G24

INTERGOVERNMENTAL GROUP OF TWENTY-FOUR

CARBON MARKETS AND BEYOND:

THE (LIMITED) ROLE OF PRICES AND TAXES IN CLIMATE AND DEVELOPMENT POLICY

by Franck Ackerman

G24 Technical Group Meeting
September 8-9, 2008
Unites-Nations Headquarters
Geneva, Switzerland

Carbon Markets and Beyond:
The (limited) role of prices and taxes in climate and development policy

Discussion paper for G24 meeting, Geneva, Sept. 8, 2008
Draft: suggestions for revision appreciated!
Please do not post on-line or reprint this draft.

Frank Ackerman
Stockholm Environment Institute / Tufts University
Frank.Ackerman@tufts.edu

The good news is that all major voices in the climate policy debate, including the Bretton Woods institutions, are taking the problem seriously. Skepticism about the science is no longer an option: the world's scientists have never been so unanimous, and so ominous, in their projections of future perils.

The bad news is that for too many participants in the debate, including the Bretton Woods institutions, climate policy primarily consists of manipulating markets and prices. If the only tool you have is market liberalization, then every problem looks like a question of getting the prices right. But setting a price for carbon emissions is only the beginning of climate policy, not the end.

This paper argues that appropriate carbon prices and functioning carbon markets are necessary but not sufficient. It begins with a review of recent publications on climate policy from the IMF and the World Bank, contrasting them with other recent recommendations. It then examines the expected impacts of a higher price of carbon, which will be both inequitable and, in some respects, ineffective if adopted alone. Turning to more positive solutions, the nature of technology, particularly its path dependence and learning curve effects, requires carefully designed public investments to launch a climate-friendly development path. And the impacts of carbon prices and markets on developing countries create both unique problems, such as proportionally greater economic burdens, and unique opportunities, in the proportionally greater incentive to innovate and establish a new leadership position in 21st century technologies.

1. The state of the debate

The IMF, in the climate change chapter of *World Economic Outlook 2008*, simply assumes that climate policy consists of getting the (carbon) price right:

> An effective mitigation policy must be based on setting a price path for the greenhouse gas (GHG) emissions that drive climate change.[1]

Although making an occasional nod to the importance of developments such as hybrid vehicles or energy efficiency[2], the IMF's focus is almost entirely on market instruments. Adaptation to climate impacts will, the Fund notes, require large increases in infrastructure spending – but much more is said about market opportunities for hedging against predictable short-term climate fluctuations, through weather derivatives and "cat" (catastrophic risk) bonds. Mitigation, i.e. emissions reduction, is addressed primarily through detailed modeling of the expected effects of carbon taxes or trading schemes. This modeling effort shows that OPEC nations will be the most important losers from a moderate carbon price, while global trading of emissions allowances will probably benefit China above all, due to that country's massive opportunities for comparatively low-cost emission reductions.

[1] WEO 2008, Chapter 4, p.2.
[2] E.g., "Energy-efficiency improvements are unlikely to eliminate the need for carbon prices, but they would reduce their level." *Ibid.*, p.40.

The IMF analysis sets a target of a 60 percent reduction in carbon emissions, relative to 2002 levels, by 2100, in order to stabilize CO2 concentrations at 550 parts per million (ppm). This is a significant change, although less ambitious than the targets advocated by many governments and independent analysts; there is a growing concern among climate scientists that 450 ppm, or even lower, concentrations may be needed to avoid serious risks of catastrophic change. Yet in the IMF's view, the world can move slowly and still reach the target comfortably:

> Carbon-pricing policies … must establish a time horizon for steadily rising carbon prices that people and businesses consider believable. Increases in world carbon prices need not be large—say a $0.01 initial increase in the price of a gallon of gasoline that rises by $0.02 every three years.[3]

Changes in carbon prices of this magnitude are dwarfed by the recent swings in the price of gasoline, a topic discussed in the next section. While it may be possible to achieve climate stabilization at moderate total cost, considerable ingenuity and new policy directions will be required; by themselves, price changes of pennies per gallon of gas are not enough to achieve anything of importance.

