Fair Shares: Crediting Poor Countries for Carbon Mitigation

David Wheeler

Abstract

This paper computes national carbon mitigation costs using two simple principles: (1) Incremental costs for low-carbon energy investments are calculated using the cost of coal-fired power as the benchmark. (2) All low-carbon energy sources are counted, because reducing carbon emissions cannot be separated from other concerns: reducing local air pollution from fossil-fuel combustion; diversifying energy sources to reduce political and economic risks; and building competitive advantage in emerging clean-energy markets. The paper estimates energy growth and incremental costs for biomass, solar, wind, geothermal, hydro, and nuclear in 174 countries from 1990 to 2008. Then it compares national mitigation burdens using per-capita mitigation expenditures as shares of per-capita incomes. The results undermine the conventional view of North-South conflict that has dominated global climate negotiations, because they show that developing countries, whether by intention or not, have been critical participants in carbon mitigation all along. Furthermore, they suggest that developing countries have borne their fair share of global mitigation expenditures. But they also show that expenditures for both developed and developing countries have been so modest that low-carbon energy growth could accelerate greatly without undue strain.

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1. **Introduction**

In the conventional narrative, carbon emissions mitigation has been in the hands of developed countries. The Kyoto Protocol formalizes this view by dividing the global community into Annex I (rich) countries that have responsibilities for emissions mitigation and Non-Annex I (poor) countries that do not. The basic dispute in Copenhagen was over whether, and when, to abandon this division and enlist poor countries in mitigation.[1] Policy analysts may have aggravated the dispute by treating negotiations as a forum for setting contentious allocation rules. For example, Frankel (2009) and Jacoby, et al. (2008) consider schemes for allocating future emissions rights that incorporate expected emissions trajectories, development levels and costs. Bhagwati (2006) argues that rich countries should pay reparations for atmospheric carbon-loading, by establishing a global fund to finance mitigation in poor countries. Stern (2008) and UNDP (2008) propose an 80%/20% formula for emissions reductions by rich and poor countries by 2050 relative to 1990. None of these schemes has gotten much traction, although a modest reflection of Bhagwati's proposal can be found in the multilateral Climate Investment Funds administered by the World Bank (CIF, 2010). To break the impasse, Birdsall and Subramanian (2009) have proposed changing the focus from conflicts over emissions rights and burden-sharing to promoting clean energy access for the poor, an objective that commands near-universal assent.

While focusing on clean energy access may well improve the negotiating climate, two sticking points remain. The first is the continued perception that clean energy development is an expensive game that only the rich countries have been playing. The second, corollary, view is that poor countries should only join the game if the rich countries provide compensation, or when technological advances in the rich countries make clean energy competitive in cost terms (Birdsall and Subramanian, 2009).

In this paper, I test the accuracy of these views with an empirical analysis of global low-carbon energy development since 1990. I focus on the power sector, the largest source of global greenhouse gas emissions. The remainder of the paper is organized as follows. Section 2 uses aggregate data to test the idea that developing countries have ceded costly carbon mitigation to developed countries during the past two decades. In Section 3, I

[1] For a discussion of the underlying equity issues, see Roberts and Parks (2006).

deepen the analysis by estimating annual mitigation expenditures for developed and developing countries. Section 4 translates aggregate expenditures to comparative mitigation burdens, using normalization of per-capita expenditures by per-capita incomes. Section 5 argues that my results are relevant regardless of whether developing (and developed) countries intended for their clean-energy investments to reduce carbon emissions, and despite possible differences in country-level costs of alternative energy sources. Section 6 summarizes and concludes the paper.

2. **Have Developing Countries Been on the Sidelines?**

The power sector accounts for about 29% of global greenhouse gas emissions (WRI, 2010). In this sector, mitigation requires switching from fossil fuels to low-carbon energy sources, principally biomass, solar, wind, geothermal, hydro and nuclear. Table 1a shows that developing countries have played a major role in low-carbon power growth since 1990, accounting for the following shares by sector: hydro (76%), geothermal (60%), nuclear (21%), biomass (26%), wind (15%) and solar (3%).[2] Overall, developing countries accounted for 47% of the global increase in low-carbon energy generation during the period 1990-2008. China alone accounted for 18% of the global increase, while the US accounted for 13%.

