India and a Carbon Deal

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There is now a growing consensus among governments that aggressive climate change mitigation is desirable, though they remain bitterly divided about how the associated burden should be shared. India's stand in climate negotiations, like that of most developing countries, has been largely negative. This paper examines the importance of a cap-and-trade mechanism as the keystone of a global mitigation agreement and estimates the cost of abating carbon in power generation in India, if and when carbon capture and sequestration technology becomes available for deployment. It concludes that India should be ready to reconsider its position and negotiate to join a mitigation treaty, say in 2020, if it can secure a fair deal.

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1 Introduction

There is now a growing consensus among governments that aggressive climate change mitigation would be desirable, though they remain bitterly divided about how the associated burden should be shared.[1] India's stand in climate negotiations, like that of most developing countries (DCs), has been largely negative. The government of India has made a commitment that it will not allow the country's per capita emissions to rise above per capita emissions in the advanced countries (ACs).[2] But this commitment, however honest and well-intentioned, is vacuous, given India's unwillingness or refusal to join a treaty and take on internationally agreed binding targets. We argue that India should reconsider its position and negotiate to join a mitigation treaty, say in 2020, if it can secure a fair deal.

We take it for granted in this paper that aggressive mitigation would be desirable from a global perspective.[3] An important India-specific point should be noted, however. India is more vulnerable to climate change than the US, China, Russia and indeed most other parts of the world (apart from Africa).[4] The losses would be particularly severe, possibly calamitous, if contingencies such as a drying up of north Indian rivers and disruption of monsoon rains came to pass.[5] Consequently, India has a strong national interest in helping to achieve a global climate mitigation agreement.

The current state of play regarding global action on climate mitigation can be summarised as follows.

– The Kyoto Protocol emissions target for 2008-12 agreed on by ACs will almost certainly not be met.

– ACs' (Annex 1) emissions in recent years have increased in absolute terms and in per capita terms (Government of India 2008d).

– Except for the flow of funds through the Clean Development Mechanism (CDM), ACs have done practically nothing to alleviate DC anxiety that they will not be helped financially – adequately in a predictable and sustainable manner – for meeting the (seriously) expensive twin challenges of mitigation and adaptation.

– The recent European Union (EU) 20-20-20 commitment may come to rely substantially on offsets from DCs rather than actual reduction in emissions.[6] (EU plans for combating global warming are reminiscent of Soviet planning – missed targets have spurred even more ambitious ones the next time round.)

– Not much by way of material and durable outcomes can be gauged, in terms of emissions reduction from current levels, until 2020 or thereabouts.

The plan for the rest of the paper is as follows. Section 2 outlines the criteria that a global mitigation agreement would need to satisfy and explains the importance of a cap-and-trade (CAT) mechanism as the keystone of that agreement. Section 3 emphasises the inescapability of ethics in determining the fair distribution of the costs of mitigation and argues that there is a strong moral case for all or most of the global costs being borne by ACs. Section 4 discusses the implications of some specific permit allocation schemes under CAT, reviews recent attempts to model them, and the financial transfers that are implied. Section 5 reviews India's energy and emissions profile, with particular reference to the electricity sector, and highlights the country's energy (electricity) challenge. It also draws attention to the fact that India is an efficient user of energy (in broad gross domestic product – GDP – terms), and is not averse to imposing taxes on energy. Section 6 attempts, against the background of a wide dispersal of "global/macro" estimates of abatement costs,[7] a bottom-up calculation for a key Indian sector – specifically, coal and natural gas fired power generation – of the cost of abating carbon if and when carbon capture and sequestration (CCS) technology becomes available for deployment.[8] It also examines ways to finance CCS-inclusive investment in India's power sector through a mitigation treaty or via an expanded CDM. Section 7 sets out our concluding thoughts on India's negotiating position in future climate mitigation bargaining.

2 Architecture and Instruments of Global Policy

A global policy framework for mitigation must satisfy certain basic widely agreed criteria. These are outlined below in an order that reflects expositional convenience, not intrinsic importance.

First, the framework should be global and comprehensive; in other words, it must cover all countries, or at least all significant emitters. The Kyoto agreement glaringly failed to do so since the US did not join it. In future agreements, the participation of the US and Europe will not be enough. The DCs need to be brought in because they are expected to contribute two-thirds of global emissions in the rest of this century in a business-as-usual (BAU) scenario. A comprehensive agreement is important for two further reasons. The first is the problem of "leakage". An agreement with partial coverage would lead to the migration of carbon-intensive industries to non-participants, thereby negating the emissions reductions in participant countries. The second is that if significant trading partners are excluded, competitiveness concerns would erode the willingness of companies in the participating countries to comply with emissions targets.