For the World Bank, the success of market based policy is already obvious:

> The carbon market is the most visible result of early regulatory efforts to mitigate climate change … Its biggest success so far has been to send market signals for the price of mitigating carbon emissions. This, in turn, has stimulated innovation and carbon abatement worldwide, as motivated individuals, communities, companies and governments have cooperated to reduce emissions.[4]

This success, according to the Bank, is based on two major markets for carbon emissions, the EU's Emissions Trading Scheme (ETS) and the Clean Development Mechanism (CDM) provisions of the Kyoto Protocol. They account for about US $50 billion and $13 billion, respectively, of the $64 billion in worldwide carbon market transactions in 2007.[5] Both markets, as it turns out, are works in progress: the ETS initially gave away virtually all emission allowances to existing emitters, rather than auctioning them – and set such a high cap that the price of allowances fell embarrassingly close to zero. (Revisions to the ETS framework have begun to address these design flaws for future years.) CDM has been beset by procedural delays and complexity, imposing unduly burdensome start-up times. A large majority of CDM funding to date has flowed to China, suggesting that CDM does not yet provide a truly global mechanism for financing emission reduction.

Meanwhile, research sponsored by the World Bank has demonstrated that there is substantial variation in carbon emission levels, at the same level of development:

---

[3] *Ibid*, p.42.
[4] World Bank, State and Trends of the Carbon Market 2008 (May 2008), p.1.
[5] Ibid.

> The ranking of countries by emissions intensity [i.e., emissions/GDP ratio] … was not systematically related to GDP per capita … Emissions per capita were positively but only moderately correlated with GDP per capita and showed no evidence of an eventual decline in emissions per capita at higher per capita income (the Environmental Kuznets Curve phenomenon).[6]

This finding should give rise to curiosity about the subtler economic and non-economic determinants of emissions. It suggests that growth is not equally good, or bad, for carbon emissions in all contexts. Therefore, merely speeding up or slowing down economic growth may not be the most efficient policy; it is also important to understand what differentiates high versus low emission countries at the same level of economic development. (The same can be said of states within the United States, which differ in carbon emissions per capita by a ratio of more than six to one – a question I am exploring in ongoing research.)

The World Bank's overall approach to the issue sounds multi-faceted, if somewhat abstract. A proposed "strategic framework" [7] for the Bank lists six "pillars," of which three are focused exclusively on market instruments,[8] while three are more general or ambiguous.[9] However, critics have claimed that reality falls short of the World Bank's rhetoric. According to a report from the Institute for Policy Studies (IPS), an NGO in Washington DC, the Bank's $2 billion in carbon finance projects suffer from an extreme lack of transparency, and have resulted in very little confirmed reduction in carbon emissions.[10] Less than 10% of the funding has gone to renewable energy, while 75% or more has gone to the coal, chemical, and iron and steel industries. In the sponge iron industry in India, IPS reports that the incentives for carbon reduction have been generous enough to cause a perverse expansion of the relatively energy-inefficient industry, in order to gain additional carbon reduction credits.

Other voices in the international debate have recognized the greater urgency of the problem, and have set more detailed reduction targets, such as 80% reduction in developed countries and 50% worldwide by 2050, with even greater reductions required by 2100. Along with the urgency of the issue, there has been a willingness to consider a broader range of policy instruments. For the Human Development Report,

> Setting ambitious targets for mitigation is an important first step. Translating targets into policies is politically more challenging. The starting point: putting a price on carbon emissions … Carbon markets are a necessary condition for the

---

[6] Robert W. Bacon and Soma Bhattacharya, "Growth and CO_2 Emissions: How Do Different Countries Fare?" World Bank Environment Department, 2007. Quote from p.2.
[7] "Towards A Strategic Framework On Climate Change And Development For The World Bank Group," Concept And Issues Paper - Consultation Draft, March 2008.
[8] "Consolidating Efforts to Mobilize and Deliver Finance," "Expanding the Bank's Role in Developing New Markets," and "Tapping Private Sector Resources for Climate Friendly Development."
[9] "Scaling Up Operational Approaches to Integrating Adaptation and Mitigation in Development Strategies," "Clarifying the Bank's Role in Accelerating Technology Development and Deployment," and "Stepping Up Policy Research, Knowledge Management and Capacity Building."
[10] Janet Redman, "World Bank: Climate Profiteer," Institute for Policy Studies, 2008.

