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Beyond Copenhagen: Reconciling International Fairness, Economic Development, and Climate Protection

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The goal of the Harvard Project on International Climate Agreements is to help identify key design elements of a scientifically sound, economically rational, and politically pragmatic post-2012 international policy architecture for global climate change. It draws upon leading thinkers from academia, private industry, government, and non-governmental organizations from around the world to construct a small set of promising policy frameworks and then disseminate and discuss the design elements and frameworks with decision-makers. The Project is directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University. For more information, see the Project's website: http://belfercenter.ksg.harvard.edu/climate

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ABSTRACT

Time to respond to the severe threat posed by global climate change is running short. Though the most recent international climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) achieved some consensus in the form of the Copenhagen Accord, they failed to produce an adequate and legally binding action plan for achieving long-term reductions in greenhouse-gas emissions. Looking beyond Copenhagen, this paper proposes a new architecture for international climate policy going forward. It highlights a top-down, burden-sharing rule that is designed to produce a fair distribution of burdens across countries while also (a) giving priority to economic development and concerns about wealth inequality and (b) achieving emission reductions consistent with holding the expected increase in global average temperature to 2 degrees Celsius. In addition, this paper discusses several key design elements that will be important, especially from the perspective of developing countries, to the success of future international climate negotiations. These design elements include agreements on burden sharing, choice of policy instruments, financial mechanisms and technology transfer, penalties for noncompliance, and linkages between trade and climate change.

Key Words: global climate change, Copenhagen Accord, burden-sharing rule, international climate fairness

JEL Classification: Q54, Q56, Q58, Q48

BEYOND COPENHAGEN: RECONCILING INTERNATIONAL FAIRNESS, ECONOMIC DEVELOPMENT, AND CLIMATE PROTECTION

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1. INTRODUCTION

Climate change is far from being just an environmental issue, and international negotiations to address it have already traveled a long and difficult path. The risks of climate change were first recognized at the 1992 United Nations Earth Summit in Rio de Janeiro; this led to the formation of the United Nations Framework Convention on Climate Change (UNFCCC) and eventually to a legally-binding international climate treaty, the Kyoto Protocol. The Kyoto Protocol, which required the world's more developed major country emitters (the so-called Annex I countries) to reduce their emissions to 1990 levels, entered into force in 2005—13 years after Rio—but it did so without the participation of the United States. At a subsequent meeting in Bali, Indonesia, in 2007, parties to the UNFCCC sketched out a time table for further negotiations aimed at reaching agreement on a post-Kyoto international climate treaty in two years; this meeting also produced an action plan (known as the Bali Action Plan) that outlined four building blocks for achieving long-term cooperative action. Nevertheless, negotiations at Copenhagen in December 2010—officially the Fifteenth Conference of the Parties to the UNFCCC or "COP 15"—were on the verge of collapsing altogether before a new agreement, known as the Copenhagen Accord, was reached in the closing hours of the conference.

The Copenhagen Accord does not establish legally-binding, emission-reduction commitments; rather it relies on an "open enrollment" framework under which participating countries simply record their emission-reduction targets along with the actions that they plan to implement by 2020 to achieve those targets. As such, the Accord is very flexible: Countries must register their domestic climate commitments by 2015, but these commitments can take the form of laws or development plans. The failure to achieve a stronger, legally-binding agreement at Copenhagen reflects the numerous points of deadlock that emerged in North-South negotiations during the first 13 days of negotiations at COP 15. The resulting agreement—while it still represents an important step in the evolution of international climate policy—therefore leaves many areas to be addressed in future negotiations.

Several features of the Copenhagen Accord are worth noting. First, the Accord recognizes the scientific consensus in support of limiting global average warming to

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2 degrees Celsius (°C) to avoid the most damaging impacts of climate change. More broadly, the Accord acknowledges the need for deep cuts in global emissions on both science and equity grounds. Critics point out that an approach based on self-committed targets and voluntary actions could well result in a global average temperature increase of 3°C or even more. Given the current impasse in North-South negotiations, however, and given that most countries view their level of commitment to emission reductions as contingent on other countries' actions, the "open enrollment" framework may provide a good starting point for building trust between Annex I and non–Annex I countries. If the Copenhagen Accord succeeds in this sense, international cooperation to undertake the much deeper emission cuts that will ultimately be needed to reach the 2°C target may be easier to achieve in the future.

Second, the Accord maintains the distinction between Annex I and non–Annex I countries, but it does not establish more stringent compliance requirements for the former group of countries relative to the latter. Given that the economic growth and emissions profiles of many countries are in flux, this change could be conducive to progress in future climate negotiations. The Annex I list was appropriate when the Kyoto Protocol was drafted in 1997, but a more current ranking of countries according to their level of economic development would show significant changes since that time. Therefore, a more dynamic allocation regime is needed—particularly for developing countries—to provide a basis for transitioning from weaker targets to stronger targets or from voluntary mitigation efforts that may be binding in only one direction to mitigation efforts that are binding in both directions. To be credible, such a transition path would need to recognize the sustainable development needs of poorer countries while ensuring that developed countries are subject to binding emission-reduction commitments consistent with their historical share of responsibility for the overall accumulation of carbon dioxide and other greenhouse gases in the atmosphere since the Industrial Revolution. Over time, all countries would converge toward the adoption of binding commitments at the level of stringency needed to achieve substantial global emissions reductions.

Third, the Copenhagen Accord encourages the use of market-based instruments to achieve cost-effective mitigation actions. Though the focus is on using such mechanisms to achieve domestic targets, efficiency at the global level demands rules and guidelines to foster voluntary bilateral and multilateral linkages between individual countries' climate programs. Such linkages could be achieved though trading, tax, or other mechanisms, but these mechanisms are missing in the current agreement. A particular question for the design of international policy is whether there should be a single global carbon price (from an efficiency standpoint, a single global market price would promote the most cost-effective overall mitigation response).

Finally, the Copenhagen Accord highlights the importance of providing developing nations with predictable and adequate sources of funding for mitigating emissions, reducing deforestation, and implementing adaptation measures. How to raise funds on a large scale without displacing other forms of Overseas Development Assistance

(ODA) support needs to be explored and resolved in greater detail before new funding mechanisms can be made operational. Besides the financing issue, further elaboration of important design elements with respect to the measurement, reporting, and verification (MRV) of mitigation actions will be needed in a future agreement. A last issue concerns likely incentives for compliance (or penalty regimes for noncompliance): Specifically, what incentives can be provided under a new agreement to ensure that nations adhere to their international climate commitments. This is another important design element that was not addressed in the Copenhagen Accord.

