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What Do We Expect from an International Climate Agreement? A Perspective from a Low-income Country

E. Somanathan

Indian Statistical Institute
India

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E. Somanathan
Planning Unit, Indian Statistical Institute
som@isid.ac.in

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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 co-directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University, and Joseph E. Aldy, Fellow, Resources for the Future. For more information, see the Project's website: <http://belfercenter.ksg.harvard.edu/climate>

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What Do We Expect from an International Climate Agreement? A Perspective from a Low-income Country¹

E. Somanathan²

Summary

Developing countries must cut their greenhouse gas emissions far below their business-as-usual (BAU) path if dangerous climate change is to be avoided. With current technologies, cutting emissions by more than a few percent will be expensive. Since climate change is not an issue in the domestic political sphere in developing countries, their governments are not going to cut emissions by very much. An international agreement cannot, therefore, realistically demand emissions quotas from developing countries that are below BAU. It is possible that developing countries take on such quotas in order to gain by selling emissions permits to richer countries that are willing to impose much more stringent quotas on themselves. However, it may well be the case that the resulting increases in energy prices in poor countries could impact the poor severely and even have perverse effects on the climate through continued use of solid fuels for cooking. Thus, it is not clear that emissions trade between developed and developing countries is either feasible or desirable at this juncture.

Technological change that lowers the prices of competitors to fossil fuels is the only way out. This can be promoted by regulation, tax, and tradeable permits in developed countries that provide inducements for R&D, and no less importantly, by the direct subsidization of R&D. The bulk of the finance for this will have to come from the developed countries. An international agreement involving developing countries should, at least in the coming round of negotiations, confine itself to promoting technical cooperation between regulators and other entities from all countries. It should include financial support from the developed countries for spreading energy conservation technologies and practices. Tropical agriculture will need a major thrust to develop new varieties that will withstand climate change. The necessary research and development cooperation should be part of the new agreement and needs major funding from developed countries. Research can also include emissions cuts from agricultural sources as long as this is financially well supported so that it does not reduce the funds available for promoting research into agricultural productivity.

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² Planning Unit, Indian Statistical Institute, 7 SJS Sansanwal Marg, New Delhi 110016. e-mail: som@isid.ac.in

1. The non-marginal nature of the climate problem and the importance of technological change

Allowing the global mean temperature to rise by more than 1 – 2 degrees C above its current level carries significant risks of positive feedbacks that further raise temperature and lead to catastrophic changes (Hansen, Sato et al. 2006; Lenton, Held et al. 2008). To achieve such a small rise in temperature, when current greenhouse gas concentrations already commit us to an increase of 0.3-0.9 degrees above a reference global average temperature of 1980-1999 (IPCC 2007a), will require massive cuts in CO₂ emissions by the middle of the century. The climate problem cannot be tackled by tinkering at the margins.

Eliminating carbon dioxide emissions is difficult for the simple reason that it is cheaper to obtain energy by burning coal, oil, and gas than by harnessing the sun, the wind, or atomic nuclei. The 2007 report of the Intergovernmental Panel on Climate Change, which reviewed the scientific literature, concluded that there are currently available, low-cost or even profitable opportunities for reducing CO₂ emissions, mainly through installation of energy conserving equipment and techniques in industry, building, and transport. However, this is true only for a cut of a few percentage points below business-as-usual emissions (IPCC 2007). With current technologies, deeper cuts can come only by raising the cost of energy.

Since low and middle-income countries, including China and India, will, due to their rapid economic growth and large populations, soon account for about a half of global CO₂ emissions (EIA 2008) tackling the climate problem requires that they have the incentive to substantially reduce their emissions.

The general public in low-income and even middle-income countries, however, is almost entirely unaware of the seriousness of the threats posed by global warming. Those few who have heard of the problem, also know that it is, so far, largely a consequence of the industrialization of the North. The now developed countries emitted three times as much fossil-fuel CO₂ between 1850 and 2002 as did the now developing countries (Baumert, Herzog et al. 2005).³ Since the developing countries have a much larger population, this means that on a per capita basis, developed countries are responsible for most of the problem. Therefore, at least until the developing countries get rich, their citizens are not going to be willing to pay more than a very small share of the costs of forestalling climate change. Consequently, there is no political support for paying more for energy in these countries and it is very unlikely that this will change substantially in the near future. This implies that the only way to get such countries to lower their CO₂ emissions substantially below their business-as-usual path is by making it economical for them to do so.