> transition to a low-carbon economy. They are not a sufficient condition. Governments have a critical role to play in setting regulatory standards and in supporting low-carbon research, development and deployment.[11]

HDR calls for carbon markets to be accompanied by government incentives for renewable energy production, tightened standards for vehicle fuel efficiency, expanded research on carbon capture and storage (CCS) technology, and increased technology transfer to developing countries.

One of the most detailed recent proposals is Nicholas Stern's "global deal on climate change."[12] Stern argues that climate stabilization requires cutting global emissions to half of the 1990 level by 2050, with continuing declines thereafter. The 2050 target is so low – 2 tons per capita, not much above the level of emissions today in India, and less than half of China's current emissions – that there is virtually no room for any large country to be significantly above the average. Stern calls for binding national reduction targets, to be adopted soon by developed countries and the fastest-growing middle-income countries, and by all other countries by 2020. Stern envisions a carbon market, in the form of a global cap-and-trade system that allows developing countries to sell emission rights, combined with arrangements for technology transfer, and large-scale government support for the development of new technologies. In the words of his summary,

> The world should aim for a liquid international carbon market in order to allow for the most effective, efficient and equitable emissions reductions. In addition, non-price interventions are required to expand the global market for low-carbon technologies, support common standards and promote cost-effective reduced deforestation.[13]

In short, all major proposals for climate policy include a substantial role for carbon markets and prices, either in the form of taxes or cap-and-trade systems. Yet while the Bretton Woods institutions, by their nature and by inclination, give primary emphasis to manipulation of prices and financing in carbon markets, others, such as Stern and the Human Development Report, see carbon markets as one part of a complex ensemble of policies.

2. What do carbon prices accomplish?

Much of the discussion of carbon markets has focused on the distinction between effects on prices and effects on emissions. A carbon tax causes a predictable, stable effect on prices, but does not lead to precisely defined reduction in emissions. A cap-and-trade system, on the other hand, causes a predictable, explicitly stated reduction in emissions, but could lead to unpredictable or fluctuating prices. Those who, like Stern, focus on the

[11] UNDP, Human Development Report 2007/2008, Summary pp. 20, 21.

[12] Nicholas Stern, "Key Elements of a Global Deal on Climate Change," London School of Economics, 2008.

[13] *Ibid.*, p.3.

need to achieve a specific level of emissions reduction tend to prefer cap-and-trade markets; those who worry more about economic disruption tend to prefer the predictable prices achieved by carbon taxes.

This is, however, only one dimension of the effects of carbon markets. Another important dimension has received too little attention: when carbon prices are increased, by a tax or a trading system, how large is the (intended) effect on emissions, and how large is the (unintended) effect on income distribution?

Increased energy costs to consumers fall disproportionately on low-income groups; energy costs are a larger fraction of income for the poor. As incomes rise, total spending on energy also rises, but more slowly; thus the fraction of income spent on energy decreases. The one major exception to this pattern occurs in countries where some people cannot afford fossil fuels, and instead rely on traditional biomass fuels. Among the population that buys and depends on fossil fuels, energy price increases are regressive, taking proportionately more from lower-income households.

To summarize in advance the point of this section, the effect of a carbon price increase depends on the price elasticity of demand for energy. A larger elasticity means that a price increase has more effect on emissions and less effect on income distribution; a smaller elasticity means that the same price increase has less effect on emissions, but does more to increase inequality.[14] Since price elasticities are fairly small for energy in general, and extraordinarily small for petroleum products in the short run, price incentives are a blunt and painful instrument for achieving lower emissions.

The price elasticity of demand is, by definition, the percentage change in demand that is caused by a one percent change in price. Consider the effects of a 20 percent increase in the price of energy at different elasticities, as shown in Table 1.

Table 1

Impacts of a 20 percent increase in energy prices

	Price elasticity of demand			
	-1.0	*-0.5*	*-0.2*	*-0.05*
Change in quantity	-20%	-10%	-4%	-1%
Change in cost to consumers	-4%	+8%	+15%	+19%

At an elasticity of -1, the 20 percent increase in price causes a 20 percent drop in demand. Consumers purchase 80 percent as much energy as before, at 120 percent of the former price per unit, so the total cost to consumers amounts to 96 percent of the former total. At this elasticity, most of the effect is felt in the change in the quantity of energy (and therefore emissions), while total consumer spending is little affected.

