries' own interests, does not raise the same collective action issues as mitigation.** However, it is difficult to provide general guidance, beyond laying out policy options and issues for consideration, as appropriate actions are highly specific to local climate impacts, national circumstances, and the need to be robust across different climate-change scenarios.

5. **There is growing debate on how financial markets can facilitate the transition to low-carbon, climate-resilient economies.** Central issues here include encouraging the disclosure and effective monitoring of firms' carbon footprints; developing and deploying financial instruments that

promote the reduction and mitigation of climate-related risks; and ensuring the efficient channeling of financial flows to low-carbon technologies.

6. **The IMF's universal membership, global perspective, established expertise, and close relationship with finance ministries and financial market participants make it well positioned to contribute to the development and implementation of policies to address the challenges of climate change**. The rest of the paper starts by taking stock of climate change impacts, especially for low-income countries (LICs) (Section II), then turns to policy design issues in regard to mitigation (Section III), climate finance (Section IV), adaptation (Section V), and financial markets (Section VI). The conclusion summarizes the contribution that the IMF can make (Section VII).[2]

II. MACROECONOMIC IMPACTS

7. **Climate change is expected to significantly impact the global economy in the coming decades.** Temperature increases and other physical effects (see Box 1) would translate into significant market impacts, with output losses through effects on climate-sensitive sectors (for example, agriculture, forestry, coastal real estate, tourism). Non-market impacts include ecosystem disruption, health damages, water stress, etc. Although the average impact from a 3°C increase in temperature is projected at about 2 percent of global GDP (Figure 1),[3] there is considerable variation across studies and essentially nothing is known about potential damages from extreme (and unprecedented) warming scenarios.[4]

8. **Vulnerabilities vary considerably across regions, with greater impacts for regions with lower per capita income and higher initial temperatures**. Most vulnerable to negative effects are sub-Saharan Africa (SSA), South East Asia (SEA), and Middle East and North Africa (MENA), while risks for the United States, Europe (EUR), and China are generally more moderate. According to a study by Roson and van der Mensbrugghe (2012) sea level rise and agriculture are the main channels of impact for SEA; water scarcity for MENA; labor productivity and health for SSA; negative impacts on labor productivity in the United States may be largely offset by tourism and agriculture in the United States; while in China, net positive effects are mostly due to increased crop productivity. In Europe, effects differ across sub-regions with the positive impact in the north slightly offsetting losses in other regions.[5] Other studies project broadly similar overall impacts across the

[2] The paper builds on an evolving body of analytical work at the IMF, see for example, IMF (2008a, 2008b, 2011a, 2011b), Parry, de Mooij, and Keen (2012), Parry and others (2014). See www.imf.org/environment

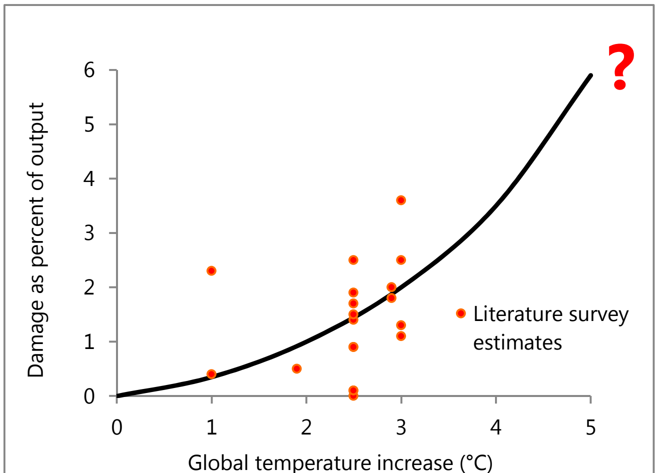
[3] This impact is measured as a percent deviation from potential output, implying that potential global GDP would be about 2 percent lower due to the climate impact.

[4] Illustrative calculations in Weitzman (2011), for example, suggest atmospheric accumulations by 2100 in the absence of mitigation would eventually increase global temperatures by more than 6°C with 22 percent probability and more than 10°C with 5 percent probability.

[5] According to most models, northern Europe will mainly benefit from positive impacts on crop productivity and tourism, while other regions are expected to experience adverse effects on labor productivity and agriculture, increased energy demand, and greater flooding.

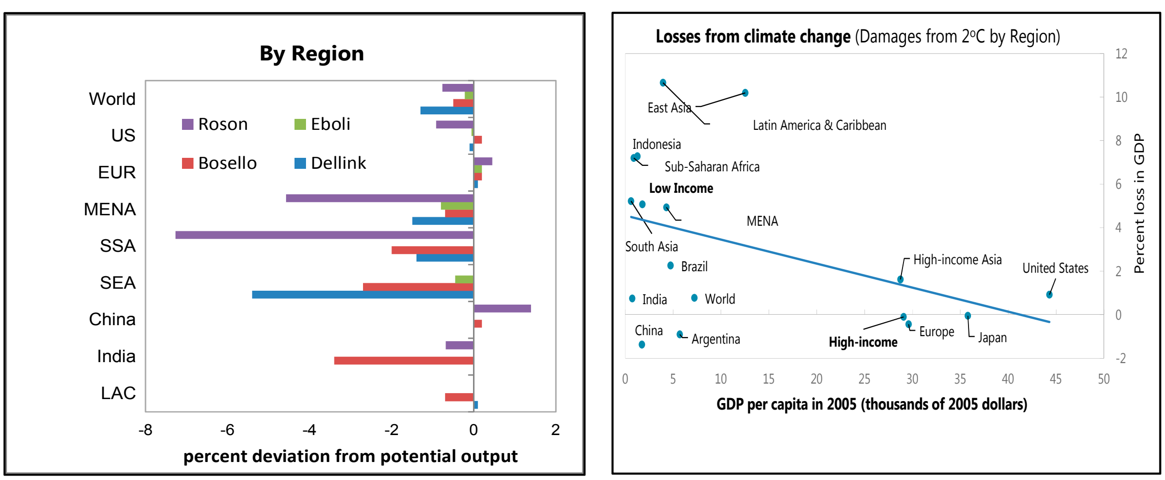
regions (Figure 2) but differ in their estimates of the specific sectoral effects (for example, Bosello and others, 2010, project greater negative impacts on agriculture in SSA ad SEA). However, most aggregate studies may underestimate effects of climate change due to relatively modest underlying assumptions and narrow distributions of risk (for example, Stern 2013). On the other hand, partial impact studies focusing on specific sectors or regions tend to show larger negative effects (not surprisingly as they often do not account for endogenous adjustment processes taking place within economies or changes in trade patterns—see Dellink and others 2014).

Figure 1. Impact of Warming on World Output



Source: Nordhaus (2013), Tol (2014).
Note. Projected damages are for some future year, typically 2100.

Figure 2. Projected Regional Impacts of Climate Change, 2050 or Thereabouts



Sources: Left panel: Bosello, Eboli, and Pierfederici (2012) (for 1.9°C increase by 2050); Dellink and others (2014) (1.5°C by 2060); Eboli, Parrado, and Roson (2010) (1.5°C by 2050); and Roson and van der Mensbrugghe (2012) (2°C by 2050). Right panel: Roson and van der Mensbrugghe (2012).

9. Greater risks for developing countries reflect in part their existing climate and limited ability to adapt. Many developing countries have large agricultural sectors, higher rainfall variability, and are relatively close to the equator where risks are greater (Figure 3, top panel):

- Although projected **temperature increases** are smaller closer to the equator, they come on top of higher baseline temperatures (already beyond the optimal for agriculture), resulting in above-average increases in the frequency and duration of extreme heat.[6]

- Projected **sea-level rise** for countries nearer the equator exceeds the global mean.[7] More generally some small island states and coastal countries (Bangladesh, Cambodia, China, Egypt, Guyana, Mauritania, Suriname, Thailand, Vietnam) could lose 10 percent of GDP or more under high sea level scenarios (for example, Dasgupta and others 2007, World Bank 2013). Rising sea levels could also increase the risks of storm surges and tropical cyclones, particularly in the Caribbean.

- Projected **water stress** (from enhanced evaporation and precipitation variability) is greater for drier climates. [8]

- Nearly 80 percent of LICs (and 50 percent of small developing states[9]) are assessed (Figure 3, middle and lower panels) as highly or extremely vulnerable to climate change, with limited "readiness" to leverage adaptation investments, compared with 40 percent in the rest of the world (See IMF 2015a on LICs vulnerability to climate change). This highlights the need for prioritizing resilience-building actions. Within countries, areas inhabited by the poor and other vulnerable groups are often the most sensitive to climate impacts (Hallegatte and others, 2015).

10. LICs and small states are often the hardest hit by natural disasters, which are expected to increase in frequency and severity. Over the period 1985–2015 (and accounting for country size), LICs are hit about one and a half times as often by climate-related disasters: floods, storms, and droughts (Figure 4, top left and bottom panels). The proportion of the domestic population affected by natural disasters is also higher compared with other countries, particularly for small developing and low-lying coastal states (Figure 4, bottom left). And within LICs, the poorest 25th percentile of countries faces the highest natural disaster risks (Figure 4, top right panel).

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[6] According to Verisk Maplecroft (2015), under a 2°C scenario, the share of land affected by unusual extreme heat at the end of the century is projected to be 30 percent in the MENA region, 30–40 percent in LAC, and 45 percent in SSA, compared, for example to 10–15 percent of land in Europe and Central Asia. Under a 4°C scenario, these shares would more than double.

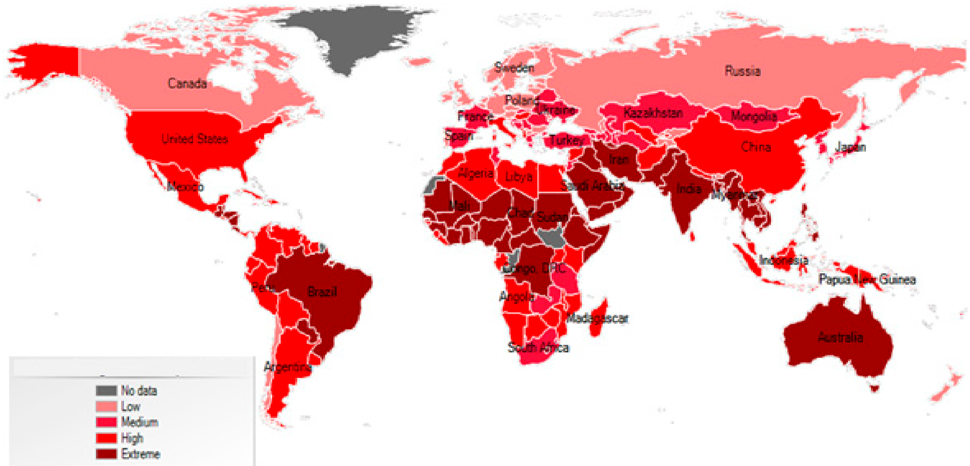
[7] For example, in a 2°C world (for the 2040s), sea levels are forecast to rise by about 30–70cm in SSA (with higher levels toward the south) and 20–65cm in MENA, and substantially more in a 4°C setting (for the 2080s).