In sum, the path toward a new and stronger international climate agreement remains difficult and probably long. Whether the Copenhagen Accord is ultimately viewed as a failure or success will depend on whether it creates a new dynamic incentive—one with the potential to engage countries and reinforce their commitment to building a more effective climate policy architecture in the future. The international community as a whole needs to regain momentum by deploying better program designs and practical mechanisms to push climate negotiations forward, while implementing trust-building measures along the way.

Olmstead and Stavins (2010) describe three essential elements for a promising post-2012 international global climate policy: (1) meaningful and differentiated mechanisms to encourage participation, (2) an extended time path of targets, and (3) a flexible, market-based approach that addresses concerns about distributional equity. To break the current impasse in international negotiations, this paper proposes a new policy architecture that provides for the three elements identified by Olmstead and Stavins. Specifically, this proposal features a top-down, burden-sharing rule that is designed to reconcile the objectives of international fairness, economic development, and climate protection. This proposal also provides dynamic and differentiated incentives to encourage participation and recognizes countries' historic responsibility for past greenhouse-gas emissions (Section 2). While the burden-sharing rule is the central feature of this architecture, several additional design elements are also likely to be important in post-Copenhagen climate negotiations. These elements—including agreements on targets and burden sharing, financing mechanisms and technology transfer, a penalty regime, and linkages between trade and climate change—are discussed in Section 3. Section 4 concludes the paper.

2. BURDEN SHARING: RECONCILING THE NEED FOR INTERNATIONAL FAIRNESS, ECONOMIC DEVELOPMENT, AND CLIMATE PROTECTION

Since the 1992 UN Earth Summit, the international community has sought to negotiate a cooperative approach to protecting the global climate system. A key challenge throughout has been to develop a regime that distributes the burden of mitigation obligations in a way that is generally viewed as both fair and feasible and also consistent with the UNFCCC's principle of "common but differentiated responsibilities and respective capacities." An ideal burden-sharing formula ought to broaden participation to include all or at least the major greenhouse-gas-emitting countries, whether developed or developing. It should also support local economic development, achieve meaningful mitigation goals, and provide effective and self-enforcing compliance mechanisms.

One of the key barriers to developing country participation in international climate agreements arises from the concern that policies to reduce greenhouse-gas emissions would perpetuate inequalities in the global distribution of wealth and hinder economic development. The recent empirical literature on climate-change mitigation and damages (e.g., Babiker and Jacoby 1999; Babiker, Reilly, and Jacoby 1999; Bernstein, Bromley *et al*. 1999; Bernstein, Montgomery, and Rutherford 1999; Ellerman, Jacoby, and Decaux 1998; Cao 2010; Cline 2007) supports the conclusion that (1) climate policies generally reduce growth and welfare and are likely to induce larger economic losses in developing countries than in developed ones; (2) climate policies are generally regressive—that is, they impose a greater burden on the poor than on the rich; and (3) because they have less adaptive capacity, developing countries are likely to suffer greater damages from climate-driven catastrophes and natural disasters. Therefore, addressing the nexus between equity and development is essential to breaking the current North-South deadlock and to inducing developing countries to accept emission-reduction commitments.

Different proposals for allocating the mitigation burden across countries can be classified according to whether they strive for fairness in terms of the initial allocation of emissions ("allocation-based" equity criteria); the ultimate costs of mitigation ("outcome-based" equity criteria); or the processes (institutional arrangements) used to make the allocation ("process-based" equity criteria) (Rose *et al.*, 1998). In this paper, we adopt the first notion of "allocation-based" equity criteria and identify a core set of principles for fairly distributing the mitigation burden:

- Egalitarian, in the sense that every individual person has the right to an equal quantity of emissions
- Polluter pays, in the sense that the burden of mitigation is proportional to historical emissions
- Vertical, in the sense that the mitigation burden is distributed according to the ability to pay

- Horizontal, in the sense that countries with similar economic circumstances accept similar burdens
- Exemption, in the sense that some countries or individuals—particularly countries or individuals below a threshold level of subsistence—should be exempt from substantive obligations if compensation regimes are not in place (this principle recognizes that even the weakest climate stabilizing measures would sometimes place an unfair burden on the poorest "victims")

The Copenhagen Accord establishes a very loose regime: It encourages nations to voluntarily take mitigation actions. Achieving meaningful global mitigation targets in the future, however, will require binding commitments. The ultimate goal for international climate negotiations remains agreement on a transparent, effective, and fair burden-sharing regime that takes into account the different development needs and status of different nations. In this section, we describe a simple burden-sharing rule, first developed by Baer *et al.* (2007, 2008), that is consistent with the five principles identified above. This rule provides an example of how one may design a reasonably fair and equitable scheme for distributing the climate-mitigation burden across all nations, or at least across the most important emitter countries.

As described above, the polluter-pay principle dictates that countries with a greater responsibility for historic emissions should bear a larger share of the mitigation burden. Similarly, the vertical principle, dictates that countries with greater capacity to undertake mitigation measures should assume a greater obligation. The challenge is to calculate a single index that (1) properly accounts for each country's historic responsibility and mitigation capacity; (2) is equitable, both in terms of the distribution of burdens across countries and in terms of the distribution of burdens across different income groups within countries; and (3) exempts the poorest populations from any mitigation obligations so as not to compromise their ability to survive and develop. There is no uniquely correct way to combine all these principles; our approach here is to adopt a simple Cobb-Douglas weighted composite index for capacity and responsibility and use this index, denoted the "Responsibility and Capacity Indicator" or RCI in the Greenhouse Development Rights (GDR) framework developed by Baer *et al.* (2007), to calculate each country's share of the overall mitigation burden.[1] The formula for deriving the RCI is described in equation (1). The exogenous weighting parameters a and b represent an ethical judgment on the relative importance of capacity versus historic responsibility. Sensitivity analysis can be used to evaluate the effect of varying these parameters.

$$RCI = R^a C^b \tag{1}$$

In our burden-sharing formula, C represents capacity—that is, a country's ability to pay for greenhouse-gas mitigation without sacrificing consumption for basic societal necessities. This capacity is defined as the integral of individual income (income

[1] Though a later paper by Baer *et al.* (2008) instead uses a simple weighted sum of responsibility and capacity, we believe a Cobb-Douglas function is better for aggregating these factors.