Given the present unwillingness of the rich countries to bear the costs of reducing even their own emissions by very much, it would be very optimistic to assume that they will be willing to pay for the elimination of Chinese, Indian, and other developing-country

³ The share of rich (Annex I countries in the Kyoto Protocol) is calculated to be 55% when land use change is taken into account (Müller, B., N. Höhne, et al. (2007). Differentiating (Historic) Responsibilities for Climate Change: Summary Report. Oxford, Oxford Climate Policy.)

emissions. We are left with technological change as the only hope of eliminating global emissions so as to avoid the dangers of disastrous temperature feedbacks.

Technological change to replace carbon-intensive activities with carbon-neutral ones can be stimulated by raising the expected returns to investment in research and development (R&D) and by increasing public-sector R&D and/or subsidising private-sector R&D. An international climate agreement may increase the expected returns to R&D so I will discuss this channel first.

2. The logic of international emissions trading

The economic logic of international emissions trading may be laid out as follows. Economic growth that will occur in large part in developing countries will require a large expansion of energy supply. The annual emissions of non-OECD⁴ countries are projected to rise from 17.3 to 22.3 Gt of CO₂ between 2010 and 2020 (EIA 2008). Additions to emissions can be avoided by building power plants fired by non-carbon emitting methods instead of fossil fuels. Although costly, this will nevertheless be cheaper than scrapping existing fossil-fuel based power plants and replacing them by carbon-neutral plants. Suppose high-income countries set themselves an annual carbon emission cap that is well below their *present* emissions, and developing countries set themselves a cap that is *above* existing emissions, and no higher than their business-as-usual path. Then, to achieve the total world cap, it will be cheaper to abate emissions in developing countries *more* than demanded by their cap, and to thus abate *less* in developed countries than their cap demands. Trading of emissions permits between the developed and developing countries will then mean that the latter will end up as sellers in the market for emission permits, and rich countries will be buyers. Thus, rich countries will pay for emissions to be lower in developing countries than they would have been in the absence of a cap-and-trade system. Developing countries will make a profit on any cuts that they make below their cap, by selling permits to rich countries. Provided the costs of reducing emissions from what they would have been (the BAU path) down to the cap are lower than these profits, they will end up making a net profit from entering such a system.

Why would rich countries enter such a system? Since the political pressure from the public to do something about climate change originates almost wholly in these countries, their governments are the ones with an interest in doing something about it. For a *given* world cap on CO₂ emissions, the argument given above suggests that it will be cheaper to achieve the cap if developing countries enter a cap-and-trade system. Since rich countries will be paying for the cuts, they have an interest in making sure they are achieved as cheaply as possible.

A second reason is so-called “leakage”. If some countries cap their emissions and others do not, or set a less stringent cap, energy prices in the countries with tighter caps will rise higher than in the others. As a result, energy-intensive industries will tend to move to

⁴ Organization for Economic Cooperation and Development, comprising 30 high-income countries.

countries without emissions caps, thus undoing the emissions caps to the extent that such industries are mobile. A cap-and-trade system will equalize emissions prices and tend to make energy prices converge among the participating countries, thus preventing leakage.

However, if all concerned are to agree to a such a cap-and-trade system, several conditions must hold. First, the rich-country cap must be tight enough that rich countries cut their emissions below their present levels by enough that it becomes cheaper for them to pay low-income countries to abate on their behalf. It is not clear if there is sufficient public demand for emissions cuts in rich countries for this condition to be met even if low-income countries were to agree to take on commitments to cut their emissions below their BAU paths.