[8] Even in a 2°C scenario (for the 2040s), water runoff declines by a projected 30–50 percent in SSA, 10–30 percent in LAC and perhaps (due to declining snow melt) more than 50 percent in the Euphrates and Tigris basin in MENA (see Schlosser and others 2014, Kochhar and others 2015).

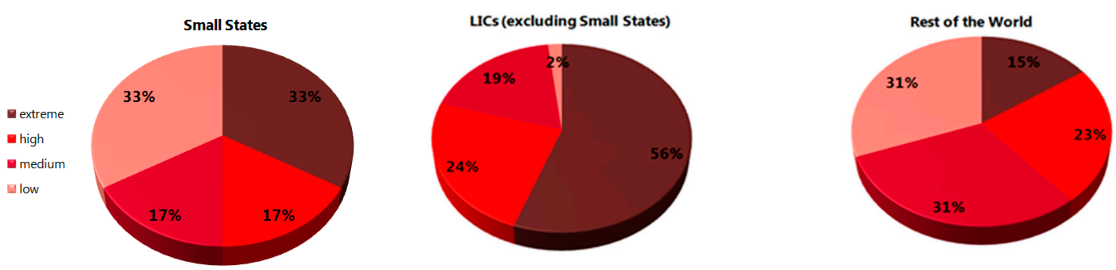
[9] Thirty-three small states (defined as countries with populations below 1.5 million) are members of the IMF, of which 20 are small developing states, 12 are middle-income, and 8 are low-income (based on the World Bank per capita income groups).

Figure 3. Impacts of Climate Change

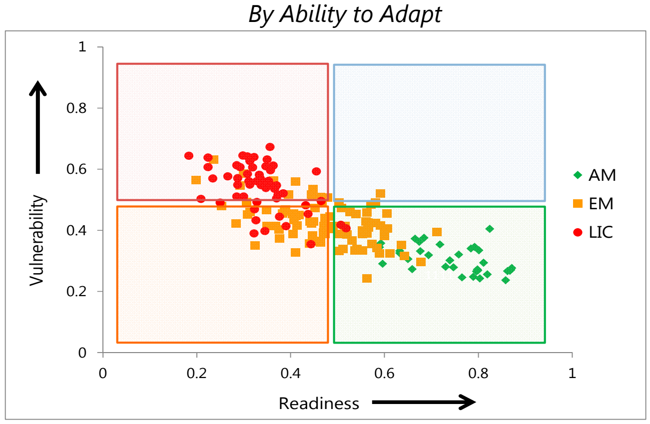
By Geographical Location



By Income Level, 2015



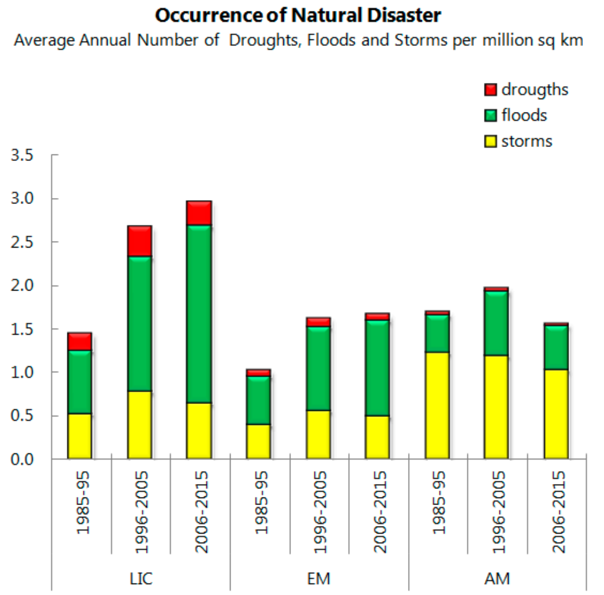
By Ability to Adapt



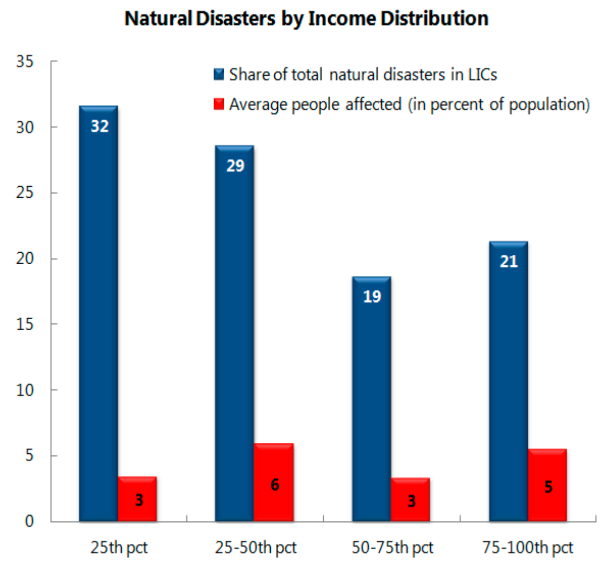
Source: Verisk Maplecroft (2015) Climate Change Exposure Index.

Note: The top and middle figures are based on the Climate Change Exposure Index, summarizing the vulnerability of human populations to the frequency and intensity of extreme climate events and predicted changes in baseline climate parameters from 2025–45, excluding the ability to adapt. The bottom figure is based on Global Adaptation Index.

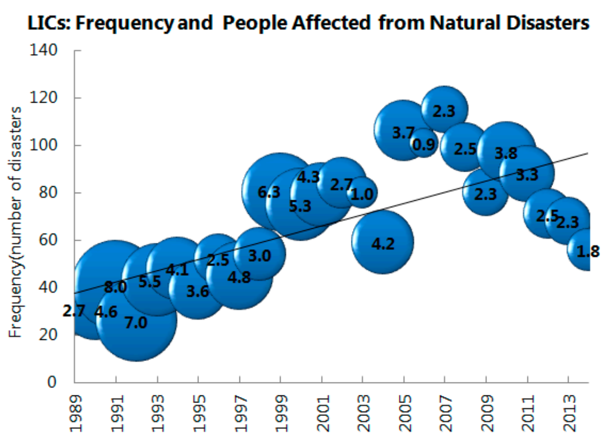
Figure 4. LICs Exposure to Climate-Related Disasters



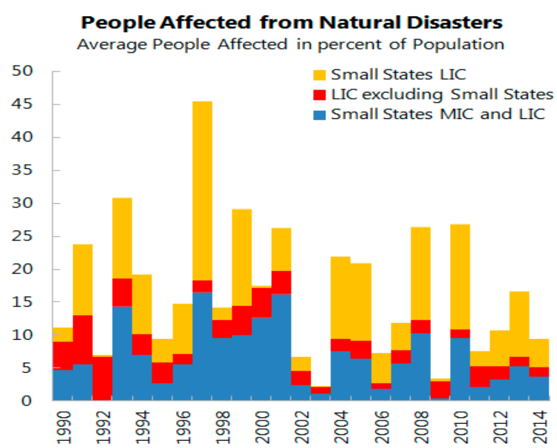
Source: EM-DAT and IMF estimates.
Note: A disaster is registered in the EM-DAT database if one of the following is met: (i) 15 or more fatalities; (ii) 100 or more people "affected" (fatal and non-fatal injuries and displaced); (iii) a call for international assistance; and (iv) the declaration of a state of emergency.
Total occurence by type of disaster (drought, floods and storms) is divided by total land area of each country grouping (LICs, EMs, and AMs).



Sources: The International Disaster Database, CRED and IMF Staff estimation.
Note: Shares do not sum up to 100 since some countries are classified to more than one group.



Source: EM-DAT Natural Disasters database.
Note: Bubble size and the number indicate percent of LIC population affetced.



Source: EM-DAT.

11. Climate-related natural disasters and higher temperatures harm growth and exacerbate poverty in developing countries. Natural disasters reduce developing country GDP growth by an estimated 1–3 percentage points, depending on the type of disaster.[10] Temperature

[10] See Raddatz (2007) and Loayza and others (2009) on climatic disasters; Reilly and Schimmelpfennig (1999) and Fomby and others (2013) on severe droughts; Acevedo (2014) on impacts for the Caribbean; and Cabezon and others (2015) on the Pacific Islands.

increases are also associated with lower growth, for example, Dell, Jones, and Olken (2012) find that in LICs a 1°C rise in temperature from a country's mean temperature reduces economic growth by 1.3 percentage points on average, mainly by reducing agricultural output. Rising temperatures and greater rainfall volatility together with more frequent extreme weather events reduce agricultural productivity in LICs, an important growth channel given agriculture's large share in output.[11] Climate change and natural disaster risks also worsen poverty due to loss of productive economic assets combined with limited savings (Hallegatte and others 2015) and food vulnerability (Adedeji and others forthcoming).

12. Exposure to climate change and related extreme weather events affects tourism. Climate change is expected to affect tourists' destination choices, creating different patterns of tourism flows at the regional level. Losses are expected for most developing countries while high-latitude advanced economies would gain.

13. The impact on agriculture and food, water, and energy security could translate into significant migration pressures and heightened conflict risks, with economic impacts in many regions. The scale of internal and international migration is expected to rise with the combined pressures of climate change and environmental degradation (Hallegatte, Lecocq, and de Perthuis 2015, Adger and others 2014, Wodon and others 2014). Physical impacts related to climate change could increase fragility and conflict by creating or exacerbating food, water and energy scarcities, and triggering migration (Burke and others 2014). These potential GDP and growth impacts, for both developing and advanced economies, are not considered in standard models of the economic effects of climate change.

14. While global economic effects will be significant, uncertainty about the magnitudes stems from several sources. These include the uncertainties in models projecting the impact of climate change on the environment, the challenges of mapping those changes into economic effects, and in accounting for future adaptation strategies and technical innovation in mitigating those effects. In addition, most models tend to rely on relatively conservative climate scenarios as modeling extreme events is significantly more challenging (Burke and others 2015).[12]

III. FISCAL POLICY FOR MITIGATION

15. From a mitigation perspective, the key practical issues are choosing and designing the policy instruments best suited for implementing countries' Intended Nationally Determined Contributions (INDCs). INDCs typically state quantitative emissions targets (Table 1, middle

[11] See Garcia Verdu and others (2015). However, these findings may not be directly applicable to estimating long-term economic impacts of climate change as they do not account for adaptation, macroeconomic adjustments, or intensified impacts of climate change relative to small weather changes (for example, Dell, Jones, and Olken 2014).