Separation by period in Table 1b reveals a consistently-important role for developing countries since 1990: They accounted for 31% of low-carbon power growth in 1990-1996, 47% in 1996-2002, and 68% in 2002-2008. To assess the implications of these results for global CO2 emissions, I estimate counterfactual emissions without low-carbon energy growth by attributing the same growth to coal-fired power. I use a standard formula for converting the coal-fired power increment to additional CO2 emissions.[3] I add the additional emissions (A) to the actual change in emissions from coal combustion (B)[4] to obtain the total counterfactual emissions change (A+B). Then I compute A/(A+B), the percent of CO2 emissions in the counterfactual that were averted by low-carbon energy growth.

Table 2 displays the results, along with the associated CO2 emissions reductions. For the period 1990-2008, I estimate that low-carbon energy growth reduced CO2 emissions by

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[2] I explain the methodology for calculating these shares in Section 3. I have drawn on EIA (2010) for the low-carbon energy generation data used for this study. The EIA data include only one composite category for solar photovoltaic (PV), concentrating solar power (CSP), and ocean (tidal, wave) power. However, the most recent report on global renewable power (REN21, 2009) reports the following installed capacities at the end of 2008: grid-connected solar PV 13 GW, CSP 0.5 GW, ocean 0.3 GW. Since solar PV and CSP account for 98% of capacity in the EIA's solar/ocean category, I have assigned all generation numbers to solar.

[3] 0.907 metric tons CO2 per MWh of coal-fired power..

[4] Source: EIA (2010).

45% for developing countries other than China and India, and by 11% and 10% for the latter, respectively. The associated volumes are very large. By 2008, annual CO2 emissions from developing countries were 1.6 gigatons less than they would have been without low-carbon energy investments since 1990. China alone accounted for 442 million tons. The corresponding reductions for the US and other developed countries were 329 million tons and 1.3 gigatons respectively.

In summary, developing countries have played a critical role in carbon emissions reduction since 1990. They have accounted for 47% of global low-carbon energy growth, and global emissions would be dramatically higher if they had not invested in low-carbon energy sources.

3. **Incremental Cost Accounting for Low-Carbon Development**

Reckoning the incremental cost of a low-carbon power investment also requires a counterfactual: a cheaper, carbon-intensive investment that would have been undertaken otherwise. For this calculation, I continue to use conventional coal-fired power as the benchmark. Table 3 provides the most recent evidence from the World Bank (2009) and MIT (2003, 2007) on comparative costs for coal-fired and low-carbon power. The levelized unit cost of coal-fired power has been estimated by MIT and the World Bank as about 4.3¢/kWh.[5] Coal's economic appeal is highlighted by the comparative levelized cost estimates for biomass (5.95¢/kWh), geothermal (6.72¢), hydro (5.38¢), nuclear (6.70¢), solar photovoltaic (PV) (51.43¢)[6] and wind (6.71¢). These estimates reflect information that was current in 2005.

Among the six low-carbon energy sources, three – biomass, solar and wind – have not yet reached technical maturity. Calculating annual unit costs for the period 1990-2008 therefore requires the use of learning curve estimates. For each sector, I use the recommended estimate from the best recent study (Neij, 2008): biomass 5%, solar PV 20%, wind 17%.[7] To estimate annual unit costs for each sector, I calculate annual global power generation for 1990-2008, use 2005 as the numeraire year for scaling the series, and apply

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[5] This is for a large facility using industry-standard subcritical technology. Levelized cost is the present value of expected costs over the lifetime of a power plant, divided by the discounted stream of power production over the same period. Costs include initial construction (capital costs), the annual costs of operating and maintaining the facility, and, in the case of fossil fuel projects, the annual cost of fuel. Power production is determined by the size of the plant and the assumed capacity utilization rate.