Second, the fast-growing lower-income countries have to take the risk of taking on commitments to cut emissions possibly below business-as-usual in the hope that they will end up making a net profit. The problem is that forecasts of profits from the sale of emission permits are very difficult to make. They depend on the relative costs of abatement in the various countries under different caps, and on the amount by which emissions would grow in the BAU scenario. Economic growth is highly uncertain and so are energy intensities (energy used per dollar of GDP). While the low-income country cap can be set by agreement so that it rises when GDP grows faster than expected, (Frankel 2007), this sort of built-in adjustment cannot be made for energy intensity without taking away the incentive to conserve energy. From the rich countries point of view, bringing developing countries into the agreement will undercut emissions reductions unless the latter agree to quotas that are below their BAU emissions. Uncertainty in the BAU means that developing countries will not agree to any cap that is not close to the upper limit of what BAU emissions could conceivably turn out to be, else they might end up worse off by entering into an agreement. If this cap turns out to be higher than actual BAU emissions, then rich countries could end up paying developing countries for so-called “hot air”, that is, to do what they would have done anyway. They will, of course, be reluctant to agree to such a cap.

Finally, the profits that low-income countries make have to be net of the costs of monitoring and implementation if the whole exercise is to be worth it from their perspective. It should be recognized, however, that while this condition may lower the chances of reaching an agreement, it could actually make one more likely. Businesses that stand to gain from the creation of a new commodity exchange will lobby for it. Governments will have to decide how to allot the emissions permits within their respective countries. These will be valuable assets that politicians can allocate in ways they find congenial. This gives them a strong pecuniary incentive to enter an agreement, especially in countries where they are not tightly constrained by political institutions and public opinion. Of course, the cost to politicians of entering such an agreement is that it will raise energy prices. This could be politically damaging for them if the sale of permits does not raise enough revenue that can be used to compensate politically relevant losers.

3. Global cap and trade and human welfare

The discussion so far has touched on the factors that make an international cap-and-trade regime with developing country participation more or less likely, but not on its

consequences for human welfare. The prospective benefits of such an international agreement for emission reduction are twofold: In the first instance, getting developing countries in will result in a greater overall emission reduction (compared to BAU). This may be amplified by more stringent quotas in rich countries, since the cost of achieving a given quota may be lower if emissions permits can be bought from developing countries at a price below the cost of emission reduction in the rich country. Rich country governments may be willing to tighten their own quotas if their firms can buy permits from developing countries and thus cushion their own firms and consumers from too great an increase in the price of energy. By preventing “leakage”, the agreement may make rich countries more willing to tighten their caps.

Second, tightening the global CO₂ emission quota will expand the market for carbon-neutral and low-carbon energy. This will increase the expected return to R&D in carbon-neutral technologies. As argued above, it is this dynamic effect that is most important in terms of actually reducing the risks of climate change.

Would an international cap-and-trade agreement add credibility to individual countries’ announcements about emissions caps in future years? If so, then this would be a strong argument in its favor. A major disincentive for private R&D in carbon-free technologies is the uncertainty about whether governments will follow through on their commitments to cap carbon emissions. If they renege, then the market for carbon-free technologies will shrink, and investments in researching them will have been unprofitable.

Is an international cap-and-trade agreement involving developing countries likely to be credible? Keohane and Raustiala (2008) argue that only wholly self-enforcing agreements are possible, since sovereign states can and do renege when it suits them. If a country does not enforce domestic quotas properly, there is not much that can be done to punish it. They argue in favor of a system of buyer liability to address this potential problem. In short, if it is determined *ex post*, by an international body, or a buyer-country government, that a seller country had emitted more than it had agreed to, then firms in buyer countries that bought emissions permits from that country would get only a suitable fraction of the carbon credits from the permits. This would give issuing countries that were net sellers incentives to enforce quotas so as not to drive down the market price of their permits. This structure depends on the willingness of rich countries to set themselves tight enough quotas, so that they generate a net demand for permits from developing countries.

Ultimately, therefore, the basis for these agreements is the political demand for emissions cuts emanating from rich countries, and it is the forecasts of these emissions cuts that are crucial for the size of the market for carbon-free technologies. The willingness of rich countries to sign an agreement of this nature, i.e., one that calls for them to make steep emissions cuts, would send a positive signal to firms contemplating R&D about the current political demand for cuts, and therefore, also about likely future demand for their products. It could, therefore, stimulate R&D. Crucial to this conclusion, however, is the nature of that agreement. It would have to be self-enforcing, or credibility would be lost.