below a minimum threshold is excluded) over a log-normal income distribution $f(y,\bar{y},G)$ for a given country. The calculation is described in equation (2):

$$C = P\int_{y_{DT}}^{\infty} dy(y - y_{DT})\, f(y,\bar{y},G) \tag{2}$$

where P is the population, y_{DT} is the development threshold or "subsistence income," $\bar{y}$ is annual per capita income, and G is the Gini coefficient (a measure of income inequality). For y_{DT}, Baer *et al.* (2007) and Baer *et al.* (2007) use 9,000 U.S. dollars (henceforward, $) and $7,500, respectively (this means that any income below this threshold[2] is excluded for purposes of determining a country's emissions-mitigation obligations. The variance of the Gini coefficient is denoted in equation (3) with N^{-1} as the inverse of the cumulative normal distribution:

$$\sigma^2(G) = 2\left[N^{-1}\left((1+G)/2\right)\right]^2 \tag{3}$$

Similarly, national responsibility (*R*) is defined as

$$R = P\int_{y_{DT}}^{\infty} dy(e(y) - e_{DT})\, f(y,\bar{y},G) \tag{4}$$

where e is emissions at a given level of income and e_{DT} represents the emissions of a person whose income is precisely equal to the development threshold. The quantity e_{DT} behaves analogously to the development threshold in that only emissions above this threshold contribute to R. Thus, a combination of capacity (per capita income above a subsistence income level) and historical responsibility (per capita emissions above a subsistence emission level) are used to allocate the mitigation burden in this simple framework. The resulting allocation rule obliges people with incomes and emissions above the threshold, no matter where they are, to bear a share of the costs of mitigation and adaptation. At the same time, it avoids placing a burden on people with incomes and emissions below the threshold.

The key idea is to highlight the right to development of individuals and not nations, so the national obligation should aggregate individual burden sharing within each nation, specifically excluding the income and emissions of individuals below a certain development threshold. The development threshold is expected to be modestly above the global poverty line, which is about $16 per day per person (PPP adjusted) defined by the World Bank, roughly $6000 per annum per person. Similar to Baer *et al.* (2007) and Baer *et al.* (2008), we choose 150 percent and 125 percent

[2] Baer *et al.* (2007) point out that $9,000 is slightly above the global average annual per capita income level (about $8,500) and thus represents a "global middle class" income level. In a later paper, however, Baer *et al.* use a lower income threshold of $7500; we include this lower threshold as well in our sensitivity analysis (Table 2).

of the $6000 per annum income (PPP), i.e., $9000 and $7500 per annum per person respectively, as defining the development threshold, above which people would be willing to contribute a share of their income for climate mitigation. Finally, one can easily calculate the relative share by comparing each country's obligation RCI with the global total. In sum, such a simple allocation rule obliges people with incomes and emissions above the threshold, no matter where they are, to bear a share of the costs of mitigation and adaptation, while also allowing people with incomes and emissions below the threshold to maintain their right to development.

Baer *et al.* (2007, 2008) only considered carbon dioxide (CO_2) emissions from fossil-fuel combustion. Other gases and emissions sources—including land-use changes and various biogeophysical and biogeochemical mechanisms—also play a role in climate change, however. For example, it is estimated that cumulative carbon emissions from the historic conversion of forests and other natural systems to other land uses between 1850 and 2000 accounted for roughly one-third of total anthropogenic carbon emissions over this entire time period (Houghton, 2003). In addition, non-CO_2 greenhouse-gas emissions[3] were responsible for about 30 percent of radiative forcing between pre-industrial times and 1990 (IPCC, 2001). In 2000, land management activities[4] were estimated to account for more than half of global anthropogenic methane emissions and more than 75 percent of global nitrous oxide emissions (USEPA, 2006a, 2006b). Therefore, activities involving land-use changes are expected to play an important role in future mitigation efforts and should be taken into account in any burden-sharing calculation.

This paper updates previous calculations by Cao (2009) using more recent data on population and gross domestic product (GDP),[5] together with Gini coefficients[6] from the World Development Indicators (WDI) published by the World Bank in 2009. The WDI dataset covers a larger group of countries than the sources used in previous work by Baer *et al.* (2007, 2008) and Cao (2009). In contrast to Cao (2009), this paper also develops a dynamic version of the burden-sharing rule to shed light on how its results would change as countries experience different rates of growth in economic output and greenhouse-gas emissions. In terms of forecasting future population, GDP, and Gini coefficients, we rely on the projections made by Baer *et al.* (2008) and their most recent database[7] to sketch out burden-sharing calculation until the year 2030. A summary of the raw data along with the results of this revised GDR calculation for selected countries and groups of countries is given in Table 1.

To calculate the responsibility index based on past emissions, we utilize a more comprehensive record of historic emissions (from 1850–2005)[8] than in previous

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[3] Non-CO_2 greenhouse-gas emissions include nitrous oxide (N_2O), methane (CH_4), and 14 fluorinated gases (F-gases).

[4] Land management activities include cropland fertilization and water management, manure management, and changes to forest rotation lengths.

[5] The GDP data are adjusted for 2005 purchasing power parity (PPP).

[6] The Gini coefficient is a widely used indicator of wealth or income inequality.

[7] http://gdrights.org/Calculator-about/

[8] UNFCCC Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto

work by Baer *et al.* (2007, 2008) and Cao (2009). Our CO_2 emission data include CO_2 emissions from fossil-fuel combustion as well as from land use, land-use changes, and forestry (so-called LULUCF emissions). The data for emissions from energy use span the period from 1850–2005; the data on LULUCF CO_2 emissions span the period from 1950–2000. This reflects the fact that the buildup of greenhouse gases in the atmosphere—which is what matters in terms of climate-change impacts—began in the Industrial Revolution. (At that time, the concentration of CO_2 in the atmosphere was about 280 parts per million [ppm], today it is about 430 ppm.) Other analyses, such as Baer *et al.* (2007, 2008), consider historic emissions only back to 1990. At that time, however, the economies of most developed countries had already shifted away from energy-intensive manufacturing toward a greater role for less energy- and pollution-intensive service industries.

Data on non-CO_2 greenhouse-gas emissions are taken from the U.S. Environmental Protection Agency (EPA) non-CO_2 Greenhouse Gas Emissions Database (EPA-report 430-R-06-003).[9] This database provides historic and projected estimates for emissions of methane (CH_4), nitrous oxide (N_2O), and the high global warming potential (GWP) gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). For purposes of aggregation, emissions of these gases are converted to carbon-equivalent units. The EPA dataset provides estimates of actual emissions of methane, nitrous oxide, and high-GWP gases for 1990, 1995, and 2000 and projected emissions for 2005, 2010, 2015, and 2020 (in metric tons carbon dioxide equivalent or MtCO2eq). However, the EPA database does not provide estimates of cumulative non-CO_2 greenhouse-gas emissions, so it is difficult to merge with our cumulative estimates of energy and LULUCF CO_2 emissions. To estimate country-level non-CO_2 emissions for each year of the study period, we apply the ratio of non-CO_2 emissions for 2005 (from the EPA database) to energy-related CO_2 emissions for 2005 (from the 2009 WDI). This ratio is assumed to stay constant over the timeframe of the analysis.[10] This methodology is used to calculate total greenhouse-gas emissions for all of the more than 90 countries listed in the EPA database. For countries not in the EPA database we apply the global average ratio of non-CO_2 to CO_2 emissions (23.3 percent).[11] Since most of these "missing" countries are very small, any uncertainty introduced by this assumption is unlikely to have a significant impact on our overall results.