The second criterion is that the framework should be efficient. Therefore, it should operate predominantly through the market and strive to achieve a worldwide common price for emissions. This would lead both to cost-effective emissions reduction and to appropriate price signals for the development of carbon-clean technology. But there remains an important choice: whether the common emissions price should be achieved by a globally uniform carbon tax (CT) or a global CAT system. We discuss this further and conclude that, for the most part, CAT scores heavily over CT overall, and especially so from India's standpoint.

Third, the framework should be equitable. The major equity issue concerns burden sharing. Mitigating global warming is costly. Distributing the cost fairly is important on moral grounds and also for obtaining participation and compliance by nation states. It is not easy to specify or agree on what is "fair" but that issue cannot be evaded. In practice, there will doubtless have to be a compromise between fairness and realism.

The fourth criterion is that the framework should be enforceable. It must have some meaningful disincentives for non-compliance.[9]

We discuss the equity criterion in some detail in the next two sections since it is critical in considering India's participation. In the rest of this section we focus on a major issue highlighted earlier. Should the centrepiece of the mitigation framework be a globally harmonised CT or a global CAT system of emissions permits? A globally uniform carbon price set at the right level would induce economic agents to carry abatement to the point where its social marginal cost equals its social marginal benefit. Under certain "ideal" conditions, it does not matter for efficiency whether this uniform price is achieved by a CT or CAT. The incentive to save energy and to innovate would be the same under the two alternatives if the CT is set at a level that induces a volume of emissions equal to the cap on the quantity of carbon emissions rights or permits under CAT. However, under non-ideal conditions, the effects of a CT and CAT differ. Two of these qualifications are particularly important. The first relates to uncertainty, for example, about the costs of abatement. If costs change, a CT keeps the price of carbon unchanged but leaves the quantity of abatement undetermined. CAT fixes the quantity but leaves the price undetermined.[10] It may be thought that CAT is preferable in the climate change context since a quantity mistake would be especially dangerous. Then again, this consideration is not of great significance because the tax rate could be changed periodically. (Certainty about the flow of emissions in a specific period is not critical since what ultimately matters is the stock of emissions, and that changes slowly.) The second non-ideal consideration is that administrative costs, as well as corruption, are likely to be higher with CAT than with a CT. On balance, a CT would probably be preferable to CAT, if efficiency were the sole objective.

Efficiency is, however, only one desideratum of a good climate change regime. The overwhelming superiority of CAT with respect to equity and compliance issues trumps any efficiency advantages that a CT may possess. In a CAT system, trading of any initial allocation of permits would lead to economic efficiency. This extra degree of freedom means that the allocation can be chosen to deliver equity as well as to offer inducements for compliance. The implied transfers would take place automatically as part and parcel of the working of the carbon trading market. With a CT, a uniform international tax would have to be agreed on – difficult enough but only half the battle. Other aims, including equity, could only be achieved by explicit, visible, government-to-government transfers, which would be impossible politically to deliver.

Since an equitable burden-sharing arrangement is the indispensable condition of Indian participation in a climate treaty, it is clear that India's interests would be much better served by CAT than a CT. Luckily for India, it is probable, given the head start that CAT has had in Europe and the US, that it will be "the only game in town" in future climate negotiations.

3 Ethics of Burden Sharing

A global climate change agreement has to be equitable; it must spread the cost of supplying the public good of mitigation justly and fairly. Philosophers have argued since time immemorial about the concept of justice without agreeing on any overarching theory. Even so, a strong moral case can be made for the proposition that ACs should pay all the costs of global mitigation, "strong" in the sense that it can plausibly be based on several different and competing theories of justice, namely, libertarian, utilitarian and egalitarian.

Libertarian justice consists of nothing more or less than the protection of individuals' natural rights, including the right to property. But the atmosphere is common, not private property. Its finite safe capacity is a resource that belongs to all human beings but was expropriated in large part by the ACs. It then follows, on libertarian grounds, that the DCs should be compensated for this loss.[11] Hence, the burden imposed by climate change mitigation should be borne by the ACs. For utilitarians, justice consists in maximising the sum total of utility. On the reasonable assumption that an extra dollar is worth a lot more to the very poor than to the very rich, it follows that there should be large transfers from ACs to DCs. A fortiori, the ACs should bear the costs of global climate change mitigation. Egalitarians, unlike libertarians and utilitarians, are foundationally in favour of redistribution from the rich to the poor. Some egalitarians invoke positive rights to a minimum standard of living. Others, like John Rawls, argue that justice consists in maximising the welfare of worst-off individuals. Either way, given the extent of abject poverty in the DCs, it is clear that egalitarian theories would endorse the ACs defraying the whole cost of global mitigation.