To summarise, a cap-and-trade agreement with developing countries can only be credible if the developed countries first demonstrate their willingness to pay for it. This they can only do by adopting cap-and-trade themselves and committing themselves to cut

emissions significantly in the years immediately following the end of Phase I of the Kyoto Protocol. These must be actual cuts, not just slower emissions growth, else there are unlikely to be significant gains from international emissions trading.⁵ Having done so, they can then ask developing countries if they wish to opt in to the system by taking on small cuts relative to BAU.⁶ At this stage, some of the developing countries may find it profitable to join the system.

All this assumes that developing countries have or will acquire the capacity to set up a credible domestic cap-and-trade system. This assumption is unlikely to hold in many developing countries with corrupt governments and weak institutional capacity. Entering a cap-and-trade system will raise energy prices, and unless there is a credible way to share the profits from selling permits to foreigners with those affected by higher energy prices, there will be domestic opposition to the agreement. Unless at least those groups with political influence can be credibly compensated, or more than compensated, for energy price increases, a government may find it impossible to enter, or to follow through, on a cap-and-trade system.

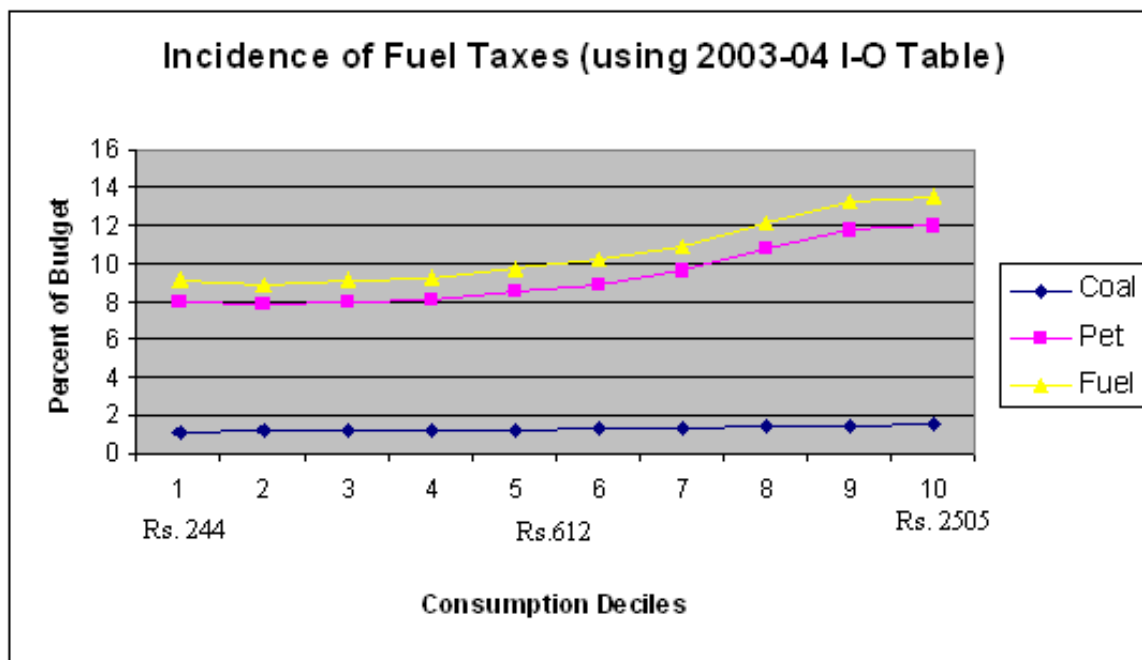
The problem, of course, is that low-income country governments are mostly characterized by high levels of corruption and low institutional capacity. This is at least a part, and very likely a large part, of the reason why their countries' incomes are low. In fact, matters could get much worse than merely having energy prices increase. During the course of writing the last few pages, sitting here in my office in New Delhi, the power supply has failed several times, and the campus has switched to its back-up diesel generator. This is a symptom of a badly governed and poorly regulated electric supply and distribution system dominated by extensive political interference. India as a whole suffers from chronic power shortages and blackouts. In this context, if power companies (whether public or private, India has both) get an incentive to supply less electricity, so as to be able to sell more emissions permits, they might end up actually rationing consumers even more. Outcomes such as these might make it politically untenable for the government to continue with a cap-and-trade system.