[14] Price elasticities are, strictly speaking, negative numbers. This discussion follows the common convention of referring to numbers farther from zero (or larger in absolute value) as “larger” elasticities; thus an elasticity of -1 is “larger” than an elasticity of -0.5.

In contrast, at an elasticity of -0.05, a 20 percent increase in price causes only a 1 percent change in quantity. Consumers buy 99 percent as much energy as before, at 120 percent of the former price per unit, for a total expenditure of 119 percent of the earlier cost. At this elasticity, there is almost no effect on the quantity of energy and emissions, but a large effect on the total cost to consumers. The other values shown in the table have intermediate results between these two extremes. Judged as a strategy to reduce energy consumption and the resulting emissions with minimal burdens on consumers, energy price increases seem quite effective at an elasticity of -1, but decidedly inferior at an elasticity of -0.05.

Which elasticity values are applicable in reality? Separate estimates have been developed for major energy markets including industrial energy use, electricity, and transportation. The largest elasticities are found in industry. Estimates from three research groups for 15 countries found the price elasticity for industrial energy demand to be between -0.77 and -0.88. The estimates for India and Brazil were not significantly different from those for the developed countries included in the studies.[15] Industrial energy use, in other words, provides fertile ground for the application of price incentives for emission reduction. Indeed, industry lowered its energy use much farther and faster than any other sector in response to the oil price shocks of the 1970s.

Household demand for electricity is much less elastic than industrial energy use. Recent estimates for the United States have found a short-run price elasticity of -0.20, and a long-run price elasticity of -0.32, broadly consistent with earlier research.[16] This finding of a relatively small elasticity for electricity does not appear to be unique to the United States; the estimated long-run elasticity for Taiwan is -0.16, described by the authors as “reasonably close” to the estimates in “numerous other studies.”[17]

In both industrial energy use and electricity generation, there are alternative fuels that yield the same result with differing carbon emissions. An increased carbon price would cause a noticeable reduction in industrial energy demand (less so in household electricity), and also a shift toward lower-carbon fuels – such as replacing coal with natural gas.

The picture is different in the transportation sector, where there is essentially only one fuel choice: almost all transportation uses petroleum fuels. (On a global basis, the

---

[15] Joyashree Roy, Alan H. Sanstad, Jayant A. Sathaye, and Raman Khaddaria, “Substitution and price elasticity estimates using inter-country pooled data in a translog cost model,” *Energy Economics* 28 (2006), 706-719.

[16] M.A. Bernstein and J. Griffin, “Regional Differences in the Price-Elasticity of Demand for Energy,” RAND Corporation, 2006. See also Peter C. Reiss and Matthew B. White, “Household Electricity Demand, Revisited,” *Review of Economic Studies* 72 (2005), 853-883, estimating a long-run price elasticity for California households of -0.39, and commenting that high-quality past studies have generally yielded estimates between -0.15 and -0.35.

[17] Pernille Holtedahl and Frederick L. Joutz, “Residential electricity demand in Taiwan,” *Energy Economics* 26 (2004) 201–224; quotes from p. 216.

available supply of biofuels is too small to make a noticeable dent in the demand for oil.) In the wake of the oil crises of the 1970s, most countries and industries have cut back on oil use wherever possible; oil-fired electricity generation, once relatively widespread, is now common only in OPEC countries. Today a majority of crude oil is used for transportation, and a portion of the remainder is dedicated to non-fuel uses such as petrochemicals, where there are no close substitutes. The connection between petroleum and transportation is projected to grow even tighter; an estimated two-thirds of the growth in oil demand through 2030 is for transportation.[18] Thus the oil/transport market is almost disjoint from the market for other fuels and end uses.

The lack of alternatives to oil means that in the short run, the price elasticity is close to zero for many consumers. A household that lives in a completely automobile-dependent environment – including the great majority in the United States, large fractions of many OECD countries, and increasing numbers in fast-growing, middle-income countries – has little control over the amount of driving required to go to work, school, stores, and other essential services. So in the short run, purchases of gasoline will be quite insensitive to price.

In the long run, as cars are replaced, high oil prices stimulate the sale of smaller and more fuel-efficient vehicles, as is happening today. This will eventually affect oil consumption, as the fleet of cars on the road slowly becomes more fuel-efficient, implying that the price elasticity will be greater in the long run than in the short run.