The results of the analysis are presented in Table 1 and Table 2. Table 1 shows the calculated RCI index—that is, each country's share (in percentage terms) of the overall global mitigation burden—for the benchmark year 2005. The methodology used here gives equal weight to global capacity and global responsibility and sets the

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Protocol, seventh session, Bonn, 29 March to 8 April 2009, Appendix Table on Cumulative Emissions: 1850–2005 (CO_2 energy) and 1950–2000 (LULUCF CO_2)

[9] http://www.epa.gov/climatechange/economics/downloads/GlobalAnthroEmissionsReport.pdf

[10] We did not utilize the EPA forecast on non-CO_2 greenhouse gas (GHG) emissions for 2010–2020, but assume the composition of CO_2 and non-CO_2 GHGs stay constant and grow at the same pace as the projections in the GDR database until 2030.

[11] http://www.epa.gov/climatechange/economics/international.html

income threshold for exemption at $9,000. This means individuals with annual income below $9000 would not be expected to bear mitigation burdens. Table 1 shows that the United States, with the highest share of both global capacity (33.6 percent) and global responsibility (42.3 percent), also has the largest RCI (38.9 percent). Following the United States, the countries with the next largest RCI are Germany, Japan, and the United Kingdom (at 7.9 percent, 7.0 percent, and 6.4 percent, respectively). Under our burden-sharing rule, in other words, these four countries together would assume approximately 60 percent of the overall global mitigation burden. We also calculated results for developing countries. Using the updated emissions and income data assembled for this analysis yields an RCI of 1.5 percent for China, 1.2 percent for Brazil, 0.7 percent for South Africa, and 0.1 percent for India.

Table 2 gives the results of a sensitivity analysis that explores how the RCI calculation changes with different income thresholds and different weightings on capacity and responsibility given projected emissions in each of the forecast years 2010, 2020, and 2030. The two income thresholds used in the sensitivity analysis, $9000 and $7500, were used in earlier work by Baer *et al.* (2007, 2008). The results of the sensitivity analysis indicate that the RCI does not vary much over the timeframe of projected emissions and over the range of income thresholds and weighting parameters considered. The calculated RCI for the United States, for example, declines from about 33–35 percent in 2010, to 29–30 percent in 2020, and 26–28 percent in 2030. The decline occurs because developing-country emissions are expected to grow faster over the next several decades than developed-country emissions. As a result, emissions from developed countries as a *share* of global emissions are expected to decline. Thus, the RCI for the European Union (27 member states) likewise declines from 30 percent in 2010 to 25 percent in 2030. By contrast, though the developing-country share of the global mitigation burden is very small at the outset, it would be expected to grow—especially as countries like China and India experience rapid GDP growth (increasing as much as 8–10 percent per year) and as an increasing number of people in these countries surpass the poverty threshold. For instance, China's RCI increases from 1.5 percent in 2005, to 4–5 percent in 2010, to 8–9 percent in 2020, and 12 percent in 2030. Brazil's RCI increases from 1.2 percent in 2005 to about 2.4 percent in 2030, and India's RCI also grows very quickly, from just 0.1 percent in 2005, to 1.8–2.4 percent in 2030.

Overall, high-income countries would assume 86 percent of the global mitigation burden in 2005 under this burden-sharing formula; thereafter their share would decline to 76–78 percent in 2010, 67–70 percent in 2020, and 61–63 percent in 2030. By contrast, the RCI for middle-income countries increases gradually, from 14 percent in 2005, to 22–24 percent in 2010, 30–32 percent in 2020, and 37–39 percent in 2030. The burden allocated to low-income countries starts at nearly zero and increases to 0.3–0.5 percent in 2030.

This burden-sharing framework provides a natural way to allocate emission budgets (and corresponding emission-reduction requirements) within a global cap-and-trade

system. As a first step, the global mitigation burden can be calculated by comparing a baseline or reference-case projection of future emissions to a benchmark emissions pathway that is consistent with achieving a given climate stabilization target, such as the Copenhagen Accord's 2°C target. According to a recent article published in *Nature*,[12] reducing world greenhouse-gas emissions to half of their 1990 levels by 2050 would very likely stabilize global average warming below 2°C. Taking a 50 percent reduction from 1990 levels as the global mitigation target, the RCI index for individual countries could be applied to set benchmark targets for domestic mitigation actions. It is reasonable to expect that a more stringent and legally-binding climate policy framework will be established after the "open enrollment" stage under the Copenhagen Accord. Under such a framework, countries that fail to achieve their domestic targets could purchase credits generated by other countries that exceed their emission-reduction quotas. Developing countries, like China and India, are likely to have surplus of credits in the early stages when their share of the global mitigation burden is relatively low. This means that efficiencies can be achieved through a global-trading system since abatement costs in most developing countries are also relatively low compared to abatement costs in developed countries.

In the closing hours of the Copenhagen conference, leaders from China, India, Brazil, and South Africa (the "BASIC" group of countries) and the United States put together a proposal that became the Copenhagen Accord. The Accord fell short of achieving legal standing as a political agreement, however, because five of the 193 countries participating in the conference (Bolivia, Cuba, Nicaragua, Sudan, and Venezuela) opposed it. To get around UNFCCC's consensus decision-making rule and facilitate future negotiations on a new agreement, it may be helpful to begin with a smaller group of countries that includes the largest developed and developing economies and greenhouse-gas emitters, such as the Major Economies Forum (MEF) or the G20. Our burden-sharing rule can be easily revised to allocate obligations within a group, as described in equation (5). The RCI for individual countries if the mitigation burden is allocated just within the group of G20 members is given in the last column of Table 1. With the exception of the United States, limiting participation to the G20 does not significantly change the relative obligations of individual members.

$$RCI_share_j^* = \frac{RCI_share_j}{\sum_j RCI_share_j} \quad (\ j \in \{\text{country with commitments}\}\ ) \tag{5}$$

This idea that emissions should be allowed to increase in developing countries to accommodate development is similar to the concept of "growth budgets" proposed by Frankel (2010) and "clean investment budgets" proposed by Wagner *et al.* (2008). Pan *et al.* (2008) have proposed a "carbon budget" model focused on per capita cumulative emissions, which is somewhat similar to our defined responsibility index,

[12] http://www.sciencedaily.com/releases/2009/05/090502092019.htm

but does not take into account capacity.