[6] Solar thermal power is much lower-cost than solar PV, but its contribution to global solar power generation has been minimal to date. See footnote 2.

[7] To illustrate, a 20% learning curve for solar PV indicates that incremental unit cost declines 20% with each doubling of output.

the Neij learning curves to the 2005 unit cost estimates in Table 2. Table 4 reports the results, using power generation index numbers for clarity. The most striking entries are the growth numbers for power generation in solar and wind. In 1990 global solar generation was 35% of its 2005 level, and solar output more than tripled from 2005 to 2008. Wind generation in 1990 was only 4% of its level in 2005, and power from this sector more than doubled from 2005 to 2008. From these totals and the Neij learning curve estimates, I calculate the unit cost index numbers in Table 4. In 1990, unit costs for biomass, solar and wind were respectively 7%, 40% and 146% higher than in 2005 (the numeraire year). By 2008, rapid expansion reduced the estimated unit costs of solar and wind to 70% and 82% of their 2005 levels, respectively.

My cost accounting exercise focuses on the incremental cost of low-carbon power, as compared with coal-fired power. First, I combine the index numbers summarized in Table 4 with the levelized costs in Table 3 to calculate annual levelized costs (in constant $US 2005) for 1990-2008. I compute net levelized costs by subtracting the cost of coal-fired power. Then I use sectoral power data from EIA (2010) to estimate annual generation growth from new capacity.[8] For each year, in each country and sector, I multiply the increase in generated power (in kWh) by net levelized cost (per kWh) for that year. Increases in generated power proxy increases in capacity, so I assign zero values (reflecting no change in capacity) to years when business-cycle effects reduce the utilization rate for existing capacity.[9] Finally, I add across the six low-carbon power sectors to obtain total incremental expenditure estimates by country and year.

Table 5 reports the results for developed and developing countries. During the entire period 1990-2008, incremental expenditure on low-carbon power was $51.2 billion: $17.8 billion in developing countries and $33.4 billion in developed countries. The period 2002-2008 has witnessed convergence, with an expenditure of $8.1 billion incurred by each group. The recent surge has been particularly strong in China, where incremental expenditure on low-carbon power jumped from $1.5 billion in 1996-2002 to $3.8 billion in

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[8] For this exercise, I use generation data to proxy the status of sectoral power capacity. For each country, I assume that a year-to-year decline in power from a particular sector reflects business-cycle effects that reduce the utilization rate of installed capacity. I therefore hold installed capacity constant during years of generation decline.

[9] In principle, I could do these calculations with capacity data rather than generation data. However, this would require using information on capacity utilization rates by country, sector and year that are not available to me. I therefore prefer to use generation data, relying on the EIA for the relevant adjustments. My approach introduces some error by assuming that all generation declines reflect capacity utilization reductions rather than power facility closures. But my errors in estimating capacity utilization rates would undoubtedly be much higher. In addition, rising interest in low-pollution power has translated to few plant closures since 1990 in low-carbon energy sectors.

2002-2008. This contrasts strikingly with the US, which has effectively traded places with China by dropping from $3.1 billion in 1996-2002 to $1.5 billion in 2002-2008.

These results clearly undermine the conventional belief that developing countries have been marginal players in global carbon mitigation because they can't afford low-carbon energy. Although they remain poor, their incremental expenditures for low-carbon energy have actually matched those of developed countries during the past decade. And China has surged ahead of the US, incurring more than twice the American incremental expenditure during the period 2002-2008.

4. Comparative Mitigation Burdens

Progress toward an international mitigation agreement has been largely stymied by disagreements about burden-sharing between rich and poor countries. Many participants have assumed that an agreement will determine whether, when, and to what extent developing countries will begin mitigating carbon emissions. But Sections 2 and 3 have shown that this assumption is mythic: Developing countries have been major participants in carbon mitigation for two decades, and their aggregate incremental expenditures have been comparable to those of developed countries during the past decade.