[12] A recent study by Burke, Hsiang, and Miguel (2015) suggests that the unmitigated impact of climate change on world GDP per capita could be significantly larger—roughly 5–10 times—than current estimates (that is, 20 percent lower by 2100). The estimates include quite wide uncertainty bands, and project significant negative effects for many economies, both advanced and developing.

column). Although quantity-based instruments to meet these targets with confidence have natural appeal, the desirability of predictable emissions prices is also widely accepted (see below). This is one attraction of meeting INDCs through explicit carbon pricing, with prices set to meet annual emissions targets on average (though actual emissions will exceed or fall short of the target in any given year). Potential revenues from carbon pricing have obvious appeal on fiscal grounds.

Table 1. Submitted INDCs, Largest Emitting Countries/Regions

Country	Main mitigation pledge	Share of global emissions, 2012[a]
China	CO_2 peaking around 2030, lower CO_2 intensity of GDP 60-65%.	25.9
US	Reduce GHGs to 26-28% below 2005 levels by 2025.	16.0
EU	Reduce GHGs 40% below 1990 levels by 2030.	11.9
India	Reduce GHG intensity of GDP 33-35% below 2005 level by 2030.	6.2
Russia	Reduce GHGs 25-30% below 1990 levels by 2030.	5.2
Japan	Reduce GHGs 25% below 2005 levels by 2030.	3.9
Korea	Reduce GHGs 37% below BAU in 2030.	1.9
Canada	Reduce GHGs 30% below 2005 levels by 2030.	1.7
Brazil	Reduce GHGs 37% below 2005 levels by 2025.	1.4
Mexico	Reduce GHGs 25% below BAU in 2030.	1.4
Indonesia	Reduce GHGs 29% below BAU in 2030.	1.4
Australia	Reduce GHGs 26-28% below 2005 levels by 2030	1.2

Source. UNFCCC (2015), EIA (2015).

Note. [a]Refers to energy-related CO_2.

A. Choice of Mitigation Instruments: The Rationale for Fiscal Policies

16. Strategies for reducing emissions will reflect countries' differing initial positions and political constraints and circumstances; however, fiscal policies—carbon taxes or emissions trading systems (ETS)[13] with allowance auctions—have two key advantages over regulatory approaches:

- *They are environmentally effective.* Pricing carbon increases prices for fossil fuels, electricity, etc., which promotes—with one instrument—and strikes the efficient balance across, the entire range of mitigation opportunities. These include: replacing coal with (less carbon-intensive) natural gas in power generation, and shifting from these fuels to (zero-carbon) renewables and nuclear power; reducing the demand for electricity, transportation fuels, and heating fuels through higher energy efficiency and less use of energy-consuming products; and so on.

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[13] Under these systems, covered sources are required to hold allowances for each ton of emissions; the government caps the quantity of allowances and market trading establishes the emissions price.

- *They can raise significant revenues,* creating space to reduce other taxes that create significant economic distortions.

Regulations (for example, emission rate, energy efficiency, and renewables standards):

- *are less effective,* as they focus on a narrower range of mitigation opportunities.[14] A combination of regulations is more effective, though not all opportunities can be exploited (for example, reductions in vehicle or air conditioner use), multiple programs are administratively complex, and implicit CO_2 prices typically vary considerably across sectors (an unintended distortion which means that the market is not left to achieve mitigation in the most efficient ways).

- *do not raise revenue.*

17. In principle, the choice between carbon taxes and ETSs is less important than doing either and getting the design basics right. Most important is to:

- *cover emissions comprehensively*

- *establish stable prices in line with environmental objectives*

- *exploit fiscal opportunities.*

ETSs can be as efficient as carbon taxes but so far:

- *have lacked full coverage,* as they have focused on large industrial sources, omitting small-scale sources, for example, from vehicles and buildings

- *require accompanying price stability provisions,* such as price floors and ceilings, to provide the certainty over emissions prices needed to encourage low-emission investments[15]

- *require auctioning of allowances* (instead of giving them away for free) so the resulting revenue can be used for broader fiscal reform.

18. The case for carbon taxes over other instruments can be particularly strong in developing economies. These countries may lack capacity to enforce regulations and trading,

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[14] See the extensive modelling results for the United States summarized in Krupnick and others (2010), Figure 10.2, where a wide range of commonly used regulatory policies for the power sector, transport sector, and buildings by themselves have effectiveness of only about 1–25 percent of that from a broad-based carbon pricing policy.

[15] Controlling emissions, with variable prices, can be appropriate when there are thresholds in emissions levels beyond which environmental damages rise rapidly (for example, Weitzman 1974). However, this is not applicable to global warming where one year's emissions in one country adds very little to the global atmospheric stock of emissions, which has accumulated over decades and centuries.

potential markets may be thin,[16] and energy taxes may be a relatively effective way of raising revenue from hard-to-tax enterprises.

19. Carbon pricing provides opportunities for reforming energy and environmental policies at the national and sub-national level. With carbon efficiently priced, other policies rationalized in part on climate grounds might be scaled back, such as energy efficiency standards for appliances, buildings, and vehicles, and subsidies for renewables and electric or bio-fuel vehicles. National-level pricing may also preempt a proliferation of uncoordinated, sub-national initiatives.

20. Where regulations are utilized, they should conform to the same design principles as carbon taxes. Regulatory approaches are inferior to carbon pricing, but can be more politically acceptable. In such circumstances, regulations would ideally:

- *promote a broad range of mitigation opportunities*—for example, an emissions standard for power generation promotes all fuel switching possibilities, not just switching to renewables (for example, Krupnick and others 2010)

- *include price stability provisions*—for example, energy efficiency or emission rate standards can be converted into "feebates" which impose explicit fees, or provide rebates, if firms or products fall short, or exceed, the standard

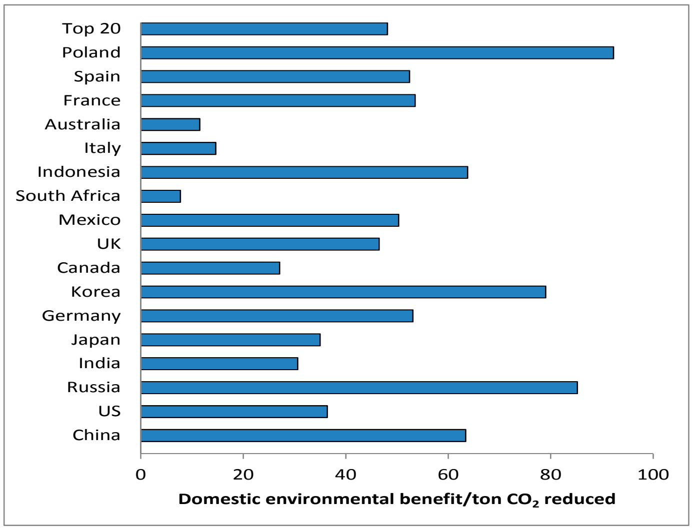
- *align implicit prices across programs and sectors and with environmental objectives.*

21. Even leaving aside climate considerations, domestic environmental "co-benefits" warrant substantial carbon pricing. These benefits include fewer premature deaths from local air pollution as carbon pricing reduces coal, diesel, and other polluting fuels and (less importantly) reduce vehicle externalities (congestion, accidents, etc., to the extent they are not already charged through fuel taxes) as higher fuel prices cut vehicle use. Co-benefits alone would have warranted estimated CO_2 prices of $57 per ton in 2010, averaged across the top 20 emitters (Figure 5), which would have reduced their collective emissions by about 14 percent. This suggests countries will gain by implementing their INDCs irrespective of what others do (up to a point): even in terms of national self-interest there may well be no need to wait for others to mitigate. Co-benefits do, however, vary substantially across countries with, for example, air pollution emission rates and local population exposure.[17]

[16] See for instance South Africa National Treasury (2013).

[17] Domestic environmental problems are in principle more efficiently addressed through other policies including local air pollution taxes and peak-period pricing of congested roads. However, it will likely take a long time for these more efficient policies to be implemented comprehensively. In the meantime, it is appropriate to account for underpriced domestic environmental co-benefits when evaluating (nearer term) climate policies.

Figure 5. Domestic Environmental Benefits from Carbon Pricing, 2010



Source. Parry, Veung, and Heine (2014).

B. Design Principles—A Closer Look

(i) Administration

22. A comprehensive carbon tax is straightforward to administer, simply requiring charges on fuel use in proportion to their CO_2 emissions rate. Charges could be administered on domestic fuel supply at the extraction stage (for example, mine mouth or wellhead), or after processing (for example, at coal "washing" plants, the refinery gate, or fuel distributors). These charges would build on existing fuel taxes, which are well established in most countries and among the easiest of all taxes to administer.[18]

23. Carbon taxes or ETSs implemented downstream on large industrial sources are less comprehensive and more administratively complex. The EU ETS, for example, excludes about 50 percent of EU-wide CO_2 emissions. New administrative expertise is also required to monitor (actual or estimated) smokestack emissions and the larger number of installations.[19]

24. Pricing non-CO_2 GHGs is more complex and will likely need to be introduced gradually. Sources include methane (from natural gas systems, landfills, livestock, coal mining),

[18] See, for example, Calder (2015) on the practicalities of carbon tax administration. There are some complications (for example, payments would be needed for industrial sources with carbon capture and storage technologies) but these should be manageable.

[19] In both the United States or European Union, more than 10,000 entities need to be monitored in downstream systems, compared with about 1,500–3,000 entities in upstream systems (for example, Calder 2015), though even the former is modest compared, for example, with the number of firms and households paying income taxes.

nitrous oxide (from agricultural practices, industry, cars), and hydrofluorocarbons/fluorinated gases (from refrigerants, air conditioners) accounting for 16, 6, and 2 percent, respectively, of current global GHGs (IPCC 2014, p. 7). Some of these sources are practical to tax on a CO_2 equivalent basis as administrative capacity is developed,[20] though others (especially agricultural sources) might be better incorporated through offset credits,[21] where the onus falls on individual entities seeking credits to demonstrate valid reductions relative to some baseline.