In the future, this burden-sharing framework could be extended to incorporate adaptation efforts. The Copenhagen Accord recognizes that "enhanced action and international cooperation" on adaptation is urgently required with the aim of "reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa." If country-specific estimates of adaptation costs are available, the formula used to calculate financial commitments to a global climate fund can be adjusted as:

$$M_j' = M_j - C_j(adpatation) \tag{6}$$

where M_j and M_j' denote each country j's monetary obligation before and after adaptation adjustments and C_j denotes the local adaptation cost of country j or international transfers from country j to other vulnerable countries. Such a regime would allow developed countries to "provide adequate and sustainable financial resources, technology and capacity building to support the implementation of adaptation action in developing countries," as envisioned in the Copenhagen Accord, while reducing developed countries' own liabilities to reflect adaptation costs and transfers (as indicated by equation (6)). A similar regime can be used on technology transfer as well, though a monetary value would be required to monetize the level and technology transfer from the North to the South. Therefore, ultimately such an extended regime allows developed countries to provide adequate and sustainable financial resources, technology, and capacity building to support the implementation of mitigation and adaptation action in developing countries.

TABLE 1 GLOBAL PERCENTAGE SHARE OF POPULATION, INCOME, CAPACITY, CUMULATIVE EMISSIONS, RESPONSIBILITY, AND RCI FOR SELECTED COUNTRIES AND GROUPS (2005)

Country	Population	Income (2005 PPP Adjusted)	Global Capacity	Cumulative Emissions* 1850–2005	Global Responsibility	Global RCI**	G20 RCI***
United States	4.6	22.2	33.6	29.6	42.3	38.9	45.4
United Kingdom	0.9	3.5	4.8	6.1	8	6.4	7.5
Germany	1.3	4.6	6.4	7.1	9.2	7.9	9.3
France	0.9	3.4	4.6	2.9	3.7	4.2	5.4
Russia	2.2	3	2.1	8.1	5.4	3.5	4.2
Japan	2.0	6.9	9.4	3.9	4.9	7	7.8
South Korea	0.8	2	2.3	0.8	0.9	1.5	1.7
China	20.3	9.5	1.6	8.4	1.3	1.5	1.8
India	17.0	4.4	0.1	2.3	0	0.1	0.1
Brazil	2.9	2.8	2.2	0.8	0.6	1.2	2.2
South Africa	0.7	0.7	0.6	1.1	0.8	0.7	0.8
High Income	15.6	59.7	84.2	63.5	85.4	85.7	
Upper Middle Income	9.4	12.1	9	17.1	11.3	9.7	
Lower Middle Income	54.7	25	6.8	17.5	3.3	4.6	
Low Income	20.3	3.2	0.1	1.9	0	0	

* Cumulative emissions include UNFCCC data on (fossil-fuel based) carbon emissions for 1850–2005, carbon emissions from land use, land-use change, and forestry (LULUCF CO_2), and non-CO_2 greenhouse gases.

** Here we assign equal weights to capacity and responsibility; hence a=0.5 and b=0.5.

*** In this case, we only calculate the relative RCI shares within G20 countries.

TABLE 2 SENSITIVITY ANALYSIS ON BURDEN-SHARING CALCULATIONS

Income Threshold	**9000**	**9000**	**9000**	**7500**	**9000**	**9000**	**9000**	**7500**	**9000**	**9000**	**9000**	**7500**
Capacity Weighting	**0.6**	**0.4**	**0.5**	**0.5**	**0.6**	**0.4**	**0.5**	**0.5**	**0.6**	**0.4**	**0.5**	**0.5**
Responsibility Weighting	**0.4**	**0.6**	**0.5**	**0.5**	**0.4**	**0.6**	**0.5**	**0.5**	**0.4**	**0.6**	**0.5**	**0.5**
Year	**2010**	**2010**	**2010**	**2010**	**2020**	**2020**	**2020**	**2020**	**2030**	**2030**	**2030**	**2030**
United States	33.9	35.2	34.6	33.3	30.0	31.0	30.51	29.3	27.0	27.9	27.5	26.5
EU (27)	30.1	30.2	30.2	29.7	27.5	27.6	27.53	26.9	25.1	25.4	25.3	24.6
- United Kingdom	5.5	6.0	5.7	5.6	4.8	5.2	4.98	4.8	4.3	4.6	4.5	4.3
- Germany	6.9	7.3	7.1	7.0	6.1	6.5	6.31	6.1	5.5	5.9	5.7	5.5
Russia	4.5	5.2	4.8	5.1	5.2	6.0	5.59	5.7	5.3	6.1	5.7	5.7
Japan	6.4	5.5	5.9	5.8	5.4	4.6	5.00	4.9	4.5	3.9	4.2	4.1
Brazil	2.2	2.0	2.1	2.1	2.3	2.2	2.24	2.3	2.4	2.4	2.4	2.4
China	4.1	3.9	4.0	4.8	8.5	8.2	8.36	9.3	12.1	11.5	11.8	12.6
India	0.2	0.2	0.2	0.3	0.8	0.7	0.75	1.0	2.0	1.8	1.9	2.4
South Africa	0.8	0.8	0.8	0.8	0.9	1.0	0.92	0.9	1.0	1.1	1.0	1.0
LDCs	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.1	0.1	0.1	0.1	0.1
All High Income	77.9	77.7	77.8	75.7	69.6	69.3	69.49	67.3	62.9	62.8	62.8	60.8
All Middle Income	22.0	22.2	22.1	24.2	30.2	30.5	30.32	32.4	36.8	36.9	36.8	38.7
All Low Income	0.1	0.1	0.1	0.1	0.2	0.2	0.19	0.3	0.3	0.4	0.3	0.5
World	100.0	100.0	100.0	100.0	100.0	100.0	100.00	100.0	100.0	100.0	100.0	100.0

3. A FEASIBLE AND EFFECTIVE INTERNATIONAL CLIMATE POLICY ARCHITECTURE: MAIN FEATURES

A politically feasible and effective architecture for international climate policy needs to (a) encourage the participation of developing countries and (b) provide an extended time path of targets with equitable burden-sharing rules and flexible market-based policies to achieve both cost-effectiveness and distributional equity. This will enable countries, particularly less developed countries, to pursue a new "low-carbon and high growth" development pathway. This section highlights some key design features of a policy that achieves these objectives, specifically: agreements on target setting and burden sharing, the choice of policy instruments, financial mechanisms and technology transfer, penalties and sanctions for noncompliance, and trade-climate issues.

Agreement on Climate Targets and Burden Sharing

The most challenging aspect of establishing an international climate regime involves reaching agreement on future climate targets and on a burden-sharing rule to allocate emissions reductions. The Copenhagen Accord is weak, though it did define a clear overarching target: limit warming to 2°C. The Accord also reaffirmed the principle of "common but differentiated responsibilities," which is of great importance to developing countries. However, the Accord does not set out a pathway for achieving the significant emissions reductions that will be needed to reach the stated climate-stabilization goal, and there remains no agreed burden-sharing mechanism to allocate mitigation obligations. In addition, the Accord's reliance on voluntary pledges along with its failure to establish a stringent sanction regime for noncompliance could easily result in a global average temperature increase of at least 3°C.