Comparison of aggregates can be misleading, however, because it does not account for differences in population and income. To incorporate these differences into country and group comparisons, I compute the average income share devoted to mitigation: per-capita mitigation expenditure divided by per-capita income.[10] This measure has a natural upper bound for comparisons of rich and poor countries, since no reasonable person could argue that the poor should pay a higher share of their income for carbon mitigation than the rich. On the other hand, it would be entirely reasonable to argue that burden-sharing should be progressive, with the poor paying lower shares.

Table 6 reports actual shares, calculated by combining the results summarized in Table 5 with population and income data for the same periods. My measure of income is GDP per capita at purchasing power parity, in constant $US 2005.[11] I report average per capita income, incremental mitigation expenditure per person and the average income

[10] This is computationally equivalent to dividing total mitigation expenditure by total income, but normalization by population makes its incorporation clearer.

[11] I use income at purchasing power parity (PPP) because I am estimating the incremental expenditure burden associated with investments in clean energy technologies. Normalization by PPP-adjusted income provides a more accurate estimate of the actual burden than normalization by dollar-denominated income.

share of incremental mitigation expenditure for 1990-1996, 1996-2002, 2002-2008, and 1990-2008.

The most general results in Table 6 are the income shares of mitigation for developed and developing countries (excluding the US, India and China) during the period 1990-2008. For the entire period, the income shares of developing and developed countries are $.45 and $.87 per $10,000 of income, respectively. China has been significantly higher than average among developing countries at $.94, and the US much lower than average among developed countries at $.44 – almost identical to the overall income share for developing countries.

Income shares have fluctuated considerably across periods, but the following patterns have held since 1996:

- Developing-country shares have been about two-thirds of developed-country shares;
- India's share has been near the developing-country average;
- China's share has been much higher than average among developing countries, higher than average for developed countries, and much higher than the US share;
- The average share of other developed countries has also been much higher than the US share.

Overall, the relative expenditure burdens of developed and developing countries are consistent with a progressive view of "fair shares". But China has done more than its fair share, and the US considerably less. Another striking result is the extremely modest burden that all countries have borne to date, with no share in the entire set exceeding $1.45 per $10,000. Given the potentially-catastrophic consequences of climate change for all countries, it would seem reasonable to expand low-carbon energy investments five- or tenfold, while preserving the progressive distribution of expenditure shares across countries. For developing countries as a whole, a tenfold increase from the most recent period would increase the incremental expenditure to about $4 per $10,000, or .04% of income. For developed countries, the corresponding figure would be $5.70 per $10,000, or .057% of income – scarcely an expropriatory figure.

5. **On Intentions, Country-Specific Costs and Results**

The contrarian results in this paper may provoke the critical reader to suggest that they are misleading because they ignore both intentions and cross-country differences in energy technology costs. Granted, developing countries have invested massively in low-carbon power since 1990. But this cannot have reflected any intention to reduce carbon emissions, since developing countries have had no incentive to do so. And the use of uniform levelized costs ignores actual cross-country differences in these costs. In many cases, countries may have invested in low-carbon technologies simply because they were lower-cost.

While the point about intentions may be largely true, it is irrelevant for two main reasons. First, the argument applies equally to developed countries -- even the EU, whose presumptive carbon mitigation activities have been widely remarked. As I note in Wheeler (2010), the EU nations that pioneered cap-and-trade regulation of carbon emissions only initiated their program in 2005, after a long period of substituting away from coal-fired power toward natural gas and low-carbon energy. Concern about climate change may well have been a motivating factor, but so were serious concerns about domestic air pollution from fossil-fuel combustion; the need to diversify energy sources to reduce political and economic risks; and, not least, the drive for competitive advantage in emerging global clean-energy markets. The same factors undoubtedly explain much of the low-carbon energy investment in developing countries. We have no realistic hope of disentangling these factors, so comparative analysis must focus on results, not intentions.