25. Forest carbon sequestration might be promoted through annual subsidies/taxes for increases/decreases in stored carbon relative to a baseline (at least where property rights are well-defined). This avoids potentially large budgetary costs from paying for the entire carbon stored in forests, and the problem of gauging, on a project-by-project basis, whether changes in carbon storage would have occurred anyway without the program. Measuring stored carbon is tricky, though carbon inventories for some countries have been established using a combination of satellite and aerial photography and on-the-ground sampling of tree species.[22]

(ii) Carbon Price Level

26. Stable emissions prices are needed to contain volatility in mitigation costs and (more importantly) promote clean technology investments. Price volatility undermines the cost-effectiveness of carbon pricing because—for a given cumulative emissions reduction—it creates large differences in incremental abatement costs at different points in time.[23] And uncertainty over long-range emissions prices may deter research into, and deployment of, emissions-saving technologies, many of which (such as renewable plants) have high upfront costs and emissions reductions persisting for decades. Market-determined prices for emissions allowances have so far been quite volatile in the EU emissions trading system (EU ETS) (Figure 6), which has lacked explicit price stability mechanisms.

27. Prices can be set so as to achieve the mitigation goals in INDCs. First-pass estimates of emissions prices consistent with INDCs might be inferred using fuel use projections, carbon emissions factors, estimates of changes in future fuel prices from carbon pricing, and fuel price elasticity assumptions. If available, computational models of a country's energy system, capturing sector-specific adoption of emissions-saving technologies, can provide more sophisticated

[20] See Calder (2015). According to US EPA (2014), a ton of methane and a ton of nitrous oxide are equivalent to 21 and 310 tons, respectively, of CO_2 in global warming equivalents over a century.

[21] Offset credits allow firms covered under a pricing regime to reduce their tax or permit obligations by funding emission reduction projects in sectors or countries outside of the pricing regime.

[22] See Mendelsohn, Sedjo, and Sohngen (2012) for further discussion of the practicalities of pricing forest carbon.

[23] For example Fell, MacKenzie, and Pizer (2012) estimate that expected price volatility under an ETS for the United States would increase costs by around 15–20 percent compared with a policy where prices rise annually at the rate of interest.

estimates.[24] Once in place, emissions prices can be periodically revised if emissions targets are systematically under- or over-shot, or adjusted as needed in response to evolving climate science.

Figure 6. Price Experience in the EU ETS

Source. Bloomberg (2015), EU ETS futures series "MO1 Comdty".

28. INDCs might include minimum price targets. These could complement emissions targets by establishing a minimum carbon price. This price might be based on the discounted global damage from future climate change caused by an extra ton of CO_2 which, for example, U.S. IAWG (2013) puts at about \$60 in 2030 (in \$2015).[25] Or prices could be aligned with climate stabilization goals: for example, models suggest global emissions prices of \$60 in 2030 would be roughly consistent with containing long run warming to 2.5ºC.[26] Under either approach, emissions prices should rise at several percent a year.[27]

29. Countries need not impose the same emissions price. Some countries may set higher emissions prices because of domestic environmental co-benefits, fiscal needs, or greater political

[24] For example, IEA (2014) has these models for large countries and regions. A rough rule of thumb for the United States from its Department of Energy's National Energy Modelling System is that cutting emissions by 10 percent requires prices in the order of \$30 per ton (Krupnick and others 2010). This suggests, speaking very loosely, the INDCs in Table 1 might require emissions prices above \$50 per ton.

[25] Though with range \$20–\$170 under different damage scenarios and discount rates (see, for example, Weitzman 2011, Stern 2007, and Nordhaus 2013 for different perspectives on this). To the extent that "last resort" technologies (such as solar radiation management or direct removal of CO_2 from the atmosphere) become feasible, there might be less need to fully reflect catastrophic risks in carbon prices (Aldy and others 2010).

[26] Nordhaus (2013) p. 228.

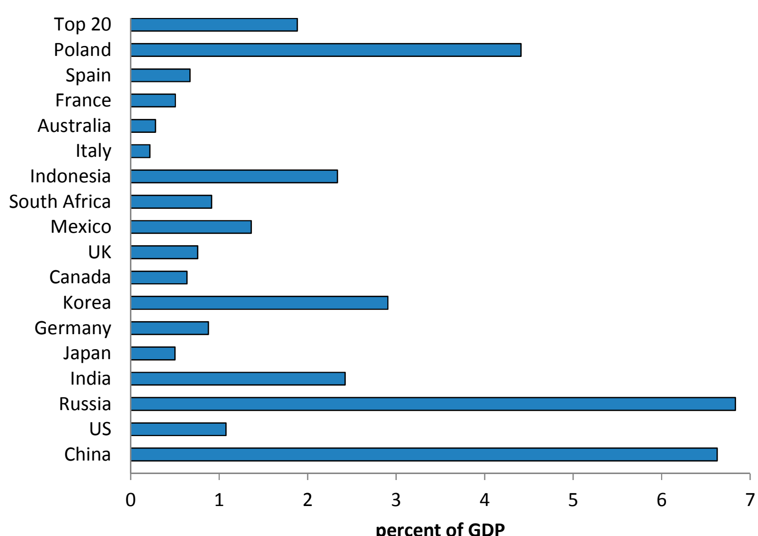
[27] Expectations of future CO_2 pricing could perversely hasten incentives for exploiting fossil fuel reserves in the near term (for example, Sinn 2012) underscoring the urgency of establishing pricing mechanisms.

support for pricing. Equity concerns may also favor low or zero emissions prices for low-income countries contributing negligibly to global emissions (Gillingham and Keen 2012), including sub-Saharan countries where electricity prices are already high, though ideally it is better to remove price distortions and help the poor through targeted measures.

(iii) Revenue Use

30. **Carbon pricing can raise significant revenue.** Pricing to reflect domestic environmental co-benefits alone would, averaged across the top 20 emitters, have raised revenues of almost 2 percent of GDP in 2010, and more than 5 percent in China (Figure 7).

Figure 7. Revenue from CO_2 Pricing for Domestic Environmental Benefits, 2010



Source. Parry, Veung, and Heine (2014).

31. **Productive use of this revenue critical for containing the overall costs of carbon pricing for the economy**. Revenues could be used for lowering taxes on labor and capital that distort economic incentives, producing a counteracting economic benefit to the costs of higher energy prices (see Figure 9 for illustrative calculations of this benefit for a typical large emitter).[28]

[28] Carbon pricing itself causes economic costs by inducing households and firms to consume less energy than they otherwise would and to pay more for cleaner (but more costly) energy. In addition, higher energy costs tend to contract overall economic activity, leading to a slight reduction in aggregate employment and investment. This produces significant additional economic costs by exacerbating distortions in factor markets created by taxes on labor and capital income. However, these harmful effects on the broader economy can be ameliorated by using carbon pricing revenues to cut taxes on labor and capital. See for example Bovenberg and Goulder (1996), Parry and Bento (2000).

The economic costs of carbon tax shifts (ignoring environmental benefits) might even be negative for modest emissions reductions if revenues cut an especially distorting tax.[29] Revenues could be used for new spending or reducing debt, though the social benefits should be comparable to those from cutting harmful taxes.

32. If revenues are not used efficiently the overall cost of carbon pricing for the economy is substantially higher. For a typical large emitter, cutting CO_2 emissions by 25 percent might cost about 1 percent of GDP when revenues finance transfer payments (that do not improve economic incentives), or under an ETS with free allowance allocation, compared with around 0.2 percent of GDP with revenues financing reductions in distortionary taxes (Figure 8). Earmarking of carbon tax revenues for environmental purposes (for example, clean technology programs, adaptation projects) also raises the cost of carbon pricing, unless this spending generates significant economic efficiency benefits. Efficient revenue use also limits any harmful effects on economic growth.[30]

(iv) Accompanying Measures

33. Measures to accompany carbon pricing may be needed to address technology barriers and burdens on vulnerable households and firms.

Technology Policies

34. Establishing a predictable CO_2 price is the single most important policy for providing across-the-board incentives for investments in emissions-saving technologies.[31] Further incentives for technology development and deployment may be needed, however, due to various market barriers.[32] The severity of these barriers varies across technologies; therefore, targeted

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[29] Early literature (for example, Bovenberg and Goulder 1996) suggested that swapping a carbon tax for a tax that distorts only labor markets has a positive economic cost (leaving aside environmental benefits). However, in reality labor income taxes cause a much broader range of distortions (for example, they also promote informal markets, excessive compensation in the form of untaxed fringe benefits, and excessive spending on tax-favored goods like housing). Accounting for the full range of distortions, the economic efficiency benefits from cutting broader taxes are larger, and the overall costs of carbon tax shifts smaller, than previously thought, and perhaps even negative over some range (for example, Parry and Bento 2000, Bento, Jacobsen, and Liu 2012).

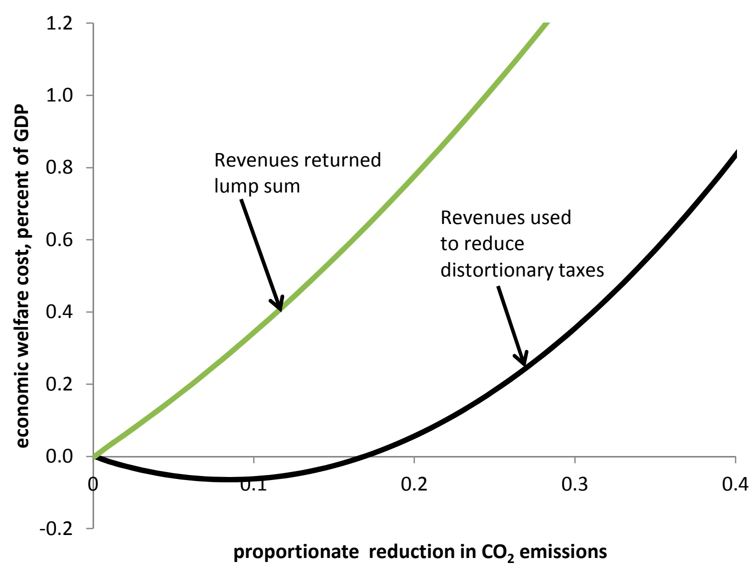
[30] See for example, Jorgenson and others (2013). Even prior to revenue use, Williams and Wichman (2015) suggest that carbon taxes are unlikely to reduce U.S. growth by more than 0.03 percent. For a broad discussion on the compatibility of growth and carbon mitigation see the Global Commission on the Economy and Climate (2014) report *New Climate Economy*.

[31] See, for example, Arezki and Obstfeld (2015).