This conclusion about the relation between moral theories and burden sharing between ACs and DCs rests on two assumptions. They are reasonable but need to be highlighted. The first is that the domain of justice embraces the whole world, not the nation state alone. This is reasonable, given the fact and the perception of growing global interconnectedness. A wholly state-centric view is no longer morally salient. As the preceding paragraph indicates, even a weakly cosmopolitan moral outlook is sufficient to reach the conclusion that the ACs should shoulder the costs of climate mitigation.[12] The second assumption is that climate-related redistribution from ACs to DCs would actually reach and benefit poor people in DCs, despite some leakage along the way. This is not an unreasonable basis for international policy, even if we grant that there are a few DCs with blatantly predatory governments.

4 Allocation of Emissions Permits

We have seen in Section 2 that a global CAT system would achieve efficiency, whatever the initial distribution of emissions permits. That leaves the critical issue of how to allocate permits in a manner that satisfies equity criteria but is also realistic.

Given a global cap, the boundaries of allocation can be established fairly easily. One extreme is to allocate permits on a status quo basis, that is, either in proportion to current emissions or emissions in, say, 1990. This alternative can be dismissed as thoroughly unjust. It offends against every moral principle discussed in Section 3. DCs could not be expected to accept such a blatantly unfair scheme. The other extreme is to allocate all permits to DCs. Since the ACs would then have to buy permits for all their emissions from DCs, this would imply a large transfer from ACs to DCs, well in excess of what the latter would need to compensate them for the costs imposed on them by a high carbon price. Though this could certainly be justified on the basis of the theories outlined above, it is unrealistic in a world in which even the 0.7% of GDP target for foreign aid remains massively underfulfilled. The allocation of permits in the "bargaining zone" between the above two limits will be determined by hard negotiation in which both moral considerations and naked self-interest will play their parts. ACs can be expected to resist and DCs to favour allocations that depart drastically from the status quo in emissions. The politics of bargaining will also involve other considerations such as vulnerability to climate change. The less vulnerable a country, the stronger its bargaining position since it would lose relatively little by walking away from a deal.

Consider allocation schemes in the bargaining zone. Allocations based on per capita incomes and equal per capita emissions are morally appealing since they would favour poor and populous countries respectively. But they would imply unrealistic bargaining outcomes since they would lead to very large transfers to DCs. A much more realistic criterion would be to allocate just enough permits to each DC to prevent any future loss it would suffer from undertaking climate mitigation. We are strongly attracted to this criterion as a reasonable compromise between fairness to DCs and acceptability to ACs. The criterion looks complex but can be implemented empirically. A model that does so is discussed below.

The model developed by Jacoby et al (2008) compares the welfare effects of different permit-allocation schemes and the implied financial transfers from ACs to DCs, given a global target of reducing emissions to 50% of the 2000 baseline by 2050. We concentrate here on the results for India of four alternative schemes of allocation. Table 1 presents the figures for 2020 and 2050. Alternative (i) has status quo allocations (as of 2000) for ACs and DCs, which are linearly reduced by 2050 to 30% of the baseline for ACs and 70% of the baseline for DCs. This alternative is similar to proposals currently being bandied about by the ACs. For India, it implies a welfare loss of 4.9% of GDP in 2020 and an annual inflow of only $10 billion from the sale of permits. It is clear that India should reject such a scheme. Alternatives (ii) and (iii) allocate permits to ACs and DCs on the basis of per capita emissions and per capita income respectively and these criteria are of course highly favourable to India. For example, the per capita income criterion leads to a welfare gain for India of 39% of GDP and an annual inward transfer in excess of $400 billion in 2020. There is no realistic chance of any such scheme being agreed on. Alternative (iv) is the one we regard as particularly noteworthy. It consists of allocating to each DC just enough permits (endogenously determined by the model) to compensate it for the expected future welfare loss from climate mitigation policies. This