The concept of national carbon-mitigation “intentions” is tenuous in any case, because the national governments of many emitters are only accountable for part of the mitigation-related activities within their borders. In the US, for example, many states, localities and private firms are independently promoting renewable energy. Many Indian states are also promoting renewable energy alongside the national government. In the context of global negotiations, this means that national commitments to targets can never be more than commitments to cover shortfalls after local efforts have been accounted for.

In a similar vein, the argument that technology costs differ across countries is undeniably true, but its practical relevance is minimized by several factors. First, there is no cross-country database to support a deeper version of this exercise. Even the average levelized cost data used for this study were not available until recently, as my citations indicate. And there is every reason to suppose that cost differences also characterize energy facilities within countries. No two dams are alike, and the same is true for nuclear facilities and coal-fired plants. Inevitably, some kind of averaging is necessary for a study of this kind. Second, we do not have sufficient data to establish whether energy technology costs in developing countries differ systematically from those in developed countries. This precludes any strong inferences about directions of bias in the current study. Finally, the available information is insufficient for separating generic levelized cost differences from those attributable to energy regulations, patterns of public/private ownership, subsidies and quotas. At present, to cite an extreme example, Germany is phasing out nuclear energy while France continues to depend heavily on its nuclear facilities for baseload power. This obviously has little or nothing to do with differences in levelized cost, which should be quite similar for the two neighboring countries.

6. Summary and Conclusions

In this paper, I have suggested an approach to computing emissions mitigation costs that is based on two simple principles: (1). Incremental costs for low-carbon energy investments are calculated using coal-fired power as the benchmark; (2). All low-carbon investments are counted, regardless of the unknowable intentions that have motivated them. My approach is comprehensive, because it recognizes the full range of low-carbon investment activity in the power sector, and it is easily-computable from publicly-available data. It introduces a simple measure of the comparative cost burden that appeals to a basic sense of fairness while incorporating a natural adjustment for relative income levels. It facilitates a more realistic discussion of “fair shares” that is grounded in actual experience. And it fully credits the contributions of countries which promote expensive options like solar PV that are still high on their learning curves, but potentially cost-competitive with coal-fired power after further expansion.

My results offer fresh insights, because they undermine the conventional view of North-South conflict that has dominated global climate negotiations. They show that developing countries have actually been full participants in carbon mitigation since 1990, while bearing their fair share of incremental expenditures. And they justify the following challenge from poor countries to rich countries: ***We are willing to assume our fair share of the mitigation expenditure burden, as we have in the past. If you invest more aggressively in low-carbon energy, we will match you and maintain our fair share of the global expenditure burden. But you can scarcely expect us to pay a greater share of our incomes than you do, particularly since you have created more than your fair share of the problem.***

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Table 1a: Distribution of Increases in Generation of Low-Carbon Energy, 1990-2008 (%)

Group	Country	Biomass	Solar	Wind	Geothermal	Hydro	Nuclear	Total
Developing	China	3	1	6	0	26	6	15
	India	1	0	7	0	3	1	3
	Other	23	1	2	60	51	27	37
	Total	27	3	16	60	81	34	55
Developed	US	11	6	24	5	4	18	11
	Other	62	91	60	35	15	48	34
	Total	73	97	84	40	19	66	45

Source: EIA (2010)

Table 1b: Distribution of Increases in Generation of Low-Carbon Energy by Period, 1990-2008 (%)

Group	Period	Biomass	Solar	Wind	Geothermal	Hydro	Nuclear	Total
Developing[a]	1990-1996	22	9	17	47	70	34	51
	1996-2002	25	20	8	80	82	23	47
	2002-2008	32	1	18	44	95	53	68
Developed[b]	1990-1994	78	91	83	53	30	66	49
	1995-2001	75	80	92	20	18	77	53
	2002-2008	68	99	82	56	5	47	32