[32] For example, firms may do too little R&D if it is difficult for them to capture spillover benefits to other firms from new technologies. And firms may be reluctant to pioneer use of a new technology because of economies of scale or if their learning about how to efficiently use the technology benefits rivals that may adopt the technology later on. These obstacles may be especially severe for long-lived, clean-energy technologies with high upfront costs, especially given uncertainty over future governments' commitments to emissions pricing or infrastructure investment (for example, grid extensions to renewable generation sites). It is sometimes suggested that the private sector also undervalues energy efficiency, though the evidence on this is mixed (for example, Allcott and Wozny 2013, Helfand and Wolverton 2011).

measures will be needed to supplement carbon pricing that encourage all technologies regardless of spillover benefits.

Figure 8. Estimated Cost of CO_2 Tax for a Representative Large Emitter, with and without Efficient Revenue Use



Source. Parry (2015).

Note. Costs can be moderately negative over some range when revenues are used to reduce an especially distorting tax.

35. Technology policies need careful design.[33] Tax credits for private R&D do little for innovative start-ups (with little taxable income) and do not differentiate between more and less socially valuable innovation. Intellectual property protection is better in the latter regard, as patent value depends on commercial viability, though patents cause tension between R&D incentives and diffusion—diffusion is greater when firms can "imitate around" patented technologies but this lowers returns to innovation. Technology prizes avoid this tension, but they require well-defined, measureable objectives that can be stated in advance.[34] Instruments targeted at deploying new technologies need to accommodate uncertainty over future technology costs, suggesting a

[33] For discussions see Newell (2015) and Dechezleprêtre and Popp (2014).

[34] For example, the U.S. Department of Energy has provided prizes for rooftop solar photovoltaic, energy-efficient lighting, and software to promote energy savings for utility consumers (Newell 2015). Incentives for demonstration projects (seeking to prove the viability of major new technologies at a commercial scale) are more contentious as they can absorb a large share of R&D budgets.

preference for adoption subsidies over regulations (the latter may force a new technology even if its costs are higher than expected) and incentives need to phase out as technologies mature.[35]

36. Under-investment in low-emission technologies may be especially severe in LICs with capital shortages. This is the basic reason for donor contributions supporting other investments (for example, infrastructure projects), and partly rationalizes the mobilization of climate finance.

Addressing Burdens on Vulnerable Households

37. Energy price burdens on low income households have been a major obstacle to carbon pricing—but can be largely overcome. Carbon pricing is mostly passed forward in higher consumer prices for energy, but the impacts may be less regressive than commonly supposed—for EU countries, carbon tax incidence can be moderately regressive, to proportional, to moderately progressive, when energy price burdens are compared with household consumption (Figure 9).[36] Distributional concerns warrant targeted relief rather than undercharging for carbon damages—the latter is highly inefficient as typically about 90 percent or more of benefits leak away to higher income groups (for example, Clements and others 2013, Figure 3.12). The focus should be on the distributional impact of the whole policy package not just the component that raises energy prices.

38. Compensating low-income households may require only a fraction of carbon pricing revenues[37] and should be practical for advanced economies through adjustments to existing tax and benefit systems. However, there are trade-offs in targeting, economic efficiency, and administration. For example, payroll tax rebates and earned income tax credits disproportionately benefit low-income households while also promoting labor force participation, but they do not reach the non-working poor. Transfer payments can reach the latter but do not provide extra incentives for work effort and may increase administrative burdens.

39. Factoring environmental impacts into energy prices makes sense for low-income countries, despite 'fuel poverty'. Efficient allocation of a country's resources implies that energy prices should cover supply and environmental costs. And energy taxes may be less regressive in countries where the poor lack vehicles and power grid access. Where low-income households are not formally registered as taxpayers or benefit recipients, they might be compensated by spending

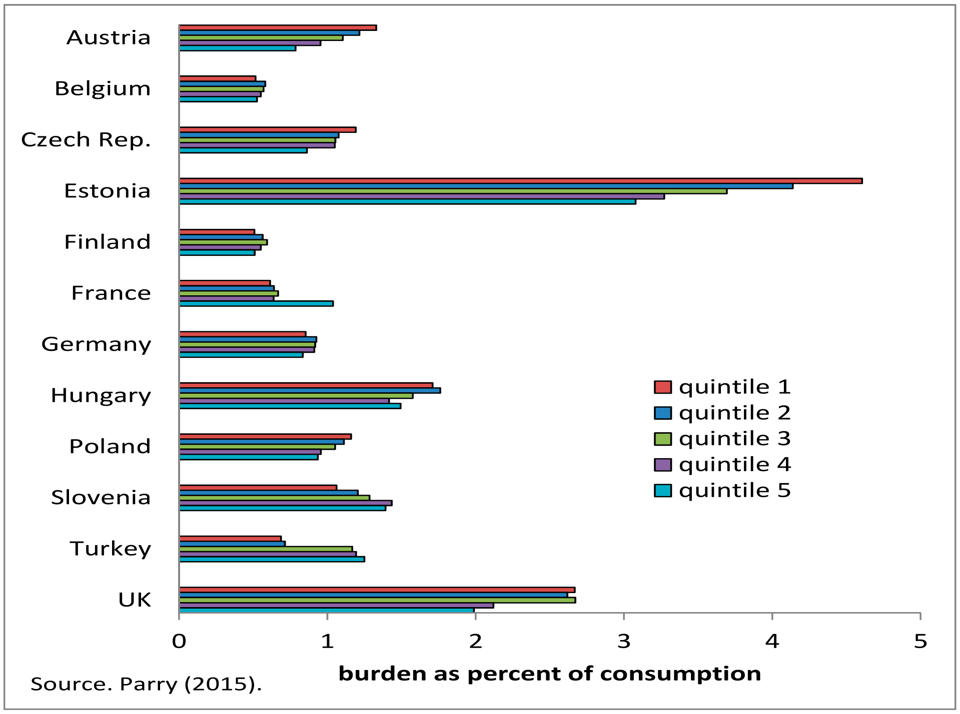
[35] Subsidies for renewables deployment totaled $121 billion worldwide in 2013 (IEA 2014), although nearly 70 percent of renewable electricity subsidies were provided by just five countries: Germany ($22 billion), United States ($15 billion), Italy ($14 billion), Spain ($8 billion), and China ($7 billion). Often these subsidies take the form of feed-in-tariffs, which provide guaranteed prices for renewables—in contrast, fixed subsidies per unit of renewable generation are more flexible as they allow prices to vary with changing economic conditions (Löschel and Schenker 2014). Subsidies for fossil fuel energy (including undercharging for climate and other environmental costs) are much larger and estimated at $5.3 trillion in 2015 or 6.5 percent of global GDP (Coady et al. 2015).

[36] Although the poor tend to allocate a greater share of their consumption to electricity than wealthier households, this is less true for transportation and heating fuels, as well as other consumer products whose prices increase indirectly as a result of higher energy costs.

[37] About 10 percent for the United States (for example, Dinan 2015).

on education, health, housing, job programs, clean fuel alternatives, and so on, though this can involve greater leakage of benefits to the non-poor.[38]

Figure 9. CO_2 Price Impact by Income Quintile Prior to Revenue Use, Selected Countries, 2012



Note: Quintile 1 refers to the bottom income quintile, and quintile 5 to the top.

Addressing Burdens on Vulnerable Firms

40. The impact of carbon charges on energy prices causes "emissions leakage"—partially offsetting increases in other country emissions[39]—and harms the competitiveness of energy-intensive, trade-exposed firms. Leakage rates are not that substantial however, typically about 5–20 percent of the first-round emissions reduction from carbon pricing if a sizeable coalition of countries price carbon (Fischer, Morgenstern, and Richardson 2015, pp. 163), and the problem is confined to a limited number of industries (for example, chemicals, plastics, primary metals, petroleum refining).[40] Efficient resource allocation generally implies that industries unable to

[38] One caveat is that higher electricity prices from charging for polluting generation fuels may encourage household burning of (unpriced) biomass, with higher environmental costs. A possible interim response is to use feebates that can promote use of cleaner generation fuels but with limited effects on electricity prices.

[39] Leakage results from migration of firms away from countries with mitigation policies to countries without these policies, as well as increasing fuel use in those countries as mitigation elsewhere puts downward pressure on international fuel prices.

[40] For the United States, industries with energy expenditures in excess of 5 percent of the value of their output account for less than 2 percent of GDP (Fischer and others 2015). However, the carbon intensity of industries in

compete when energy is properly priced should ultimately cease operation (with programs to ease transitions), though policy adjustment should be gradual. Using carbon pricing revenues for labor and capital tax reductions provides offsetting improvements in general competitiveness.

41. Border tax adjustments (BTAs) could reduce leakage concerns, and encourage participation in carbon pricing schemes—but raise serious legal and practical concerns. BTAs would levy (or remit) charges on imports and exports to ensure a level playing field given carbon prices levied elsewhere. This can in principle have beneficial efficiency effects,[41] but there are challenging practical issues (in measuring embodied carbon), uncertainties (on compatibility with World Trade Organization obligations) and risks of abuse. In the absence of strong evidence that the benefits would be significant, the case for carbon BTAs will be weak[42]—and is lessened by the generality of commitments to implement INDCs.

C. Experience to Date

42. Increasingly, policymakers are relying on pricing instruments to reduce emissions. As of mid-2015, about 40 national governments and more than 20 sub-national governments have implemented, or are implementing, some form of carbon pricing (WBG 2014 2015). Most of these schemes are ETSs, for example, in the EU scheme covering 31 countries, Korea (introduced in 2015), California, and some provinces in China. But 15 national and sub-national governments now have explicit carbon taxes (Table 2); recent examples include Chile, France, Mexico, and the United Kingdom.

43. But these programs just scratch the surface. Only 12 percent of global GHGs are currently priced, reflecting the lack of national schemes in many large emitters, and limited sectoral coverage of existing schemes.[43] And current prices—often below $10 per ton of CO_2—are below those consistent with environmental objectives. Besides price volatility, and in contrast to carbon taxes (which are often explicitly paired with reductions in broader taxes), ETSs have generally not formed part of a broader fiscal reform.[44] British Columbia's carbon tax (CAN $30/ton and covering all fossil fuels) is viewed as a poster child, though political economy factors were favorable.[45]

developing economies tends to be about 2–3 times as high on average (Böhringer, Carbone, and Rutherford 2013, Figure 2).

[41] Keen and Kotsogiannis (2014).

[42] Burniaux, Chateau, and Duval (2013).

[43] Coverage will roughly double, however, when China introduces pricing on industrial sources in 2017.

[44] One exception was the—now defunct—ETS in Australia (introduced in 2012 but repealed in 2014). The majority of allowances were auctioned, raising revenues of approximately 1 percent of GDP, about half of which were used for progressive personal income tax reductions.