Turning to the impact of higher prices for fossil fuels on the poor, I first note that they will, on the whole, be quite progressive, because fuels account for a higher share of expenditures for higher-income households (Datta 2008).

Figure 1: Budget shares of fuel in India in 2004-05 by consumption expenditure decile, accounting for its use as an intermediate input. Reproduced from Datta (2008). "Pet" denotes Petroleum.

⁵ As explained earlier, it is cheaper to prevent emissions from growing than to reduce emissions because the former can be achieved by installing new equipment that emits less GHG's while the latter entails scrapping old equipment before the end of its useful life in addition to installing new equipment. If developed countries stop their emissions growth and start reducing emissions, it would at that point be cheaper to pay developing countries to slow their emissions growth instead.

⁶ These cuts would eventually have to get much bigger once a country grew sufficiently rich or reached a sufficiently high per capita emissions quota. The determination of just how this "graduation" should occur would, of course, be subject to conflicting interpretations of fairness, and, therefore, to bargaining.



This pattern exists because the poor in a low-income country are too poor to use mechanised transport much, and because the goods that the poor consume are less energy-intensive, on the whole, than those consumed by those who are better off. This progressivity should make it easier to protect the poor. If the government cut indirect taxes that have a greater incidence on the poor, then this could compensate them for the rise in fuel prices. It is, of course, not at all clear, whether this or any other compensation would actually happen.

Figure 1 shows that coal accounts for less than 2 percent of the budget of Indian consumers. Since cap-and-trade schemes are likely to focus on coal, it may appear at first glance that the impact of a rise in the price of coal on the welfare of Indian consumers may not be very large. But this is not the whole story. Most Indian households still use traditional solid fuels like firewood for cooking. In the year 2000, about 70% of Indians used such fuels (Gangopadhyay, Ramaswami et al. 2006). Combustion of solid fuels on traditional stoves releases fine particles and gases that have adverse health effects. A review of the evidence concluded that indoor air pollution from the use of solid fuels for cooking resulted in about half a million excess deaths of women and children per year in India (Smith 2000). Economic growth will bring a transition to sources of household energy such as cooking gas and electricity that do not emit particulate matter and other local and regional air pollutants. Any rise in energy prices and any prolongation of electricity rationing that delays this transition will prolong the excess deaths and ill health.

In addition, solid fuel use in India is large enough to generate regional climate effects arising from the production of particle matter that leads to the formation of a brown cloud of aerosols that may be up to three kilometers thick. More than 40 percent of the black carbon in the atmosphere over South Asia is estimated to arise from cooking fires (Venkataraman, Habib et al. 2005). The aerosol cloud has been estimated to reduce the summer monsoon and, consequently, rice harvests in India by 10 percent (Auffhammer, Ramanathan et al. 2006). Soot in the cloud heats the upper atmosphere (Ramanathan,

Ramana et al. 2007) and some of it is deposited in Himalayan snow and glaciers. Although there is no firm evidence of this, it seems likely that upper atmospheric heating will contribute to glacial and snowpack melt, as will the deposited soot. The latter has contributed to the melting of the Greenland icepack even though there is far less particulate pollution in that region (Hansen and Nazarenko 2004). If Himalayan snowpack and glacier melt driven both global greenhouse gas accumulation and by regional particulate pollution continues for more than a few decades it will lead to a sharp reduction in winter flows in northern Indian rivers. This could cause major declines in agricultural production in an already poor and densely populated region that is projected to add hundreds of millions of people to the population during the course of this century.

There is thus the distinct possibility that a cap-and-trade agreement involving India, by delaying a reduction in atmospheric black carbon, could end up making a majority of Indians, especially the poor, worse off. Although the details of such worries about the effects of carbon trading are specific to India, its general form applies to many low-income countries.