A comparative international analysis estimated oil price elasticities for many countries for 1979-2000.[19] For the United States, it found a short-run elasticity of -0.06 and a long-run elasticity of -0.46, broadly consistent with other published estimates. For the G7 group of industrial countries, short-run elasticities ranged from -0.024 to -0.071, and long-run elasticities from -0.18 to -0.57. Using these estimates for the United States, a doubling of oil prices causes a 4 percent reduction in demand in the short run, and a 27 percent reduction in the long run.

A study focused specifically on U.S. gasoline consumption found that the short-run price elasticity in 2001-06 was -0.034 to -0.077, lower than estimates for earlier periods.[20] The data did not permit estimation of a long-run elasticity. The authors speculated that increasing suburbanization and decreased availability of mass transit have made it more difficult for most households to reduce their automobile use today. They concluded that changes in vehicle fuel efficiency would be the key to future changes in U.S. gasoline consumption.

---

[18] U.S. EIA's *International Energy Outlook 2007* says transportation will account for two-thirds of the growth in world oil use through 2030; OPEC data in *World Oil Outlook 2007* implies that transport will absorb 62 percent of the growth in oil use.

[19] John C.B. Cooper, "Price elasticity of demand for crude oil: estimates for 23 countries," *OPEC Review* 27 (2003), no. 1, pp. 1-8.

[20] Jonathan E. Hughes, Christopher R. Knittel, and Daniel Sperling, "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand," NBER Working Paper 12530, September 2006.

Short-run price elasticities for gasoline and other transport fuels are close to zero; this is why the recent surge in the price of oil did not cause an immediate collapse in demand. It is clear that this increase in oil prices is primarily a burden on consumers, and only causes a modest change in short-run oil demand; its sole beneficial effect is to accelerate the transition to a more fuel-efficient vehicle fleet.

Any plausible carbon policy would, in the near term, raise fossil fuel prices by less than the recent oil price increases. While such a policy might have an important effect on industrial energy use, it would presumably have less effect on transportation than the recent surge in oil prices. Something more needs to be done, to reduce emissions on the scale and timetable projected by Stern and others.

3. Where do new technologies come from?

Market-based incentives such as a carbon price are much better at some objectives than others. Price signals lead to efficient choices among existing alternatives; this is the great success of the market economy. On the other hand, as noted in the previous section, carbon prices will generally make the distribution of income and resources more unequal. In addition, carbon prices alone will not create the new technologies needed to solve the climate crisis.

The pure theory of competitive markets has little to say about technical change. If, as in the textbook model, all commodities are bought and sold by small, competitive firms, and all resources are used to produce the maximum possible satisfaction for consumers, who has the incentive and the ability to invest in research? Yet new technologies do emerge, and productivity grows over time. Conventional economic models have often addressed this question with the ad hoc assumption of a predictable, constant rate of technical change, unrelated to investment choices or policy decisions. In the arena of climate modeling, this takes the form of the "autonomous energy efficiency improvement" (AEEI) parameter.[21] That assumption has the unfortunate consequence of biasing results toward waiting for new technology to appear: abatement will always be cheaper if it is done later, after better technologies have "autonomously" made their appearance.

In reality, new technologies do not drop from the sky, independent of investments and public policies. New technologies are created by conscious effort; they often start out expensive and become cheaper over time, a process that is often described in terms of "learning curves" or "experience curves." As a result, investment in start-up costs can determine which technologies are cost-effective in the future. Technological change is path-dependent: the current suite of available choices depends on past policies and actions, just as the available technological options in the future will depend on our policies and actions today.

[21] The model used by the IMF, in the analysis discussed in Section 1 above, assumes an AEEI of 0.5 percent per year: *World Energy Outlook 2008*, Chapter 4, p.46.

The learning curve phenomenon is particularly important when there is a benefit to standardization; in such cases, an early market leader can become "locked in," whether or not it represents the ideal technology (as occurred with the Windows operating system and other Microsoft software for computers).[22] The current style of industrialization has been referred to as "carbon lock-in," meaning that carbon-intensive technologies gained an early lead at a time when fossil fuels were cheap and concern about global warming was not yet on the horizon.[23] Today, the economic benefits of standardization and the low costs of imitating and replicating existing technology keep the world locked into that same undesirable path.