[45] For example, British Columbia has no reliance on coal.

D. International Coordination of Fiscal Policy

44. International cooperation, which would enhance mitigation efforts, is challenging because of "free riding"—the reluctance of any country to mitigate unilaterally, since it bears the costs, while the climate benefits accrue to all countries. The 1997 Kyoto Protocol, which set emission reduction targets for individual countries in 2008–12 relative to 1990 levels, was largely ineffective. Key problems included lack of coverage (developing countries were not included and the United States did not ratify), the differing burdens of mitigation (depending partly on a country's emissions growth from 1990 to 2008), and the lack of enforcement (there were no penalties for non-compliant countries). The first problem at least has been addressed, as advanced and developing economies alike submitted INDCs for the Paris Agreement.

Table 2. Carbon Taxes Around the World

Government	Year adopted	Tax rate in 2015, US$/ton CO2	Coverage rate, % of GHGs
Br. Columbia	2008	25	70
Chile	2014	5	55
Denmark	1992	31	45
Finland	1990	40	15
France	2014	16	35
Iceland	2010	10	50
Ireland	2010	23	40
Japan	2012	2	70
Mexico	2014	1-4	40
Norway	1991	50	50
Portugal	2015	5	25
South Africa	2016	10	80
Sweden	1991	168	25
Switzerland	2008	62	30
UK	2013	16	25

Source. WBG (2014, 2015).

45. Underpricing from an international perspective is familiar from situations where countries compete for mobile tax bases, in which context some progress has been made through tax floor agreements. The climate analog would be a coordinated CO_2 price floor among a coalition of willing countries, which could be pursued alongside the INDC process and would represent a natural extension of existing fuel tax policy. This arrangement would provide some degree of protection against competiveness concerns and cross-border fuel smuggling. Individual countries could set prices exceeding the floor, which they may wish to do for domestic environmental or fiscal reasons, or because carbon pricing is more politically acceptable than elsewhere. Previous experience (for example, with EU value added taxes and excises for alcohol, tobacco, and energy products) suggests it is easier to agree over tax floors than tax rates—and a single minima itself should be easier to negotiate than numerous country-level emissions targets.[46]

46. Monitoring carbon price floor arrangements should be feasible. Taxes or subsidies for road fuels, electricity consumption, natural gas, and so on, are pervasive and a price agreement should account for future adjustments in these provisions, as they offset or enhance the emissions impact of formal carbon pricing. Allowance could also be made for country-specific special needs (for example, influential lobby groups may prevent higher energy prices for particular sectors). But conventions can be agreed for measuring, and accounting for, fiscal provisions, exemptions, etc.

47. International coordination could occur through linked ETSs. A difficulty, however, is that countries then lose control over their domestic emissions prices, as these depend on energy and policy developments (for example, cap adjustments) in all countries within the emissions trading bloc. Countries can retain control over their emissions price through price floors (as in the United Kingdom), but if one cap applies to the trading bloc these floors (or other domestic mitigation efforts) have no impact on aggregate emissions.

48. Enforcement remains a key concern in ensuring an effective international agreement, though for now countries acting in their own self-interest can make significant progress. Mitigation costs need not be large if recycling of carbon pricing revenues is done well, and, accounting for domestic environmental benefits, many countries are better off, on net, from carbon pricing. The priority is to start the process—implement carbon pricing domestically and work out coordination practicalities later as a coalition of the willing emerges.

IV. CLIMATE FINANCE

49. The climate finance issue is that of meeting the advanced economies' pledge to mobilize—from public and private sources—$100 billion a year by 2020 for mitigation and adaptation in developing economies. There are concerns on the spending side about the balance between mitigation and adaptation (currently most is on the former), allocating funding across countries and projects accounting for efficiency and equity, and avoiding paying for projects that would have gone ahead without funding. The most pressing challenge, however, is achieving the $100 billion goal.

50. Climate finance in 2014 has been estimated at $62 billion (Table 3). About a third of this was from multilateral sources and this funding is likely to increase in future as multilateral

[46] See for example Weitzman (2014).

development banks strengthen their climate action plans. Bilateral contributions were slightly larger, and the rest was largely made up of private flows co-financing bilateral and multilateral sources (private flows in particular are difficult to measure).

51. The Green Climate Fund (GCF) was established in 2013 to help manage public contributions. The GCF raised $10 billion in pledges from 35 countries in 2014,[47] though it will take time achieve more substantial funding levels.

Table 3. Climate Finance

Targets and (Actual and Potential) Sources of Climate Finance		
Goals for 2020	Mobilize from advanced economies $100 billion per year for climate mitigation and adaptation in developing countries by 2020.	
Actual flows in 2014	$23.1 bn	Bilateral (e.g., Overseas Development Assistance).
	$20.4 bn	Multilateral (mostly Multilateral Development Banks).
	$16.7 bn	Private finance (leveraged from public sources).
	$1.6 bn	Export credits (mainly for renewable energy).
	$61.8 bn	Total flows.
Potential extra revenues	$25 bn	$30/ton CO_2 charge, advanced economy domestic fuels (7% apportioned).
	$25 bn	$30/ton CO_2 charge, international aviation/maritime fuels.[a]

Source. OECD (2015), authors' calculations updating Keen and others (2013).
Note. [a] Includes revenues from advanced economies only.

52. The use of carbon pricing in developing countries would catalyze, and efficiently allocate, private sector climate finance. Carbon pricing promotes across-the-board incentives for clean energy projects (renewables, energy efficiency, etc.) and the efficient ordering of these projects. Under top-down finance, on the other hand, there is no automatic mechanism for ensuring that the most cost-effective projects are selected first and high transactions costs prevent funding for numerous small-scale opportunities (for example, people switching to energy efficient vehicles, appliances, or lighting).

53. Additional climate finance from donor countries need not come from innovative sources. To date, bilateral contributions have typically come from general government budgets. There may be some natural appeal in using carbon pricing as a direct source of climate finance. A charge of $30 per ton of CO_2 in advanced economies would have raised about $25 billion for climate finance in 2014 with 7 percent of revenues apportioned. Indirectly, carbon pricing in

[47] Statement by Héla Cheikhrouhou, Executive Director of the GCF, Financing for Development Conference, Addis Ababa, July 2015.

advanced economies leverages private flows to developing economies through offset markets (but there are problems—see below).

54. Charges on international aviation and maritime emissions (about 4 percent of global CO_2 emissions, but rising rapidly) are promising. National governments have a weaker claim on these tax bases than they do for domestic fuels, making them appealing as a possible source of climate finance. There are challenges, including the need for international coordination (especially important for maritime, given the mobility of the tax base) and legal issues (especially for aviation, due to treaties and bilateral air service agreements limiting fuel taxes) but the practicalities should be manageable. A global $30 per ton CO_2 charge on these fuels could have raised about $25 billion for climate finance in 2014, even after compensation for developing countries (see Table 3).[48]

55. Carbon offset markets remain depressed. Offset markets through the Clean Development Mechanism resulted in a cumulative $28 billion of flows to developing countries up to 2012 (WBG 2014, pp. 44–45). However, transaction value in the primary offset market fell sharply in 2009 and has stayed low since then, amid uncertainties about the scale and stringency of carbon pricing in advanced economies and concerns over the validity of offsets. Depending on the level of ambition, offset market flows could range from $5–40 billion per year in 2020 (World Bank 2011). Given that offset flows so far have largely gone to a relatively small set of middle income countries, broadening access among developing countries is a priority.

V. ADAPTATION

56. Adaptation policies complement mitigation and are largely in countries' own interests, but design specifics are highly dependent on national circumstances. Adaptation refers to deliberate adjustments in ecological, social, and economic systems to moderate adverse impacts of climate change and harness any beneficial opportunities (Agrawala and others 2011). Adaptation includes "hard" policy measures (for example dyke construction, changing crop varieties, adapting infrastructure) and "soft" measures (for example early warning systems, building codes, insurance). These measures might reduce the urgency of mitigation—but only moderately (for example, there are limits to how far one can protect against extreme climate outcomes). The benefits of adaptation are largely domestic, though there are potential cases of cross-border spillovers.[49] Preventive actions are typically more cost effective, and more common, than reactive actions, but are hindered by uncertainties and, for developing economies, funding constraints.[50] Economic aspects of adaptation

[48] The International Civil Aviation Organization (ICAO) Assembly agreed in October 2013 to implement, by 2020, a market-based mechanism to stabilize industry CO_2 emissions, but envisaged that any revenues would be retained by the industry.

[49] For example, diversion of water systems to counteract drier climates, and efforts to stem climate-induced population migration may have spillover effects on neighboring countries.

[50] Bosello,, Carrano, and De Cian (2010) estimate that about 88 percent of adaptation measures in OECD countries are preventative, compared with 43 percent in non-OECD countries.

policy have received much less attention from analysts than has mitigation, reflecting their strong dependency on country-specific circumstances and uncertainty over local climate impacts.

57. In developing countries, adaptation and development strategies are closely interlinked. Many aspects of development (for example, better education, healthcare, and infrastructure) facilitate adaptation, while some adaptation strategies (for example, efficient water use, climate-resilient housing, robust crops) facilitate development even without climate change—these complementarities are likely to rise with increasing urbanization (Margulis and Narain 2010, Khan and others 2009). Maximizing synergies between adaptation and development requires close policy integration and evaluation of climate impacts.

58. Some adaptation will occur privately and governments should support, not discourage, these adjustments. For example, measures encouraging urban development away from vulnerable coastlines, or requirements for flood insurance, reduce exposure to sea level rises, while automatic compensation payments for the failure of traditional crops might discourage a shift towards varieties more suitable to a changing climate.

59. But governments have a key role, and external finance for developing countries is needed. Policy intervention can help overcome market failures (for example, where private agents are imperfectly informed about adaptation benefits, or where measures, like soil retention, by one actor benefit others) and promote private sector adaptation (for example, through information provision, regulations, and institution-building). Governments also provide public goods and services, including resilient infrastructure (for example, paving roads in response to more intense precipitation),[51] and are better positioned to internalize long-term consequences of investment projects.

60. Public adaptation costs are potentially significant, and more so for LICs. Assessments of adaptation costs aggregated across developing countries are conservatively estimated at $80–100 billion annually out to 2050 (Figure 10).[52] These costs average about 0.1–0.2 percent of GDP for most regions, but are substantially higher (0.6 percent) in sub-Saharan Africa and dramatically higher—more than 5 percent of GDP for some small Pacific islands (for example, Margulis and Narain 2010).