Table 1: Effects on India in 2020 (2050) of Different Permit-Allocation Schemes

	Alternative (i)	Alternative (ii)	Alternative (iii)	Alternative (iv)
Permit allocation				
(2000 emissions = 100)	98 (70)	265.4 (147.1)	405.2 (224.6)	127.6 (93.3)
Welfare effect (% of GDP)	–4.9 (–11.4)	20.9 (21.0)	39.0 (48.9)	0.0 (0.0)
Net transfer ($ billion)	10.1 (14.7)	232.7 (513.9)	439.7 (1056.3)	51.8 (176.4)

Source: Jacoby et al (2008).

criterion produces an inward transfer to India of about $50 billion in 2020, a figure that is reasonably realistic. We also commend the model developed by Frankel (2008), which explicitly incorporates politically realistic constraints on permit allocation and yields results that may be acceptable.

Of course these models are only as good as their assumptions, so their results have to be taken with several pinches of salt. They suffice to show, however, that models can be built to accommodate pragmatic restrictions and produce solutions that may potentially be acceptable to all sides. Although permit allocations instantly geared to equal per capita emissions or permanently geared to current emissions would doubtless be unacceptable to ACs and DCs respectively, there is a large grey area between these boundaries which would be amenable to bargaining and negotiation.

5 Under-Provision of Energy in India

Asking India (or, for that matter, DCs more generally) to "contribute" towards emissions reduction, essentially by making energy more expensive (in the absence of financial compensation) is hardly tenable from any conventional dimension. Consider the following.

– The Indian power sector has about 1,60,000 megawatts (MW) of installed capacity, but its per capita electricity consumption is still among the lowest globally; for example, about a third of China's (Patel and Bhattacharya 2008 for a recent analysis of India's power sector).

– 44% of the population is without access to electricity (GOI 2008c).

– Over 70% of the energy requirement of households (mainly for cooking) is satisfied by fire wood and dung cake, which result in eye infections and respiratory problems linked with indoor pollution (GOI 2006); the large health externality (not to mention, the resultant output loss) may warrant a household subsidy for fuel stoves and for liquefied petroleum gas (LPG) and kerosene.[13]

– India consumes 16 million British thermal units (MMBtu) of primary energy per capita/year compared to 56 MMBtu in China, 335 MMBtu in the US and a world average of 72 MMBtu.

– CO_2 intensity in tonnes/million 2000 \$ GDP is 287 for India, 544 for the US, 693 for China and 383 for Organisation for Economic Cooperation and Development (OECD) Europe (EIA/IEO 2008).

– India imposes significant energy taxes.

Not only is India's recent emissions performance creditable, but even the BAU scenario for the period up to 2030 makes it clear that India will continue to be a relatively frugal consumer of energy on both a per capita and an output basis.[14]

Table 2: Estimates of Energy Sector Tax and Subsidy Aggregates (Rs crore)

	2006-07	2007-08
Taxes		
Petroleum related:		
Central excise duty	58,821	54,769
State sales tax	53,949	55,677
Customs duty	10,043	12,625
Other central taxes	4,822	12,569
Other state taxes	6,006	6,789
Tax and duty on electricity	8,559	9,052
Natural gas related [a]	2,400	2,500
Coal related [b]	3,025	3,500
Total	1,47,625	1,57,481
Subsidies		
Petroleum	48,000	73,000
Electricity	34,800	34,400
Natural gas [a]	16,800	18,700
Coal [b]	0	0
Total	99,600	1,26,100

[a] Domestic production of natural gas accounts for about ¾ of total consumption. India consumed in 2006-07 and 2007-08, respectively, 31,368 million metric standard cubic metres (MMSCM) and 34,328 MMSCM of gas. The (weighted) average ex-terminal price of gas sold in India is estimated at \$3.1/MMBtu (2006-07) and \$3.3/MMBtu (2007-08); the average international price – using the Henry Hub Index – is \$6.6 (2006-07) and \$7.3 (2007-08). For estimating the indirect tax burden on natural gas consumption, we have used a composite/weighted average rate of 16.5% (comprising state sales tax, central sales tax, and duty on imports, but excluding service tax on transportation and regasification services).