Research on learning curves has often found that as the cumulative total production of a new product increases, the unit cost declines at a predictable rate. This is often measured by the "progress ratio," defined as the change in unit cost per doubling of cumulative production. In a historic example from the early twentieth century, Ford's Model T had a progress ratio of 85% throughout its long production run: every time the cumulative total production of Model Ts doubled, the price per car dropped by an average of 15%.[24]

New energy technologies often display strong learning-curve effects. Research on wind power has found progress ratios as low as 80% (i.e., cost reductions as great as 20% from doubling of production).[25] While wind power is now competitive in the marketplace under many conditions, this success was made possible by decades of US and European government investment in research and development. Brazilian ethanol production, another industry launched by government policy, reportedly had a progress ratio of 71% from 1985 through 2002.[26]

With technological progress at these rates, it is often the case that private enterprises only find it profitable to buy a new product after someone else has been buying it and bringing down the price for ten or twenty years. Hence the role for public sector involvement: governments can and must choose the new technologies to support, especially when – as with climate policy – there is a clear need for change. The market alone is not enough; without public investment, no credible carbon price would do an effective job of launching the crucial new renewable and low-carbon technologies. On the other hand, with adequate public support, vast changes are possible. A plausible model of energy development, incorporating learning curves, projects that solar photovoltaics, now one of

[22] The classic references on technological lock-in include Paul David, "Clio and the Economics of QWERTY," *American Economic Review* 75 (1985), 332-337, and Brian Arthur, *Increasing Returns and Path Dependence in the Economy* (University of Michigan Press, 1994).
[23] Gregory C. Unruh and Javier Carrillo-Hermosilla, "Globalizing carbon lock-in," *Energy Policy* 34 (2006) 1185–1197.
[24] W. J. Abernathy & K.Wayne, "Limits of the Learning Curve," *Harvard Business Review*, Vol. 52, No. 5 (1974), pp.109-119.
[25] M. Junginger, A. Faaij, and W.C. Turkenburg, "Global experience curves for wind farms," *Energy Policy* 33 (2005) 133–150.
[26] Jose Goldemberg, Suani Teixeira Coelho, Plinio Mario Nastari, and Oswaldo Lucon, "Ethanol learning curve—the Brazilian experience," *Biomass and Bioenergy* 26 (2004) 301 – 304.

the most expensive ways to generate electricity, could be one of the cheapest options by 2100.[27]

This is not a unique characteristic of new energy technologies; rather, it is the norm in technological change. The US has funded the development of numerous innovative weapon systems, technologies that would not have automatically appeared without government support. Most of them, fortunately, have never been used. Along the way, many other technologies have been developed, with more peaceful applications to civilian life. In the words of a history of microelectronics[28],

> The U.S. military initially purchased nearly the total production of transistors in the early 1950's, using them to make the new generation of communications, radar and improved avionics systems, command and control systems, as well as for missiles and jet fighters…
>
> The U.S. government acted as the major market for integrated circuits in the early years… In 1962 … the U.S. government, with extensive research interests in space, defense, and other areas, purchased virtually 100% of all integrated circuits manufactured in the United States.

As with wind power, a few decades of generous public support were sufficient to launch the microelectronics industry as a success in the marketplace. And the list goes on and on: computers got their start with military purchases; the Internet grew out of ARPANET, a Defense Department-sponsored network set up in the 1960s to connect military researchers around the country.

None of these technologies appeared automatically; if the world had waited for autonomous technical change or relied on getting the prices right, microelectronics might never have happened. Instead, the U.S. government moved rapidly, and succeeded in launching a suite of technologies that now dominate private markets and shape modern life.

4. Carbon markets and developing countries

The discussion of learning curves, path dependence, and technological lock-in applies equally to climate policy and technologies in developed and developing countries. However, the current discourse on carbon markets and climate policies has unique implications for developing countries, posing obstacles and creating opportunities that are not present in higher-income countries.

[27] Shilpa Rao, Ilkka Keppo and Keywan Riahi, "Importance of Technological Change and Spillovers in Long-Term Climate Policy," *Energy Journal* special issue on endogenous technical change, 2006, 25-42.
[28] Dave Morton, "The Electrical Century: What Difference Did Semiconductors and Microelectronics Make?", *Proceedings of the IEEE* 87 no. 6 (1999), 1049-1052.