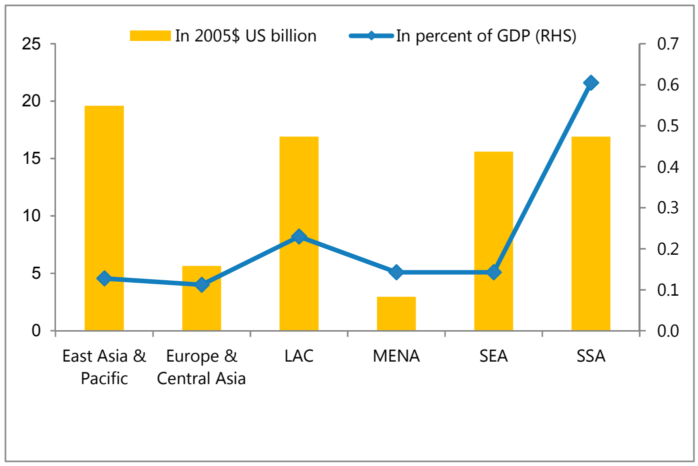
61. Infrastructure spending accounts for the largest share of adaptation costs. The main sectoral components of adaptation costs are related to infrastructure, coastal zones, water supply, agriculture, human health, and extreme weather events (Figure 11). While the share of these

[51] See for example Jones, Keen, and Strand (2013); Osberghaus and others (2010). National governments are beginning to promote local adaptation initiatives through sub-national grants (for example, the U.S. Environmental Protection Agency's Local Climate and Energy Program, Bhutan's LoCAL program). See World Bank (2014).

[52] Estimates in Figure 10 exclude, for example, adaptation costs related to ecosystem services, energy, manufacturing, retailing, and tourism. Adaptation costs for advanced economies are more modest, for example, equivalent to about $17 billion in Europe according to Osberghaus and Reif (2010).

components varies across regions,[53] infrastructure spending is the highest, and is expected to increase over time with urbanization (Margulis and Narain, 2010, Figure 10). East Asia and the Pacific and South Asia currently face the highest costs owing to their population size and density, while SSA is expected to see the largest increase over time (from $1.1 billion to $6.1 billion for 2040–50 under the "wettest scenario" for climate change).

Figure 10. Annual Adaptation Costs, 2010–50



Source. Margulis and Narain (2010).

62. **Fiscal responses need to account for the uncertainties and wider fiscal risks from climate change.** Government policies, programs, and projects need to be flexible—meaning they are warranted on cost-benefit grounds across a range of climate scenarios,[54] and that they can be adjusted as climate impacts materialize. Governments would benefit from developing frameworks to reflect the fiscal risks from climate change, account for climate change-related public expenditures, and for strategic resource allocation, efficiency of spending, institutional capacity and fiscal sustainability. Adaptation strategies should also ensure that public policy complements rather than substitutes for private sector actions in generating desired social outcomes.

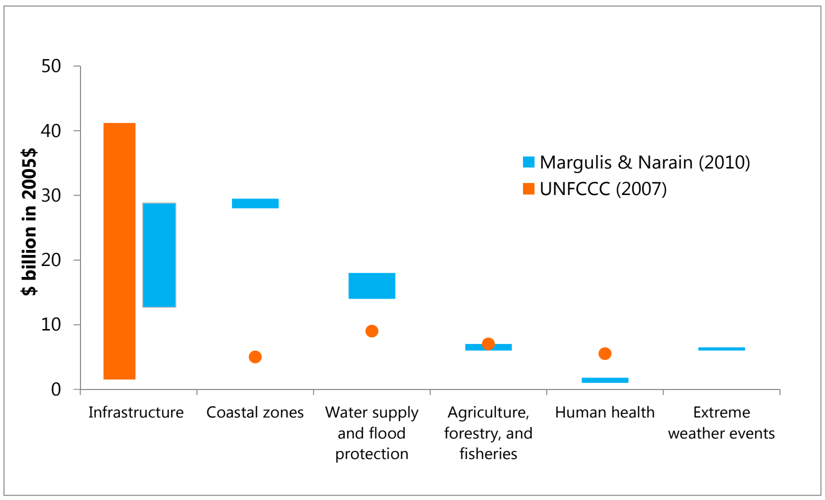
63. **Many countries are beginning to develop integrated climate strategies and incorporate climate adaptation into medium-term budget frameworks**. A number of countries (for example, Brazil, China, India, and Mexico), have developed climate change strategies setting broad directions for government policy (World Bank 2014). These strategies, however, often address climate change in isolation, without reconciling it with other objectives such as growth and poverty

[53] The highest costs for East Asia and the Pacific are in infrastructure and coastal zones; for SSA, water supply and food protection and agriculture; and for LAC, water supply and flood protection and costal zones (Margulis and Narain, 2010).

[54] For example, investments in hydroelectric plants may be worthwhile across a variety of wet and dry scenarios (Margulis and Narain, 2010).

reduction. In some cases, environmental, climate, and growth objectives are combined through "green growth" strategies to account for synergies (for example, National Strategy for Green Growth in Korea), although often they remain general and not integrated with the budget framework. Some countries that are highly vulnerable to climate change (for example, Bangladesh, Cambodia, Indonesia, Morocco, and Nepal) attempt to classify all climate-related expenditures in their budgets.[55] These initial steps provide important lessons (such as addressing difficulties in comparing programs across sectors, or accounting for off-budget climate expenditures). Further internalizing climate-related expenditures into fiscal frameworks can help in assessing fiscal sustainability, measuring adaptation gaps, and identifying the extent of additional financing needed to combat the negative impact of climate change.

Figure 11. Annual Adaptation Costs by Sector



Note: Rectangles indicate range estimates and dots point estimates.

64. Enhancing resilience to natural disasters and climate change requires a comprehensive, multi-pillar risk management framework. Key elements include: (1) identifying and assessing climate-related risks and integrating them into budget planning; (2) self insurance through fiscal and external buffers; (3) risk reduction through structural reforms and targeted investments in infrastructure; and; (4) risk transfer through disaster risk insurance, multilateral risk-sharing mechanisms (for example, the Caribbean Catastrophe Risk Insurance Facility) and precautionary instruments. Ex post disaster risk management entails resilient recovery through emergency

[55] SEEA System of Environmental Accounting provides a statistical framework for the classification and reporting of environmental activities, expenditures, and other transactions. Nepal's 2013/14 budget statement indicated that 10 percent of total government expenditures were climate related. The analysis allowed government to improve the allocation of resources. Tagging climate expenditure in Morocco helped to reveal considerable differences among sectors in accounting for climate-related spending and lack of appropriate performance indicators for climate change programs. See World Bank (2014).

response and reconstruction efforts (such as resettlement away from coastlines) that also reduce future risks.

VI. THE FINANCIAL SECTOR AND CLIMATE CHANGE

65. **Climate change entails potential risks to macro-financial stability.** This section outlines (1) the nature of these risks, (2) the role of the financial sector in reducing them, and (3) financial-sector policies facilitating those roles.[56]

A. Financial Sector Risks

66. **Climate-related risks affecting financial stability are broadly categorized as physical and transition risks.** Physical risks include those to insurance and reinsurance sectors from increased costs and frequency of climate-related natural disasters, on both the liability (increasing property and casualty claims) and asset (losses on investments in real estate or equity of firms affected by climate-change-related events) sides. These risks are relatively well recognized, though more quantification is needed. Transition risks are 'stranded assets', or potential financial losses from investments losing value (for example, coal reserves) as a result of climate mitigation, or shifting consumer and investor preferences to greener products and technologies.[57]

67. **To minimize repercussions for financial stability, changing physical risks should be reflected in the financial sector's risk modeling.** Increased physical risks could present major challenges to insurance business models, altering the balance between premiums and claims and leaving insurance companies exposed to uncovered losses. Adjusting premiums could also pose financial stability challenges through reduced ability of policyholders to get private insurance cover, which may contract mortgage lending and lower property values (Carney 2015).

68. **Few investors are aware of the carbon footprint of companies in their portfolios, while companies holding potentially stranded assets may be overvalued.** Many institutional investors' asset allocation decisions do not take into consideration the carbon content of eligible securities. The perceived long-term nature of stranded asset risks also makes investors hesitant to incorporate them in portfolio investment and risk management frameworks. A cycle of fire sales and asset price declines could affect even seemingly unrelated institutions and asset classes, exacerbating investors' concerns, and leading to sizeable market fluctuations and further asset portfolio losses. Modeling these systemic risks still has a long way to go.

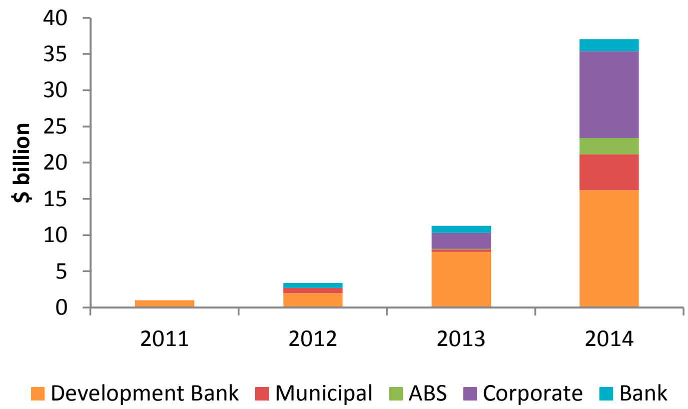
[56] For further discussion see UNEP (2014).

[57] The stranding of assets can also be a concern to countries richly endowed in fossil fuels.

B. Role of the Financial Sector

69. The green bond market, facilitating low-carbon investment, has expanded rapidly since its inception in 2007. Green bonds satisfy investors' demand for bonds that integrate environmental factors into their investment practices and help asset-management firms boost their public image with investors. Investors range from green-dedicated funds to asset managers, banks, corporations, pensions, and insurance and re-insurance companies. With the AAA investment-grade issuances from the European Investment Bank and the World Bank, total green bond issuance reached $37 billion in 2014 (Figure 12). A typical strict transparency requirement may increase financing costs, while a key challenge to a sustained development of the market is a lack of strict standards for green bonds.

Figure 12. Green Bond Market: Size and Compositions, 2011–14



Source. Olsen-Rong (2015).

70. Green stock indexes facilitate environmentally-minded investors' decisions, but their use by institutional investors has been relatively limited. The performance of some green indexes—which include green technology companies, along with investment vehicles that track these indices—has not been significantly different from that of major financial indexes (for example, S&P U.S. Carbon Efficient vs. S&P 500) in recent years. But their use may have been hindered by limited climate mitigation policies, investor expectations of delays in emissions reduction policies given sluggish global economic growth and slow political progress, and the sharp oil price decline that has shaken investors' confidence in profitability of green technology companies.

