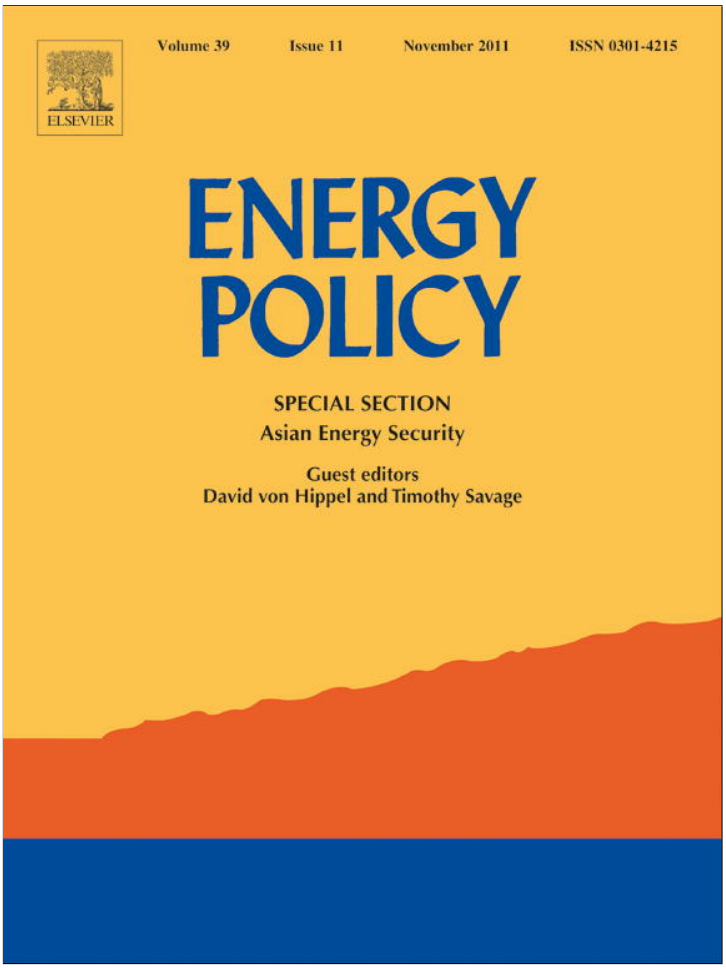

Energy Policy 39 (2011) 7165–7173

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Green growth in the post-Copenhagen climate

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ARTICLE INFO

Article history:
Received 27 May 2011
Accepted 16 August 2011

Keywords:
Green growth
Climate change
Fairness

ABSTRACT

Global climate change stands out from most environmental problems because it will span generations and force us to think in new ways about intergenerational fairness. It involves the delicate problem of complex coordination between countries on a truly global scale. As long as fossil fuels are too cheap, climate change policy will engage all major economies. The costs are high enough to make efficiency a priority, which means striving toward a single market for carbon—plus tackling the thorny issues of fairness.

Hopes for a grand deal were mercilessly shattered at Copenhagen in December 2009 and in other recent UNFCCC meetings, with the result that "green growth" is promoted as an alternative path. Indeed, green growth is clearly the goal, but it is no magic bullet. The world economy will require clear and rather tough policy instruments for growth to be green—and it is naïve to think otherwise. Growth, green or not, will boost demand for energy and coal is normally the cheapest source. The magnitude of the challenge is greater if we also consider the problems related to nuclear (fission) energy and, in some instances, to bioenergy (such as its competition for land that may be essential for the poor). This paper discusses some necessary ingredients for a long-term global climate strategy. As we wait for the final (and maybe elusive) worldwide treaty, we must find a policy that makes sense and is not only compatible with, but facilitates the development of such a treaty.

1. Is growth sustainable?

This is a unique moment in history. In the past decade, unusually rapid economic growth has lifted hundreds of millions of people out of the deepest poverty, not only in Asia and Latin America but also Africa (Sala-i-Martin and Pinkovskiy, 2010). This has inspired great hope, but this hope has been seriously shaken by two factors: the brutally severe global financial crisis (with luck a short-term phenomenon); and undeniable climate change (especially the impacts of its unpredictability and instability).[1]

"Green growth" has, in the last two years, become something of a mantra in the global debate. Hopefully, it may provide a way out of the stagnation that threatens in the wake of the financial crisis and succeed better than the aging catchword "sustainable development" in supporting the material aspirations of the poor, while still respecting general environmental concerns. Multilateral agencies report anecdotal evidence that many developing countries feel "sustainable development" (Brundtland, 1987) is synonymous with holding back their growth rates. The governments of these countries are deeply concerned about climate change, but they share a conviction that mitigation should start in the richer, industrialized countries, which bear the largest responsibility for historical emissions. Their views on the distribution of burden should not be mistaken for views on climate. For instance, they also perceive any suggestion that all countries should reduce their emissions by similar percentages as fundamentally unfair because it favors countries with large emissions today. In 2009, Prime Minister Meles of Ethiopia spoke on behalf of many African nations when he demanded that industrialized countries, such as the United States and the United Kingdom, should recognize their responsibility for historic emissions and compensate developing nations for the damage they caused historically to the earth's climate.[2]

Climate change is far from the only environmental problem humanity faces. The Millennium Ecosystem Assessment (MEA, 2005a, 2005b) analyzes a series of often-interrelated threats. For

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[1] For thorough documentation of the impacts of climate change, see the IPCC's 4th Assessment Report (2007) or the World Bank's World Development Report (2010).