Moreover, because the Copenhagen Accord is built on a loose framework of pledge and review, it elides the link between historical responsibilities and future actions. This shortcoming will complicate future efforts to negotiate on the principles of historical responsibility and equity in burden sharing. To establish a policy that (a) achieves substantial greenhouse-gas reductions without significant emissions "leakage" and (b) is viewed as fair in light of countries' different historic contributions to the climate problem and different capacities for undertaking mitigation it will be crucial, for both Annex I developed and non–Annex I developing countries, to reach agreement on an approach that combines an overall cap on emissions with an equitable, long-term, burden-sharing regime and effective sanctions for noncompliance.

So far developing countries have been unable to agree on any binding mitigation commitment at all. This poses a dilemma: How to induce developing countries to participate and take meaningful action? In the Copenhagen Accord's "open-enrollment" stage, developing countries such as China and India commit to achieving a carbon intensity target based on a specified benchmark year. One option is to simply "waive the fare" for these major developing-country emitters to board the "global climate policy train" during this stage, with the understanding that binding

commitments will follow in a later stage. Also, in order to continue providing incentives for countries to conduct deeper cuts, countries should be able to trade reduction surplus as credits with other countries through linkage with cap-and-trade programs or other policy regimes or to roll over the credits to the next stage, if banking is allowed. In order to attract the participation of more developing countries, developing countries *in the early stage of development* should be allowed to prioritize their right to development: If targets are not reached as committed in the Copenhagen Accord, they suffer no penalty, but if these targets are exceeded, surplus reduction credits are generated and are tradable to other countries. By contrast, pledges made by the Annex I countries should be binding: Commitment failure will be subject to penalty regime. For the time being, such a "common but differentiated" pathway toward a low-carbon economy looks more politically feasible. After greater trust has been established between Annex I and non–Annex I countries, all countries would agree to binding emission targets for the post-Copenhagen stage.

Ideally, a top-down, independent international institution is required to mitigate free riding and carbon leakage by determining overall targets, projecting emissions reduction pathways, and establishing multitrack timetables along with the climate-change negotiating process, while updating knowledge on scientific findings of climate change and potential breakthrough on abatement technology innovations. Often it is easy to build upon an existing institution, such as the UNFCCC. However, with the failure of the Copenhagen COP 15 to provide a legally-binding agreement on emission cuts, many doubt whether the UNFCCC should continue to be the primary institutional venue for the future global climate-change negotiations. Not only was the expected binding commitment not achieved, even the nonbinding Copenhagen Accord with only a statement of principle was rejected. The current UNFCCC involves 194 countries and requires unanimity of all—such a regime makes the chances slim for any meaningful agreement to take place (Stavins, 2010).

Finally, the UNFCCC's penalty regime is also too weak to prevent countries from failing to take any action at all. The Copenhagen Accord stated that developing-country actions depend on developed-country actions, and some developed countries like the European Union member states' actions depend on U.S. actions, etc. The current UNFCCC process is very difficult to uniformly assess such a complicated contingency relationship. As Stavins (2010) confirmed the institutional importance of the UNFCCC, alternative venues such as the Major Economies Forum on Energy and Climate, G20, or other bilateral and multilateral approaches are likely to shape into regional coalitions, though at the current stage they are more helpful working as complimentary regimes to the UNFCCC, instead of substituting for the political status of the UNFCCC. Therefore, it is likely that at the current stage, the UNFCCC will focus more on shaping agreements on negotiation principles in a top-down manner, while the actual actions and policies are discussed more thoroughly and coordinated in a bottom-up manner.

Policy Instruments and Linkages

The Copenhagen Accord encourages nations to pursue various market-based approaches to achieve cost-effective mitigation results. To that end, policy instruments are needed to induce high-emitting economies to shift to a low-carbon pathway and low-emitting countries, particularly those that are still developing, to pursue economic growth on a low-emissions pathway. In the short term, countries are likely to implement a variety of policy instruments to fulfill their voluntary mitigation pledges, with differences in culture, political environment, and preferences driving each country's choice of particular instruments. Such instruments could include cap-and-trade systems, carbon taxes, credit mechanisms such as the Clean Development Mechanism (CDM), sectoral policies, or carbon offset projects.

Countries with existing cap-and-trade markets for other types of pollutants, such as the sulfur trading regime in the United States, are likely to bring greenhouse-gas emissions under a cap-and-trade or cap-and-dividend type program. European countries, meanwhile, are likely to extend the existing EU Emissions Trading Scheme (ETS) and perhaps link it with other trading nations. As mentioned in Olmstead and Stavins (2010), besides the European Union and the United States, a number of major industrialized countries (including Australia, Canada, Japan, and New Zealand) would likely be interested in linking subnational, national, and regional programs to form a larger cap-and-trade network for CO_2 emissions. Thus, linkages between hybrid cap-and-trade systems will probably emerge as a significant element of any future international climate policy architecture.

In developing countries such as China and India, monitoring difficulties, a different political economy, or a combination of high transaction costs and less flexible market structures in major emitting industries such as the electricity sector may favor the use of alternative policies, such as carbon taxes. With no current regime in place that would allow them to participate in global-trading markets, China, India, and other developing countries may also start with carbon offset projects, extend current CDM activities, or adopt sectoral policies. Similarly, countries that face risks from sea-level rise could work together to design policies that address common adaptation issues. Thus, a portfolio of national and international cap-and-trade programs, carbon taxes, CDM projects, sectoral approaches, and adaptation policies would likely do a better job of accommodating each country's self-interests and fitting their actions to their particular stage of development. Of course, an international pact that allows for a portfolio of different policy approaches is unlikely to maximize economic efficiency (since it would be unlikely to produce a single, harmonized world carbon price), but it could offer advantages in terms of making participation more feasible for a variety of countries during the Copenhagen Accord's transitional stage. For developing countries, this stage provides a crucial window of opportunity to catch up economically, but without copying the dirty-production growth pattern that most wealthy countries followed as they industrialized.

Theoretically, variations in policies, though more political feasible and catering to local taste and preferences, sometimes can lead to substantial inefficiencies, if uncoordinated (Metcalf and Weisbach, 2010). Theory shows that both efficiency and cost-effectiveness of carbon policies requires a uniqueness of the carbon price in a heterogeneous world. Ideally, the construction of the climate policy architecture should be based on this principle to ensure global cost-effectiveness. Though it is still possible for an equilibrium point to exist in the "open-enrollment" stage where the whole portfolio policy instruments are harmonized to produce a common carbon price across all countries, in practice it would be very difficult to implement. Uncoordinated actions will also induce carbon leakage, that is, industries are likely to relocate to less carbon-stringent locations, and emissions in non-regulating regions would then increase and impair the effects of climate policies. Also, in terms of the cap-and-trade market, the transaction costs will be higher in a smaller-sized market, and market power is more likely to induce further distortions or corruption. Therefore, a coalition of these policy instruments is very important to mitigate such inefficiencies.