Similar concerns apply to the possibility of linking emissions markets in developed countries to markets for reduced emissions from deforestation and degradation in tropical countries. NGO's have already expressed the fear that logging companies will use the threat of clear felling to extract any rents that arise from such trading. Politically weak forest dwellers and indigenous peoples may face eviction from forest lands if these acquire value as a consequence of the creation of emissions markets (FOEI 2008).

However, markets for reduced emissions from deforestation and degradation (REDD), as well as markets for afforestation, may have a better chance of working than those for industrial emissions reductions, simply because monitoring can be done more cheaply with modern satellite imagery, supplemented by ground surveys. If agreements are based on buyer liability, then agencies external to the seller countries will evaluate effectiveness as well as the protection of the rights of vulnerable groups. The same NGOs that are today protesting the introduction of these markets may then perform the valuable function of monitoring them to prevent land grabs and other injustices. It is not clear whether this would afford sufficient protection to vulnerable groups, but it is a possibility. It is certainly true that in some high profile cases, activist groups in the North have succeeded in forcing the World Bank to withdraw from financing projects that would have displaced vulnerable populations in poor countries. The case of the Narmada dam in India is an outstanding example. In that case, the government went ahead with the dam with domestic finance. When the market is predicated on external finance, which would largely be the case for tropical countries participating in a REDD market, the threat of pullout by buyer countries would presumably provide stronger incentives to seller countries to abide by conditions stipulating fairness.

This sort of external intervention to protect the poor from the consequences of higher energy prices or energy rationing occasioned by low-income country participation in a cap-and-trade scheme for fossil fuel emissions seems far less likely. The victims in those cases will be neither easy to identify nor as picturesque.

4. What should an agreement aim for?

Given these dangers posed by emissions trading for the vulnerable in poor countries, it is pertinent to ask whether the prospective benefits are large enough. From the foregoing discussion, this seems to be in doubt. Annual energy-related CO₂ emissions in the OECD between 2010 and 2030 are projected to increase from 14 to 16 Gt in a BAU scenario (EIA 2008). Abating even this 2 Gt increase would very likely ensure quite a large market for new technologies, and the OECD countries are most likely to set more ambitious targets, thus ensuring an even larger market for the new technologies. If they did not, then cap-and-trade with developing countries would, in any case, be unattainable.

I conclude that an international climate agreement involving the developing countries is of secondary importance to solving the climate problem. Of primary importance is the creation of markets for carbon-neutral technologies in the OECD countries, whether by tax, tradeable permits, or traditional regulation, and an increase in direct financial incentives for R&D. Global public energy R&D investments have halved in real terms since their peak in 1980 following the second oil shock (Stern 2007), Chapter 16). This means, of course, that as a share of GDP, the fall has been even greater. In the case of the United States, the largest spender, public energy R&D's share of GDP in 2005 was less than one-third of what it was in 1980. And private energy R&D also fell, though not as sharply. Indeed, the evidence suggests that public R&D stimulates private R&D rather than crowding it out (Nemet and Kammen 2007). This is, of course, exactly what we would expect basic research to do. Nemet and Kammen argue that a five to ten-fold increase in energy R&D in the US is both feasible and desirable.

There is, as yet, little public support for the price signals that economists advocate as the efficient method of dealing with the carbon externality. The American public, for example, doesn't like higher taxes on gasoline if the object is the economic one of reducing consumption of energy. But a majority does support higher taxes on gasoline, *if* the revenues are used for R&D for new non-polluting energy sources.⁷ Given this pattern of public opinion, it seems difficult to argue that raising energy prices through cap-and-trade or any other tax, disguised or not, should be the main instrument of public policy. As noted above, in order to stimulate private investment in R&D in alternatives to carbon, certainty about the future market is desirable. Relying solely on price incentives in the face of opposing public opinion does not appear to be a realistic way of inducing certainty. Clearly, increasing funding for energy R&D is a policy that is more likely to receive consistent public support simply because it is a mechanism the public understands. This can take the form of an expansion of funds allocated through the usual peer-review process to universities and government research laboratories for basic research in the whole gamut of activities that may contribute to emissions reduction and sequestration. It should also include support for large projects such as carbon capture and storage or new electric power transmission systems that may require private sector collaborations.