[b] India produces about 450 million tonnes of coal. The average price of coal supplied to the National Thermal Power Corporation (NTPC) in 2007-08 is estimated to be Rs 1,800/tonne (about \$45/tonne), which we have assumed is valid for all customers (NTPC consumes 27% of domestic coal production, and about 70% of domestic production is used for electricity generation). The average calorific value of Indian coal is 3,500-4,000 kcal/kg, which is comparable to low-quality Indonesian coal (4,200 kcal/kg at a price of \$30-38/tonne for 2007-08).The average price of coal supplied to NTPC in 2006-07 is estimated at Rs 1,750/tonne (about \$39/tonne); and the average price of low quality Indonesian coal in 2006-07 was about \$28-31.5/tonne. Coal-related tax revenue reported in the table is an (interpolated) estimate and comprises only royalty payments by national coal companies. It is an underestimate since the figure does not include mining-related cesses and taxes (like entry tax, among others) imposed by various state governments at diverse rates, as also customs duty by the central government on imported non-coking coal.

Sources: Union Budget documents at finmin.nic.in, GoI (2008a, 2008b), ppac.org.in, Ministry of Coal web site.

There is a perception that energy consumption in India is (highly) subsidised (WEO 2008). Concurrently, availability of power at a reasonable price is often cited as the most important constraint to India's (industrial) growth prospects by foreign and domestic investors. While subsidies constitute one part of the fiscal overlay on the energy sector, taxes are another. We aggregated all energy-related taxes (that we could figure out) and compared the magnitude with (actual and implicit) subsidies on petroleum products, natural gas, electricity and coal. It turns out that taxes on energy account for over a quarter of national indirect tax revenue, and close to a fifth of total (direct and indirect) tax revenue. Overall, the hydrocarbon sector is taxed even after deducting subsidies, albeit with sub-segments treated differently (Table 2).

In net terms, the petroleum sector is taxed most heavily, electricity consumers enjoy the largest subsidy,[15] and coal consumption is not subsidised. Against this background, any questioning of India's effort towards curtailing emissions would need to recognise, inter alia, the contribution to "net carbon taxes" of the present (and past), often heavy, taxation of energy (Nordhaus 2005 and Frankel 2007). A rough and ready proxy calculation indicates that the net taxation on petroleum entails an "emissions tax" of about \$49/tonne of CO_2 emitted from this source in 2007. On the other hand, emissions from coal are (implicitly) "taxed" at around \$1 per tonne, and for the energy sector as a whole, emissions (on average) are "taxed" at about \$6/tonne.[16]

6 Inescapability of Coal

(a) (i) Abundance, Affordability and Energy Security: Given the legacy of the extant energy profile, the overall energy demand growth in emerging markets, and the broad availability and evolution of prices, it is accepted that despite an increasing use of renewables, fossil fuels will continue to comprise a significant part of the global energy mix until 2030 (even for developed blocs like Europe and the US).[17] The single largest fossil fuel in the energy mix is coal, at 40% of global energy consumption. Coal has major attributes: (i) it is the lowest-cost fuel source for base load electricity generation; and (ii) coal endowments are widely distributed around the world; hence, it supports the national energy security objectives of a number of large economies, including India.[18] Coal accounts for three-quarters of India's hydrocarbon reserves, and is the most abundant domestically available primary energy resource other than thorium and solar insolation.[19]

(b) (ii) CCS Abatement Potential: Coal's contribution to total global CO_2 emissions declined to about 37% early this decade (compared to 39% in 1990), but is projected to exceed 40% by 2030. In all scenarios, a major potential contributor to global emissions reduction by 2050 is the curtailment in CO_2 emissions from coal to half or less of today's level and to one-sixth or less of BAU projections.[20] CCS is the only known technology for capturing emissions from CO_2. While many of the component technologies of CCS are relatively mature, to date there are no fully integrated power generation-related, commercial-scale CCS projects in operation (to the best of our knowledge). However, current knowledge gaps do not appear to cast doubt on the essential feasibility of CCS (MIT 2007). According to IPCC's 2005 report on CCS, its economic potential would be 200-2,200 gigatonnes (Gt) of CO_2, or 15-55% of the cumulative global mitigation effort to 2100, under likely greenhouse gas (GHG) stabilisation scenarios of between 450 and 750 parts per million (ppm), in a least cost set of mitigation options. It is worth emphasising that this paper is not espousing CCS as the "silver bullet" technology for carbon mitigation. Rather, the important point is that reputable scenarios for reduction in CO_2 underscore the critical role of CCS in achieving global targets. To their credit, these scenarios deploy a portfolio of technologies and strategies (including CCS) for achieving long-term goals. Needless to say, there is large uncertainty over the timing and efficacy of rolling out these technologies and strategies in the coming decades.