A considerable body of literature suggests linking cap-and-trade systems with other policy approaches, such as carbon-tax systems or emission-reduction credit systems (Hahn and Stavins, 1999; Olmstead and Stavins, 2010; Metcalf and Weisbach, 2010). Domestic cap-and-trade programs can be linked directly unilaterally or bilaterally, allowing one-way linkage or two-way linkages, or indirectly linked with CDM or offset programs in developing countries, though the latter would raise the issue of "additionality" for difficulty in establishing the baseline for comparison. Linking cap-and-trade systems with carbon-tax systems would in theory require that the tax be treated as a special form of cap and trade with a fixed price instead of varying permit prices, but in practice, trading with the tax may rely on governmental transfer and determining the mechanism of augmenting the trading from the firm level to the national level would be difficult. In addition, the government may be hesitate to trade tax credits with quotas for revenue reasons, unless the permit prices allowed for trading are based on auction. In terms of linkage with command-and-control approaches, quantity-based or intensity-based regulation can be linked with cap-and-trade systems, while technology mandates are more difficult to quantify as tradable amounts. Overall, these policy instruments require a thorough calculation of the emission reductions that they produce with corrections for "additionality" adjustments.

In sum, the goal of constructing linkages between developed countries and developing countries is to achieve a uniqueness of carbon price in such a heterogeneous world while allowing flexible policy regimes, so the outcome is win-win to both. For developing countries, it is also beneficial to reap greater trading benefits from the extending the CDM and emission-reduction credit systems to larger scale national mitigation policies. However, building linkages across all the market is simply an investment on building the infrastructure, such as norms and market and institutional rules for more effective policy architecture in the future. In

the end, trading without an overall global cap will weaken the policy impacts, at least in the long-term view. Achieving a consensus on the carbon-reduction target as a global cap and agreement on a fair burden-sharing rule should be continuously attempted in future rounds of climate negotiation, and such discussions should be viewed as a dynamic process for building the architecture of policy linkages in order to achieve global cost-effectiveness of emission reductions.

Financial Mechanisms and Technology Transfer

The Copenhagen Accord calls for "scaled up, new and additional, predictable and adequate funding to developing countries, approaching USD 30 billion for the period 2010–2012 with balanced allocation between adaptation and mitigation" and for developed countries to "commit to a goal of mobilizing jointly USD 100 billion dollars a year by 2020." The Accord does not spell out what mechanisms could be used to facilitate such a large and historically unprecedented transfer of resources. Though a number of public- and private-sector mechanisms for funding climate mitigation have recently been established—including funds to promote low-carbon investments and R&D, funds for adaptation that are linked with development assistance and related initiatives such as the CDM program, the Global Environmental Facility (GEF), and "Green Bonds" issued by the World Bank in partnership with the Swedish Bank SEB—current levels of funding continue to fall far short of the amount needed to avert potentially catastrophic climate risks. Current programs are also falling short in terms of ensuring that funds are distributed in a manner that is effective and fair and promotes local development. Addressing this enormous financial gap will require expanding and reforming existing institutions, as well as creating entirely new ones. Private and public resources will need to be mobilized to reconcile the need for mitigation and adaptation investments with the need to promote eco-efficient energy infrastructure while ensuring that the poor can meet their basic energy needs.

Under the burden-sharing framework described in this paper, richer nations will need to purchase credits from developing countries because their share of the global mitigation burden will lead to reduction obligations that will exceed what they can plausibly achieve through domestic measures alone. Conversely, many developing countries should be able to generate surplus credits to sell in global carbon markets. Credit trading therefore provides a natural mechanism for transferring financial resources from developed countries to developing countries, though in the initial stage such transfers may need to rely on an expanded CDM and offsets market. In later stages, however, financial transfers can be implemented on a larger scale as more developing countries enter the global carbon market (either through a cap-and-trade system or through government transfers if countries are implementing a carbon tax). At that point, CDM and offsets markets should gradually be phased out for cost-effectiveness reasons. Ideally, these financial transfers can be achieved primarily through the private sector. In practice, however, financing for climate mitigation in most developing countries where carbon markets are not mature or do not yet exist will depend on external resources or on public-sector support. Public

funding, particularly in the early stages, can act as a catalyst to facilitate the transition to a low-emissions, high-growth pathway. In addition, given large uncertainties about the ultimate costs of climate mitigation and given the very long timescales involved, the private sector has less incentive to invest in low-carbon activities and technologies. Thus, market-based mechanisms, complemented by public sector and multilateral funding, are important to quickly establish the right conditions for private investment.

Another important element for the design of a post-Kyoto climate policy centers on the handling of international technology transfer and intellectual property rights. On the one hand, protecting intellectual property through patents can stimulate innovative activities. Moreover, the willingness to publicly disclose these activities because they are protected by intellectual property rights allows future innovators to build on that knowledge and, in that sense, also helps to facilitate technology transfer. On the other hand, patents assign a temporary monopoly right that tends to impede the near-term diffusion of new technologies (Newell, 2010). Developing countries often voice the concern that intellectual property protections create barriers to international technology transfer (noting, for example, that patents for some technologies explicitly forbid transfer to other countries), though a counterargument can also be made that no clear evidence exists for intellectual property rights impeding actual technology transfer in this arena. Indeed, many existing climate-friendly technologies are no longer protected by patents. In sum, international agreements on a reasonable approach to sharing the costs and benefits of low-carbon R&D investments and on harmonizing technical standards are needed to reduce impediments to technology transfer and accelerate the development, diffusion, and adoption of low-carbon technologies.

Penalties and Sanctions for Noncompliance

A credible climate policy architecture should encourage countries to adhere to their commitments. The Kyoto Protocol included an enforcement mechanism but failed to impose penalties and sanctions for noncompliance. For example, Canada ratified the Kyoto Protocol but is unlikely to comply. Under Kyoto, countries that fail to reach their own emission targets are required to make up the shortfall plus a penalty of 30 percent in subsequent compliance periods. However, this approach fails to account for the possibility that a country that does not achieve its target in the first period may fall short again in the second period. In fact, no country has a strong incentive to comply under such a weak sanction rule.