(Anderson 2006), in a background paper for the Stern Review, reviews a range of carbon-neutral technologies and suggests that some are likely to become cheaper than the

⁷ NYT (2004). New York Times/CBS News poll, April 20-24, 2004. <http://nytimes.com/polls>.

relevant fossil-fuel option by 2050 and possibly sooner. Several are expected to become economical at modest carbon prices and some, such as nuclear power, are already in use on a large scale. It is relevant to observe that the probability that some subset, and in particular, at least one of them will become cheaper than the fossil fuel option is greater than any of the individual probabilities. Anderson, moreover, suggests that his estimates are conservative.⁸ As (Goodstein 2002) shows, this is usually the case with prior estimates of the cost of achieving any given environmental target. This is because the new technology that is stimulated by the target is very often unanticipated.

I conclude that government support for increased R&D can reasonably be expected to deliver lower costs for alternatives to CO₂ emitting energy sources. It has the advantage that resources are truly committed because they are spent now, rather than being promised in the future. R&D induced by appropriate policies is thus a realistic way of making it economical for all countries, including developing countries, to reduce their CO₂ emissions. It accomplishes what is necessary, a transfer from rich to developing countries to induce the latter to cut emissions, albeit with some delay, in a manner that is most likely to be acceptable to the public in the developed world.

A new agreement will take advantage of those domains in which there is public support for domestic action in the various countries. In developed countries, this means cap-and-trade, a greatly increased financial commitment to R&D, and expansion of existing labeling and standards to promote energy efficiency.

In developing countries in which there are chronic shortfalls of electricity, and an increasing import bill for petroleum, there is considerable interest in improvements in energy efficiency.⁹ An international agreement can facilitate information and technology flows in this domain. A formal agreement for the sharing of expertise and information between the agencies in each country that are responsible for regulating energy, greenhouse gases, and associated pollutants could improve the quality of regulation in many countries. Labeling, smart metering and billing, and other information programs for appliances and energy consumption have been widely used in the United States and the European Union and are estimated to have had a considerable impact on energy consumption (Stern 2007).

One issue that arises immediately is the prospect of shifting baselines. Countries anticipating being sellers in a global cap-and-trade scheme may want to postpone emissions reductions until they can be paid for them (Narain and van 't Veld 2008). With regard to energy efficiency, this may not be a serious problem in practice because postponements are immediately costly for the countries concerned, while the prospect of profits from emissions trading are highly uncertain. Developed countries could help this process along by committing not to disadvantage countries that put energy efficiency measures into place relative to those that do.

⁸ He has already been proven correct in at least this part of his story. His baseline estimates assume an oil price of \$30/barrel, with another scenario using a price of \$50/barrel. The price at the time of writing is about \$70/barrel.

⁹ For example in 2001, India passed an Energy Conservation Act creating a Bureau of Energy Efficiency that is supposed to advise government regulators and disseminate information.

In the case of equipment and appliances, technology is largely embodied in machines. The information problem arises because consumers find it hard to evaluate the energy costs that will accrue after purchase of the machine.¹⁰ Labeling programs and standards can, therefore, address this problem. In the building sector, however, technology has to be disseminated to builders and architects, in addition to information being given to consumers. In this sector, therefore, funds are needed for information dissemination. The technology fund proposed by the Government of India (GOI 2005), to be financed by all countries, could be used for this purpose, among others.¹¹

Urban transport is another sector in which information sharing and financial support to local authorities might make a significant difference to carbon emissions. The world's urban population is expected to increase from 3 billion to 5 billion by 2030, with nearly all the increase occurring in developing countries (UN 2004). Planning and good design of public transport could greatly reduce the increase in carbon emissions and prevent a lock-in to a motor vehicle intensive pattern of development. While urban governance in developing countries is often dismal, there is a felt need for reduction in traffic congestion and pollution. For example, the Confederation of Indian Industry has been trying to promote public transport improvements in many Indian cities, since traffic congestion is proving to be very costly for its members (CII 2007). Creation of an international body that would provide information and expertise to local authorities on these issues could promote the diffusion of successes in urban transport planning.¹² Financial support for demonstration projects would accelerate the process. The emphasis should be on the financing of public projects that are very well-monitored and can be modified after study, and then scaled up.