Table 3: Relative Cost of Electricity Without and With CO_2 Capture*

	MIT	GTC	AEP	GE
PC no-capture, reference case	1.0	1.0	1.0	1.0
PC capture	1.60	1.69	1.84	1.58
IGCC no-capture	1.05	1.11	1.08	1.06
IGCC capture	1.35	1.39	1.52	1.33

PC: pulverised coal (super critical); IGCC: integrated gasification combined cycle.
*Results reported in the MIT Coal Study (2007), including from the Gasification Technology, Council (GTC), American Electric Power (AEP), and General Electric (GE).

(iii) CCS Is Very Expensive: CCS in the context of coal necessitates integration of coal combustion and conversion technologies to CO_2 capture and storage. It also entails transportation of CO_2 produced at the coal-fired plant to the injection point at the reservoir site (onshore or offshore). In comparison to a status quo thermal power plant, CCS adds four supplementary costs: (i) installation of capture equipment; (ii) powering the capture process, which results in additional fuel use;[21] (iii) building a transport system; and (iv) storage of CO_2.

Estimates of electricity costs from thermal power generation with CCS exhibit a fair dispersion, albeit around elevated levels compared to the status quo, as indicated in Table 3.

DCs will find it very difficult (if not impossible) to deploy CCS without substantial financial support; they would simply not be able to afford electricity that is likely to be up to two-thirds more expensive than that produced by plants without CCS. Indeed, in the present context, the transfer of technology per se is not the critical issue; the principal challenge is who will pay for (eventually) decarbonising thermal power generation in a country like India. (If the finance were available, the technology could be purchased when it becomes commercially available.)

(iv) Back of the Envelope Calculation for India:[22] During the seven years, 2000-01–2006-07, India's total installed capacity increased at an average annual rate of 4.9% (and electricity shortage intensified), with thermal capacity addition of 4%/annum over the same period (GOI 2008a).[23] If we (simplistically) extrapolate capacity addition at the same growth rate up to 2030, then during the 2020s (when CCS could be commercially available) total thermal capacity addition over the decade would be 77.4 GW. Coal-fired plants of India's largest thermal power utility, the National Thermal Power Corporation (NTPC), on average, emit 820g of carbon/kilowatt hour (kwh),[24] which compares favourably with plants elsewhere.[25]

If we assume a plant load factor (PLF) of 75%, 80% of the capacity is coal-based, 20% is natural gas-based (where emissions/kwh is half of that from burning coal) and 90% of emissions are captured (CO_2 prevented from being released into the atmosphere), then by 2030, 0.338 Gt of CO_2 – about 15% of total energy-related BAU emissions in 2030 – will be captured annually from CCS-enabled plants with an aggregate capacity of 77.4 GW.[26] By way of illustration, at the mid-point of (real) expected CO_2 prices in 2030 of €30-48/tonne ($40-63), 0.338 Gt of CO_2 abated, if compensated fully, could result in an inflow of $17.4 billion (for other scenarios that also comprise a broader range of CO_2 prices, see Joshi and Patel 2009).[27]

In the absence of outright subsidies and grants, the economics of CCS rests on the (expected) price of CO_2, which can vary and, of course, there are no guarantees in a CAT system. However, it may be feasible to design hedging mechanisms/insurance – say, long-dated put options – to alleviate some (tail risk) aspects of price fluctuations in this regard. Among the many x-factors inherent in CCS, including safety (and "live" data from yet-to-be-built industry-scale pilot projects), the potential in India for storing CO_2 underground (natural rock formations, depleted oil and gas fields, and exhausted coal seams) is yet to be comprehensively assessed, but this task need not take an inordinate amount of time. The National Geophysical Research Institute is probably best placed, in conjunction with the Directorate General of Hydrocarbons, to carry out geocapacity surveys.