The recent Copenhagen Accord provides no penalty regime at all for Annex I countries that fail to achieve their targets or for developing countries that do not follow through on their voluntary pledges. Though its emphasis on measurable, reportable, and verifiable (MRV) mitigation actions is appropriate, it is also important to impose more stringent sanctions for noncompliance. In the context of market-based instruments, penalty regimes can be implemented by raising carbon taxes or discounting permits from noncomplying countries in the global

cap-and-trade market. Either approach would create strong internal pressures for countries to comply with their pledges and for governments to follow through with necessary monitoring and enforcement efforts.

However, another dilemma is that if stringent sanctions indeed exist, then there also may be concerns that countries would be more reluctant to raise stringent targets or even choose not to participate. At the current stage, considering voluntary pledges and graduation regimes from nonbinding targets to binding targets for developing countries, the positive incentives from the global carbon market will exceed the sanction threats, therefore it should not deter participation. Though what actually happens in the Copenhagen Accord is that many major countries have plans contingent on deeper cuts made by other countries. For instance, the European Union proposes to offer an unconditional 20 percent reduction and a 30 percent reduction contingent on "comparable emissions reductions" by other developed countries and "adequate contributions" by developing countries; and Australia committed to a conditional target of up to 15 percent by 2020 compared to their 2000 level if there is a global agreement which falls short of securing atmospheric stabilization at 450ppm CO2-eq and under which major developing countries commit to substantially restraining emissions and advanced economies make commitments comparable to those of Australia. So one or more cases of noncompliance would cause most ambitious plans in the Copenhagen Accord to fall apart with likely negative peer effects; therefore, an internal coalition regime with further monitoring external to the UN process is very important for ensuring compliance.

Without a top-down central agency to enforce penalties on noncompliance and with the UN acting mainly as a forum for drafting agreements on principles, ex-ante rule making is especially crucial. Keohane and Raustiala (2010) propose a compliance regime based on a model of buyer liability coupled to annual ex-post assessments and discounting of invalid permits through a global cap-and-trade market. Both buyers and sellers have incentives for monitoring the system and maintaining their reputations for trading. With the linkage regimes created by merging the multiple, market-based instruments previously discussed, compliance regimes can be implemented through raising local carbon taxes or discounting of valid permits in the global cap-and-trade markets, if noncompliance is observed. Raising the carbon price in the noncompliant nations would create strong internal pressures for countries to comply with their pledges, and governments would also have more incentives for necessary monitoring and enforcement, so that a coalition may come into being even without external enforcer.

Finally, some countries have proposed using trade sanctions to penalize noncompliance. As Frankel (2008) has pointed out, however, this approach could introduce additional trade distortions, conflict with the efficiency of the overall policy, and set free trade and climate regimes on a collision course. In addition, Frankel (2010b) provides several guidelines to impose border penalties to prevent leakage and undue loss of competitiveness and are likely to be consistent with WTO

rules; however, he also emphasizes that there is a very great danger using such trade sanctions in practice.

The Linkages between Trade and Climate Change

A number of studies have examined the linkages between trade and climate change. Specifically, trade economists have looked at three channels by which increased trade may affect the environment: (1) the scale effect (i.e., greenhouse-gas emissions may increase as a result of increased economic activity from trade); (2) the composition effect (i.e., greater openness to trade may affect relative prices, thus changing the relative size of various sectors); and (3) the technique effect (i.e. increased trade may facilitate technological improvements or diffusion) (Grossman and Krueger, 1993). Conversely, climate change itself could alter patterns of international trade by affecting the comparative advantage of countries faced with different climate targets or commitments.

Scholars in developed and developing countries tend to focus on different sets of concerns with regard to trade and climate change. The primary worry in developed countries is that carbon "leakage"—the migration of emissions-intensive activities from countries with stringent control regimes to countries with weak or nonexistent regimes—could reduce the effectiveness of greenhouse-gas mitigation actions undertaken in the developed world. By contrast, researchers in developing countries have argued that the carbon embedded in goods that are produced for export accounts for a large share of developing countries' greenhouse-gas inventories. Accordingly, they have recommended that the world's emissions accounting system should shift from production-based emissions to focus on consumption-based emissions (Fan *et al.*, 2009).

Meanwhile, policies aimed at preventing carbon leakage are also being debated. Border tax adjustments may partially solve leakage problems; they could also put pressure on countries with a low or non-existent carbon price to implement more stringent policies. On the other hand, this approach could also encourage protectionism. Moreover, carbon tariffs or border-tax adjustments could be extremely difficult to implement, since measuring the embedded carbon content of a particular product and selecting an appropriate benchmark against which to compare this content is far from straightforward in practice.

From the perspective of developing countries, though carbon leakage is mostly emphasized for impairing the effectiveness of global emission-reduction efforts, another important concern is the additional damage from locally burned fossil-fuel air pollution which causes substantial environmental public health damage in developing countries, where levels of environmental pollution are already alarming. In fact, with more energy-intensive industries relocating production from countries with commitments to countries without or with weaker commitments, another possibility is that a plant relocated to a poor, unregulated country may use dirtier technologies and emit more than it would had it been located in a regulated country with stricter environmental regulation—global emissions would thus increase instead of declining

(Frankel, 2010b). Accordingly, the local environmental damage to the developing world would be quite large as well. The issue of co-pollution is sometimes overlooked in the debate of border tax and carbon leakage issues.

In sum, trade intersects with climate change in a number of ways; as a result, international climate negotiations must be mindful of WTO rules and strive to address leakage and other concerns in ways that still allow trade to serve as a conduit for the diffusion of low-carbon technologies.

4. CONCLUSION

Climate change is far more than just an environmental problem, it is also a development and political issue. To address the looming climate crisis on the one hand, while avoiding a crisis of poverty and inequality on the other hand will require an equitable, flexible, and effective post-2012 international climate policy framework. Looking beyond Copenhagen, this paper reviews the shortcomings of current agreements, including the Copenhagen Accord, and develops a new, top-down, burden-sharing rule that is designed to reconcile considerations of responsibility and capacity in allocating future mitigation burdens. The analysis uses a new dataset that incorporates estimates of carbon emissions from energy use and land-use changes and forestry, as well as non-CO_2 greenhouse-gas emissions. The last section discusses some key design elements for a post-Copenhagen climate policy architecture, including the need for agreements on climate targets and burden sharing, choice of policy instruments, financial mechanisms and technology transfer, penalty regimes for noncompliance, and linkages between trade and climate change.

In sum, though the Copenhagen Accord provides a basis for further negotiations and, by initiating a "voluntary enrollment stage," may help to increase participation and overcome the current North-South political impasse, the weakness of the Accord itself may impede future progress. If there is to be hope for renewed negotiations leading to effective, legally-binding agreements, it will be very important to look beyond the Accord itself and remedy its shortcomings. Most critically, incentives must be aligned to ensure that developed countries adhere to their commitments and to help developing countries graduate from voluntary mitigation actions to more stringent binding commitments.

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