Perhaps the most important sector in which international information exchange and technological cooperation is needed is in agriculture. Developing country governments have stressed the importance of adaptation to climate change as an issue in any international agreement because they will be affected earlier and more severely than developed countries even if mitigation succeeds in holding the global mean temperature increase to 2 degrees Celsius or less, a target that appears increasingly unlikely (GOI 2008). Agriculture is the sector in which, perhaps more than in any other, research has a public good characteristic. With the exception of a few inputs such as hybrid seeds and fertilizers, technology is disembodied rather than embodied in products. Firms are farms, in developing countries, typically very small farms. As a result, the externalities associated with a new disembodied technology are enormous. Moreover, when such technologies include a package of

¹⁰ Consumers appear to systematically under-estimate costs they will incur in the future. See Stern (2006, Section 17.2) and the references therein. In other contexts, firms take advantage of consumer myopia by locking them in to future purchases of supplies after offering a discount on the up-front purchase of equipment Gabaix, X. and D. Laibson (2006). "Shrouded Attributes, Consumer Myopia, and Information Suppression in Competitive Markets." *Quarterly Journal of Economics* **121**(2): 505-540.

¹¹ The government of India's proposal is for a fund to finance technology transfer to developing countries. It leaves open the issue of relative contributions to the fund. It also proposes a new network of research institutes for energy issues modeled on the CGIAR (Consultative Group for International Agricultural Research) network to be financed by developed and developing countries.

¹² Diffusion of "best practice" policies is discussed in Aldy, J. E. and R. N. Stavins (2008). The Role of Technology Policies in an International Climate Agreement, The Harvard Project on International Climate Agreements.

complementary practices, diffusion and learning may not be easy. Thus the public sector takes on a crucial role.

As the climate changes, farmers will be able to adapt only to a limited extent with existing technologies, and, in much of the tropics, conditions will become much less favourable. In these circumstances, technological progress in agriculture that anticipates the conditions to come is critical (Brown and Funk 2008). Food security in South Asia and Africa are most seriously threatened by climate change so international funding and technology transfer for these regions' crops should be an important part of any international agreement (Lobell, Burke et al. 2008).

Agricultural research is also needed to address possibilities of reducing greenhouse gas and black carbon emissions from agriculture. The latter are significant in South Asia (Venkataraman, Habib et al. 2006). Agriculture's "economic potential" contribution to greenhouse gas reduction by 2030 is estimated to be comparable to that of energy supply and second only to that of buildings (IPCC 2007b). For example, recent research (Marris 2006) suggests that the addition of charcoal to soil can increase fertility. Since this is a stable form of carbon, it can also be used to sequester carbon from biomass that would otherwise be returned to the atmosphere. It is necessary to ensure that an expansion of the mission of international agricultural research to include climate mitigation is well-funded, else it could actually subtract resources from the original and primary object of raising food output.

An agreement can require developed countries to increase their funding for international agricultural research, for example, to the CGIAR group of institutions that was so important for the Green Revolution. It can require developing countries to make matching investments in their own national agricultural research systems and in their agricultural extension services so that the new techniques can diffuse faster.

I summarize my conclusions as follows. It is not at all clear that it is either necessary, desirable, or realistic for developing countries to agree to binding emissions cuts in the next phase of an international agreement. Instead, an agreement should institutionalize technical cooperation between all countries and financial support from the developed world for the spread of technologies and practices that would cut emissions in developing countries. Energy conservation in building, transport, and industry, and technical progress in agriculture are areas in which developing countries would see significant co-benefits from emissions cuts, so these are areas that should be included in an agreement.

The major action that is needed to realize the necessary huge emissions reductions over the next few decades is the promotion of research and development that will make low-carbon and carbon-neutral energy sources competitive or nearly competitive with fossil fuels. The developed countries will have to promote this development not only through domestic regulation, taxes, and tradeable permits for fossil fuel use, but also by committing more government funds to research and development of non-carbon energy sources.

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