(v) Financing CCS – Carbon Trading or Enhanced CDM: The continuing importance of coal in the global energy portfolio (especially for electricity generation) implies that development and dissemination of CCS technology is essential for emissions control of any significant magnitude.[28] India's involvement in this process is critical for both it and the world. The main constraint is financial. The cleanest way to break the constraint from India's standpoint would be for it to be a full member of the carbon trading mechanism, but with a generous allocation of permits that would enable it to sell them and buy the relevant technology.[29]

The best, however, should not become the enemy of the good. If India cannot get the right terms to join a mitigation treaty, it will have to obtain financing for CCS via the existing CDM. The CDM is presently the only market instrument in the Kyoto Protocol where DCs participate (China and India are, by far, the largest beneficiaries of the CDM). The CDM has been a modest success in terms of financing mitigation in DCs whereby Certified Emission Reductions (CERs), issued to developing country sponsors who can show that their projects will emit less than the stipulated baseline, can be bought by EU emitters so that the latter can emit beyond their allocation. In the most optimistic scenario, if the current 400-project per year capacity of the CDM is fully successful in terms of both registration and issuance of expected CERs, the resultant annual financial flows to DCs will be in the region of $6 billion at current carbon prices. If CCS is ready for large-scale deployment by 2020, a CCS-specific facility for using the technology extensively in DCs is an option. A relatively uncomplicated course would be to expand the scope of the CDM, call it C-CDM, to incorporate sequestration of CO_2 as an offset that can be traded into a carbon trading system, which will help to increase financial flows to DCs compared to the extant CDM.

7 Concluding Remarks: India's Negotiating Position

India has so far been opposed to joining an international climate mitigation treaty. We think this stand should be abandoned. Climate change mitigation will require a global carbon trading agreement with a tight carbon cap to produce a high price for carbon across the world that would curtail carbon emissions directly and induce large investments in clean-carbon technology. It is in India's interest to help achieve a comprehensive agreement since it is particularly vulnerable to climate change.

Of course India should join a climate treaty only if the terms are right. But India can achieve the appropriate terms and have a real share in controlling the progress of the talks only if it is prepared to negotiate. In a negotiation, India could begin by pushing for permit allocations based on per capita emissions or per capita income. However, this initial move has negligible chance of success. A reasonable fall-back position would be to insist on an allocation of permits with enough "hot air" or "headroom" to compensate India fully for the future welfare cost of undertaking its share of global mitigation. (The allocation would inter alia include making due allowance for the cost of decarbonising electricity generation.) India may also be able to use its offer to negotiate to get other things it wants, both climate-related and climate-unrelated. An example of the former would be long-term adaptation finance. An example of the latter would be a seat on the United Nations Security Council or increased voting power in the International Monetary Fund (IMF). (Note that when Russia joined the Kyoto agreement, it extracted the price of western assistance in joining the World Trade Organisation.)

In sum, India should regard the issue of climate change mitigation as a diplomatic challenge of getting the right terms, not as a bugbear to be feared and shunned. It should declare itself willing to negotiate to join a mitigation treaty, say in 2020, provided (i) the ACs demonstrate their good intent by making significant actual reductions in emissions by 2020; and (ii) the ACs are ready to admit India on equitable terms. The second condition involves agreeing on an allocation formula for permits which would compensate India for its mitigation costs for several decades.

Notes

1 The influential Stern Report (Stern 2006) estimated the cost of mitigation to be around 1% of global gross domestic product (GDP). It has been cogently argued by Helm (2008) that this is an underestimate. Note also that the Stern Report does not allow for the important possibility that the shadow price of capital may be greater than unity.

2 See Government of India (GoI) (2008c). In other words, if ACs reduce their per capita emissions to level *x*, India is committed not to allow its per capita emissions to exceed *x*.

3 Mitigation should be distinguished from adaptation to climate change. Adaptation is an inadequate response on its own because there are severe limitations to the human ability to adapt to climate change. Our paper ignores adaptation and the need for international assistance to DCs to help them adapt.

4 See Nordhaus and Boyer (2000), Mendelsohn et al (2006) and IMF (2008). The effects of higher temperature are also felt in growth (and not just level) of output; Dell et al (2008) estimate a panel data-based relationship based on historical temperature and precipitation readings and find that higher temperatures may reduce economic growth substantially in poor countries, but have little effect in rich countries.

5 See Lenton et al (2008) for impact on the latter.

6 The European Union (EU) agreed (after much public haggling from the former East European bloc) on commitments for a 20% reduction in emissions and for sourcing 20% of energy from renewable sources by the end of the second decade of this century (hence, 20-20-20).

7 Prominent estimates include Stern (2006, 2008) and *World Energy Outlook* (WEO) (2008). Associated with the range of costs is a dispersion of estimates of social marginal damages and optimal carbon taxes. See, for instance, IPCC (2007), Nordhaus (2005) and Metcalf (2008).

8 Globally, electricity generation has to be virtually decarbonised for meaningful progress by 2050.

9 The disincentives may eventually take the form of trade-related penalties. This is a complex issue, which we do not pursue in this paper.