It has become commonplace to insist on the need for a globally harmonized price of carbon. Price harmonization is thought to ensure efficiency in the worldwide distribution of abatement effort: with appropriate market institutions, investment in emissions reduction will flow to the countries (presumably developing countries) where the costs of reduction are lowest. Fears about the effects of unharmonized carbon charges have slowed climate policy initiatives in some high-income countries, and have prompted an unproductive and potentially protectionist discussion of border tariff adjustments. This notion is mistaken both in fact and in theory. Empirically, only a handful of industries are so carbon-intensive that a difference in carbon charges could lead them to move from one country to another – and many of them have already moved to middle- and low-income countries.

In theory, remarkably enough, marginal abatement costs do *not* have to be equal in every country in order to achieve economic efficiency. Theorists who reach this conclusion generally rely on the unexamined assumption that the world income distribution is equitable – or equivalently, that the marginal utility of additional consumption is the same everywhere.[29] In the absence of that assumption, it is more efficient to have higher abatement costs in richer countries (or to transfer large amounts of income from rich to poor, in order to achieve an equitable distribution).

It seems unlikely, however, that the enthusiasm for a consistent worldwide carbon price will be dampened by these considerations. Climate analyses from the Bretton Woods institutions (see Section 1), among many others, place a priority on establishing a single global carbon market. Thus developing countries are likely to face a global carbon price, while their local prices for labor, land and other inputs remain far below the levels of higher-income countries. Carbon emissions, or the credits for avoiding them, will account for a much larger fraction of the value of production in lower-income countries. The potential dissonance between expensive carbon and cheaper local inputs creates both an obstacle and an opportunity.

The obstacle is that development may be distorted in the direction of activities that yield marketable carbon reductions. Even undesirable activities may be promoted, such as the expansion of the sponge iron industry in India in order to generate carbon reductions (as cited in Section 1). Safeguards are needed to prevent “carbon-allowance-seeking” investments along these lines; in any global carbon market, it will be essential to verify that emissions are not newly created in order to profit by reducing them. The temptation to seek such bogus allowances, unfortunately, is a natural consequence of a global carbon price in a low-cost local economy.

The positive side of the same pattern of prices is that much deeper reductions in carbon emissions will be economical in developing countries. In the simplest terms, saving a ton of carbon is “worth” more hours of labor at a lower wage rate. So there may be a category of carbon-saving investments and technologies that are profitable only in

[29] Kristen A. Sheeran, “Who Should Abate Carbon Emissions? A Note,” *Environmental and Resource Economics* 35 (2006), 89-98; Graciela Chichilnisky and Geoffrey Heal. (1994). “Who Should Abate Carbon Emissions? An International Perspective,” *Economic Letters* 44 (1994), 443–449.

developing countries, where the tradeoff between carbon and other inputs is more favorable to emission reduction. With appropriate public initiatives and financing for these technologies, developing countries could “leapfrog” beyond the patterns of energy use in higher-income countries, establishing a new frontier for carbon reduction.

The potential for leapfrogging beyond the current technology frontier has been much discussed, but is difficult to achieve. The classic example is in telephones, where developing countries can now skip the expensive development of universal land lines, and go directly to cellphones. This is not, however, an example of jumping to an entirely new technology; it became possible only after cellphones were invented and commercialized in developed countries.[30] Likewise, research on the Chinese auto industry has shown that there is little tendency toward leapfrogging beyond international standards; in fact, US auto companies, left to themselves, have often allowed their Chinese plants to lag behind their home-country technologies.[31] Stronger Chinese government policies and initiatives would be required to achieve the potential for newer, cleaner vehicle technologies. Even for a developing country with the extensive resources and potential of China, there is much that needs to be done to reach this new technological frontier.

To realize the opportunity created by a global carbon price in low-cost economies, there will be a need for research and development in appropriate, cutting-edge technologies for carbon reduction. As with many of the new energy technologies that will be needed around the world, decades of public investment may be required before the developing-country technologies are successful in the marketplace. This is one more reason why carbon prices are necessary, but not sufficient, for an equitable solution to the climate crisis.

[30] Unruh and Carrillo-Hermosilla, “Globalizing carbon lock-in.”
[31] Kelly Sims Gallagher, “Limits to leapfrogging in energy technologies? Evidence from the Chinese automobile industry,” *Energy Policy* 34 (2006), 383–394.