[a] Low, lower middle and upper middle income countries
[b] High income OECD countries only

Source: EIA (2010)

Table 2: CO2 Emissions Averted by Low-Carbon Energy Growth, 1990-2008

		Percent of Counterfactual Total				Million Metric Tons			
Group	Country	1990-2008	1990-1996	1996-2002	2002-2008	1990-2008	1990-1996	1996-2002	2002-2008
Developing	China	11	12	20	9	442	72	103	266
	India	10	7	11	12	73	12	13	48
	Other	46	43	115	34	1,077	647	186	245
	Total					1,592	731	303	559
Developed	US	51	46	55	57	329	151	116	63
	Other	62	70	48	62	974	551	223	200
	Total					1,303	702	339	262

Table 3: Levelized Costs of Energy Sources (US Cents/kWh)*

Source	¢/kWh
Low-Carbon	
Biomass[a]	5.95
Geothermal[a]	6.72
Hydro[a]	5.38
Nuclear[b]	6.70
Solar PV[a]	51.43
Wind[a]	6.71
Coal[a,c]	4.29

Sources: [a]World Bank (2008); [b]MIT (2003); [c]MIT(2007)

* Estimates are for large-scale power facilities. Levelized cost is the present value of expected costs over the lifetime of a power plant, divided by the discounted stream of power production over the same period. Costs include initial construction (capital costs), the annual costs of operating and maintaining the facility, and, in the case of fossil fuel projects, the annual cost of fuel. Power production is determined by the size of the plant and the assumed capacity utilization rate.

Table 4: Learning-Adjusted Unit Costs, 1990-2005

	Power Generation and Unit Cost Indices by Technology (1.00 in 2005)					
Year	Global Biomass Generation	Biomass Unit Cost	Global Solar Generation	Solar Unit Cost	Global Wind Generation	Wind Unit Cost
1990	0.39	1.07	0.35	1.40	0.04	2.46
1995	0.58	1.04	0.42	1.32	0.08	1.97
2000	0.74	1.02	0.47	1.27	0.30	1.38
2005	1.00	1.00	1.00	1.00	1.00	1.00
2008	1.18	0.99	3.05	0.70	2.08	0.82

Table 5: Incremental Expenditures on Low-Carbon Power, 1990-2008 ($US 2005 Billion)

Group	Country	1990-1996	1996-2002	2002-2008	Total
Developing	China	1.1	1.5	3.8	6.5
	India	0.2	0.4	0.7	1.3
	Other	11.0	3.1	3.6	17.6
	Total	12.4	5.0	8.1	25.4
Developed	US	3.4	3.1	1.5	7.9
	Other	12.7	6.2	6.6	25.5
	Total	16.1	9.3	8.1	33.4

Table 6: Incremental CO_2 Mitigation Expenditure Shares of Per-Capita Income, 1990-2008

Period	Group	Country	Incremental Expenditure Share (Per $10,000)	GDP Per Capita[a]	Incremental Expenditure Per Capita[b]
1990-1996	Developing	China	0.98	1,594	0.16
		India	0.32	1,324	0.04
		Other	1.78	4,359	0.78
	Developed	USA	0.66	33,000	2.16
		Other	1.45	24,658	3.53
1996-2002	Developing	China	0.71	2,601	0.19
		India	0.38	1,685	0.06
		Other	0.43	4,515	0.19
	Developed	USA	0.47	38,059	1.82
		Other	0.61	27,697	1.68
2002-2008	Developing	China	1.13	4,385	0.49
		India	0.43	2,330	0.10
		Other	0.39	5,310	0.20
	Developed	USA	0.19	41,860	0.81
		Other	0.57	30,584	1.74
1990-2008	Developing	China	0.94	2,860	0.28
		India	0.38	1,780	0.07
		Other	0.86	4,728	0.39
	Developed	USA	0.44	37,640	1.60
		Other	0.87	27,647	2.32

[a] $US 2005 at purchasing power parity
[b] $US 2005