10 A credible CAT system will require some safety-valve mechanism which prevents extreme fluctuations in permit prices. There are many suggestions for achieving this (see IMF 2008). We assume throughout this paper that CAT systems incorporate this essential feature.

11 This argument is dented (but not entirely overturned) by two considerations: (a) the "expropriation" was unintended in the sense that it was carried out under the supposition that the atmosphere is an infinite resource; and (b) the descendants of the expropriators cannot be held morally responsible for actions they did not themselves commit.

12 See Kapur and Mchale (2006) on nationalism versus cosmopolitanism in a different context.

13 Black carbon and organic carbon emissions from kerosene and LPG stoves have been estimated to be lower than from biofuel stoves by a factor of 3 to 50; combustion of biofuels is a potentially significant source of atmospheric black carbon and associated climatic effects in south Asia (Venkataraman et al 2005).

14 It is instructive that even the benchmark (reference) multi-decadal scenarios for energy-related national and global emissions put out by credible sources differ significantly. For instance, the global BAU estimate for 2030 is lower by 1.75 Gt in WEO (2008) compared to the Energy Information Administration (EIA)/International Energy Outlook (IEO) projection, also made in 2008. On the other hand, for India the estimate for 2030 in WEO is larger by 1 Gt. The EIA assumes, for India, an annual GDP growth rate of 5.8% (2005-2030), while WEO deploys 6.4% (2006-2030).

15 The subsidy has been declining in recent years (see Bhattacharya and Patel 2008 for a detailed investigation into the financial health of the electricity sector).

16 These "tax" calculations should, of course, be treated with caution for obvious reasons. Indian CO_2 emissions for 2007 are taken to be 4% higher than the figure for 2006 reported in WEO (2008), and the net taxation figures are from Table 2.

17 With a predicted increase in electricity demand – almost double by 2030 to 35.4 TWh – fossil fuel-based generation is also expected to double by this date, and the concomitant share of coal in electricity generation will increase from 40% to 45%.

18 Fossil sources provide 80% of global energy. In the US, 50% of the electricity generated is from coal; in 2007 coal-based power generators in the US emitted 1.98 Gt of CO_2 while generating 2.02 gWhr (EIA 2008).

19 While the recent civil nuclear agreements with various countries can facilitate huge investments in nuclear energy, the Indian government envisages a modest addition of 3,400 MW during the 11th Plan period (2007-08–2011-12). The high initial cost on account of upfront capital imports, as also the obvious implementation problems of a large-scale roll-out in a sensitive sector (due to concerns over security and safety) are plausible drivers for the government's cautious approach.

20 There is a view (recently espoused, most notably, in the *Economist* magazine, 14-20 March 2009) that CCS is unlikely to become a viable option as an instrument for climate change mitigation.

21 The three principal capture processes are oxy-fuel, post-combustion and pre-combustion.

22 Note that the calculations in this subsection are by way of illustration based on (plausible) assumptions.

23 Coal is the dominant fuel in India for electricity generation (about 70%), with a share of over 40% in the overall energy mix. Over time, the share of non-commercial energy (fuel wood, agricultural waste and dung essentially used by households for cooking) in total primary energy requirement is expected to decline from 28% at present as households transit to cooking gas and electricity (GoI 2006).

24 NTPC analysis as reported in Bhaskar (2008).

25 Joshi and Patel (2009) provide some comparative data.

26 The BAU emissions estimate of 2.24 Gt for 2030 is from EIA/IEO projections.

27 CO_2 price estimates are from Deutsche Bank, UBS, Soc Gen, New Carbon Finance and Point Carbon.

28 The foot dragging over funding demonstration projects and the relative paucity of encouragement from policymakers to its importance is baffling given CCS' potentially central role in mitigation. (Do ACs know something about CCS that they do not want to let out?) Both difficult technical design and economic issues have to be solved, and a functioning regulatory framework for CCS needs to be established. The list of outstanding issues is long and includes access to land to test potential sites and monitor existing sites; establishing rules for third-party access to infrastructure (transport, injection or storage); competing land uses (between extractor and sequesterer); long-term liability over leakage; and CO_2 ownership. Governments may, at the least, be required to indemnify early developers from CO_2 leakage to kick-start meaningful industry-scale (pilot) projects. For a planned project in Florida even permitting requirements have not been forthcoming, although the utility is ready to experimentally deploy CCS.

29 A scheme in this spirit has been proposed by Wagner et al (2008).

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