71. The private sector is decarbonizing its investment portfolios on a voluntary basis. A prominent initiative is the Portfolio Decarbonization Coalition, a group of long-term institutional investors seeking voluntary commitments to move institutional investments to low-carbon-exposure firms (commitments have exceeded $230 billion at end-2015). This shift will require information on carbon footprints, and how these might respond to future mitigation policies. Firms are increasingly requested to provide better carbon footprint disclosure,[58] though a key concern is the lack of consistent standards for measuring footprints and effective disclosure schemes.[59]

72. Investors also use other financial policies and instruments to lower carbon risk. These include restraining capital spending of high carbon footprint companies through dividend policies, or requiring them (as BP, Shell, and Statoil shareholders did in 2015) to publish stress tests of their current and future investment opportunities against climate policy scenarios.

73. Disaster-risk insurance and related weather hedging instruments transfer climate damage risks to those more willing to bear it. For example, catastrophe bonds were first issued (by insurers, reinsurers, corporations, and government agencies) in the mid-1990s, as the insurance industry looked for alternative methods to hedge catastrophe-related risks. Pension funds and other large institutional investors bought about four-fifths of issued catastrophe bonds in 2014—returns are generally higher than, and largely uncorrelated with, returns on other fixed income or equity investments. More than $40 billion of catastrophe bonds have been issued in the past decade, with new issuance in 2014 reaching $8.8 billion and an outstanding amount of about $25 billion.[60] Obstacles to wider private investor involvement in these and related instruments include their very long maturity, a risk-return profile that may not satisfy private investors' objectives and risk mandates, and difficulties in estimating potential losses given the newness of the markets.

C. Financial Sector Policies and Regulations

74. Financial sector regulators and central banks can help identify climate change risks for the financial sector. For example, the Financial Stability Board (which monitors and makes recommendations about the global financial system) is considering the implications of climate change for the financial sector and financial stability.[61] The Bank of England recently prepared a Climate Change Adaptation Report focused on the insurance sector, and the People's Bank of China has undertaken similar analysis. Financial sector regulation and supervision should support market development and protect financial stability, while ensuring affordable, sufficient and sustainable insurability. Proper implementation of the International Association of Insurance Supervisors (IAIS)

[58] This requires, for example, assessing emissions from a company's electricity use, from direct fuel combustion, and from other sources (such as the transportation of inputs and finished products, and upstream emissions associated with extraction of raw materials it uses).

[59] There are some 400 different initiatives underway, underscoring the lack of consensus on standards for effective disclosure.

[60] Over the last two decades, several countries—for example, Caribbean and Pacific islands, Ethiopia, and Mexico—have used catastrophe bonds.

[61] It recently recommended establishment of an industry-led task force to develop consistent climate-related disclosures. Adequate disclosure is a prerequisite for the private and public sectors to understand and measure the potential effects of climate change on the financial sector. The proposal envisages that (1) firms regularly disclose information on the size of their carbon footprint and strategies to manage their transition to a lower-carbon business model, (2) higher-quality corporate information be available to help financial institutions better assess firms' climate risk management and transition plans, and (3) financial institutions be encouraged to disclose their carbon footprints and the management of their exposures to climate risks, including by running suitable stress tests.

Insurance Core Principles (including Valuation, Enterprise Risk Management for Solvency Purpose, and Capital Adequacy) will encourage insurers to take appropriate actions, such as proper pricing, and ensuring sufficient reserves and capital in a forward looking manner.

75. More work on stress-testing of climate-related risks for the financial sector is needed. While insurers conduct stress-tests of physical risks, climate change scenarios are not typically considered. Also, corporate and financial sector stress testing of transition risks is not common, and enhanced risk management tools are needed for evaluating stranded asset risks. Official and private sectors are considering issues such as how to incorporate climate change stress-testing in corporate and financial sector risk management practices and potential roles for supervisors and financial authorities in market-wide tests to assess systemic level risk.

76. Altering prudential regulations may not be the best way to address climate risks. There have been proposals to adapt capital risk weights, liquidity standards, and other prudential regulations to provide incentives for low-carbon investment. However, alterations to prudential rules seem far less suited as a tool to address climate-related externalities and would hamper their effectiveness at achieving their primary goal of maintaining the resilience of financial firms. The focus of financial regulation should remain on building resilience to shocks, with a systemic approach accounting for all material risks to the financial system, including from climate events, and ensure adequate capitalization, risk management, and disclosure.

VII. ROLE OF THE IMF[62]

77. On mitigation, the IMF is continuing its analytical agenda and stands ready to offer technical assistance. Besides providing practical guidance on the design of fiscal policy for climate mitigation and finance, the IMF has developed spreadsheet tools to quantify, for more than 150 countries, the efficient level of energy taxes to address climate and other environmental costs, and the carbon, fiscal, economic, and broader environmental benefits of price reform. Ongoing work is quantifying carbon pricing consistent with country-level mitigation pledges and the trade-offs across a broad range of fiscal and regulatory mitigation instruments. Working with other international organizations, the IMF promotes dialogue on these issues among policymakers.[63] The IMF regularly provides technical assistance to member countries on energy pricing reform, and carbon taxation is a natural extension.

78. On climate finance, the IMF emphasizes the attractiveness of carbon pricing instruments. Applied to developing countries these instruments attract private flows, and applying them to fuels used in international aviation and maritime transport can raise significant public sources.

[62] See also IMF (2015b).

[63] See www.imf.org/environment for details on recent events.

79. On adaptation, the IMF will assist countries, particularly small states, facing increasing natural disaster risks. In partnership with other stakeholders, the objective is to help countries enhance disaster risk management frameworks, determine the appropriate combination of building buffers and risk transfer through insurance or financial market instruments, and tailor investment and growth policies to building resilience. IMF policy advice for vulnerable countries will integrate the implications of these policies into country macroeconomic frameworks by incorporating the likely costs of natural disasters into medium-term macroeconomic projections, ensuring that fiscal and monetary strategies build and maintain adequate buffers, and balancing the need for infrastructure spending to enhance natural disaster and climate change resilience with debt sustainability (Box 2). The IMF has recently strengthened the financial safety net for developing countries faced with pressing balance of payments needs, including those resulting from natural disasters (IMF 2015c). These efforts could help ensure existing and potential financing is prioritized within a comprehensive strategy and sustainable macroeconomic framework that appropriately takes account of natural disaster risks. In other countries vulnerable to climate change where the issues are macro-critical, the fiscal costs of adaptation, and the effective use of climate-related financial flows will need to be integrated in sustainable, medium-term fiscal frameworks.

80. On financial sector resilience, IMF staff will work with member countries and other partners to support initiatives encouraging consistent climate-related disclosures, prudential requirements, and stress testing. This will focus on aspects that are macro-financially critical including: (1) enhancing understanding of the transmission mechanisms between climate risks and macro-financial stability; (2) helping to design disclosure rules for climate risk exposure; (3) developing best practices for stress-testing climate risks; (4) supporting work on globally consistent prudential requirements for the insurance sector, including on a Global Insurance Capital Standard allowing for catastrophe risk; and (5) capacity building to promote development of markets and instruments for managing climate-related risks. The latter will include support for countries strengthening their regulatory oversight to ensure sound and resilient institutions and assisting in developing well-functioning financial markets providing instruments for managing climate risks.

Box 2: Climate Change, Natural Disasters, and Debt Sustainability

Climate change can affect debt sustainability through different channels. Extreme weather conditions could severely reduce output and increase fiscal spending in the short term, generating borrowing needs while eroding the public sector's capacity for debt repayment. The macroeconomic shock from natural disasters, including balance of payment pressures and currency depreciations, could also intensify external debt vulnerabilities. Climate change could also negatively affect countries' debt sustainability over the medium to long term, as it could reduce long term growth potential and the equilibrium exchange rate, and fiscal spending may have to increase to adapt to the impact of climate change.

Debt sustainability analysis (DSA) can be a useful tool to help countries assess both the short-term and long-term debt sustainability implications of natural disasters and climate change.[1] This can be done by 1) incorporating the growth implications and fiscal costs of climate change in the macroframework underlying the DSA, and 2) including in the DSA a customized scenario to evaluate the impact of natural disasters on debt. A few countries have already started to do so: the Kiribati 2015 DSA incorporated conservative long-term growth assumptions and a 3½ percent-per-annum fiscal cost of adapting to climate change. The Samoa 2015 DSA included a natural disaster shock scenario, calibrated using historical natural disasters, which would increase public external debt by 10 percent of GDP at its peak. The St. Kitts and Nevis 2015 (market access country) DSA also included a natural disaster shock, under which public debt in 2020 would be 13 percent of GDP higher than baseline owing to lower growth and high fiscal deficits. While these issues are particularly relevant for the long term projection horizon in the LIC Debt Sustainability Framework (LIC DSF), they are also applicable for a 5–year horizon in the DSA framework for market access countries.

The upcoming joint IMF-World Bank review of the LIC DSF will explore ways to strengthen the DSF framework—while not undermining its usability and versatility—to address debt challenges arising from natural disasters and climate change. While it is premature to commit to any particular area that will be integrated in the DSF, some of the following areas could be explored in the underlying work for the DSF review:

- The link between natural disasters and debt distress could be further examined. Empirical work could test whether countries that are more vulnerable to natural disaster shocks tend to have higher probability of debt distress. If significant links are found, the results could inform the debt sustainability framework when assessing debt vulnerabilities in this country group.
- A "severe natural disaster" scenario could be applied for countries that are vulnerable to natural disasters. The design of this shock scenario, including the magnitude and duration of the macroeconomic impact, could draw on recent empirical work (for example, Laframboise and Loko 2012, Acevedo 2014, Cabezon and others 2015).
- While this issue goes beyond the LIC DSF, the long-term impact of climate change on growth, and fiscal and external balances needs to be considered when developing medium- and long-term projections. An important element is to account for adaptation efforts, which would increase public expenditure (including investment) and debt in the short run but could support growth and resilience to future climate change and natural disasters in the long run. Estimating such impacts can be challenging but can help improve long-term macroeconomic frameworks as an input to debt sustainability analyses.
- This work could draw on the World Bank's expertise and past work in this area, including in the assessment of country-specific vulnerabilities to climate change, costs of adaptation measures, and damage and reconstruction costs from severe natural disasters.

[1] The IMF assesses public debt sustainability in all member countries using two distinct frameworks; one for LICs (that generally rely on concessional financing), and another for countries that have market access.

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