[2] For Meles' comments, http://www.guardian.co.uk/commentisfree/cif-green/2009/nov/28/africa-climate-change
Blaise Compaoré of **Burkina Faso** expressed similar views (http://www.afrik.com/article17747.html).
See http://www.unep.org/climateneutral/Resources/Quotes/tabid/362/Default.aspx for positions of other heads of state, from **Brazil**, see http://beta.worldbank.org/news/low-carbon-growth-brazil; and from **India**, see http://www.hindustantimes.com/Copenhagen-accord-not-legally-binding-Basic-countries/Article1-501441.aspx.

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doi:10.1016/j.enpol.2011.08.036

example, countries converted more land into cropland in the 30 years of 1950–1980 than in 150 years between 1700 and 1850. Human activities now dominate the geo-biochemical processes of the earth: we appropriate much of the proceeds of photosynthesis and we have destroyed 20 percent of the world's coral reefs and 35 percent of its mangrove area. The MEA goes on to say that, although some changes have contributed to current welfare, they have also degraded many ecosystem services (including increasing the risk of abrupt and unpredictable, or nonlinear, changes) and exacerbated the poverty of some groups of people. Recently Rockström et al. (2009) further emphasized how human civilization is simultaneously coming up against several essential physical restrictions that shape the preconditions for our life-support systems (see Collier, 2010).

Sometimes the solutions to several environmental or resource problems may coincide. For example, lower population growth might alleviate the scarcities related to both food and energy. More typically, we find that a solution to one problem may exacerbate other problems. The various ecosystem restrictions studied by the MEA combine to become a bigger problem. Inherent in several "alternative" energy supply technologies are examples of these unexpected negative effects. Growing biomass (more quickly renewable, non-food plants) on a large scale may be quite ineffective, particularly if done with inappropriate conversion of land. In addition to loss of oxygen-producing, CO_2-absorbing trees and emissions of fossil carbon dioxide and others, in the forest-clearing phase, such practices threaten biodiversity and commandeer land that may be needed for food.

A couple of years ago, food prices escalated rapidly, causing hunger riots as famines threatened a number of poor countries. This led to severe critiques of biofuels that have to be taken seriously. Some criticisms may be misguided: it is possible that rising prices of agricultural products will elicit a supply-side response (more agricultural production) with considerable potential for many developing countries. At the same time, these countries are not homogeneous. Even if some groups (agricultural producers and land owners) benefit, others may lose harshly, especially those net consumers of food already close to the absolute poverty line (see Hertel, 2010 or WEF, 2011, which focus closely on the coexistence of scarcities of water, food, and energy).[3]

Nuclear energy is another alternative, essentially carbon-free energy source seen as a potential solution. However, current nuclear (fission) technologies present safety problems, recently illustrated by events at Fukushima, plus others pointedly germane in an era of terrorism. In the past, much of the safety debate has focused on secure, long-term disposal of radioactive wastes as much as on reactor safety itself. However, the accident at Fukushima thrust into the public eye a number of other weaknesses, such as the even more dangerous *short-term* storage of radioactive spent fuel rods, which are typically stored in containment areas not much more protected than swimming pools.[4]

Talk of a "nuclear revival" was thought by many to be exaggerated before the tsunami ravaged Fukushima, but it is now even less likely.[5] This nuclear accident has publically underscored the need for more inherently "safe" reactors, which are still on the drawing board. One reason is that building nuclear power plants is extremely costly and each additional layer of safety costs even more. Also, building new nuclear plants is resisted by local citizens. Therefore, old reactors continue to be refurbished to extend their lives, presenting another dimension of risk. This, combined with the risks of the nuclear fuel cycle and of terrorism, constitute formidable challenges that will at the very least delay expansion significantly (Allison 2004).

Taken together the restrictions we face (both when it comes to energy, and to the bio-geophysical cycles of nitrogen and carbon, or for that matter water, biodiversity and land) show that our current patterns of growth are not sustainable. This does not however necessarily mean that no growth would be possible in the future. Only certain items cannot grow, such as the emissions of carbon dioxide or other radiative forcing gases. This is no trivial restriction and incorporating it into the economy will require strong policy instruments and a new composition of consumption and production as well as new technologies.

2. Climate change is special: long run and global

In the last half million years, the carbon content of the atmosphere slowly oscillated between 200 and 280 parts per million (ppm)—taking roughly 100,000 years for each full cycle. Now we are emitting carbon so fast, at a rate corresponding to an increase of 2 ppm of GHG concentration per year, that the same 80 ppm change in carbon concentration occurs in only a few decades. A generation ago, people skied all winter in Sweden or Norway. Now, electricity for the snow-canons is the biggest cost for ski resorts and they even make artificial snow in Piteå on the Arctic Circle. Climate change will similarly increase cooling costs in homes, offices, and hospitals, and these are just a few examples of new energy needs that absorb the energy saved with insulated buildings, smaller machines, or fuel-efficient transportation—unless these initiatives are backed by aggregate instruments, such as a global tax. Snow and ice cover is receding toward the poles and mountains, and the Arctic will soon be ice free in summer.[6] The change is more visible in the far north because temperature variations are magnified there and because with a temperature rise of 2°C, ice and snow are replaced by bare ground. However, dramatic effects are expected in many places. Some areas in Africa that are already hot and arid may face big increases in temperature or decreases in rainfall, pushing them over the threshold for what is bearable for humans or feasible for agriculture.

The major civilizations of this world evolved along the giant rivers, such as the Ganges or Brahmaputra. Large populations still rely on the predictable flow of river water, many regulated by glaciers that are now fast receding. Irregular water flow implies new or longer periods of drought and increased severity of floods, all of which can be lethal to densely farmed areas. Likewise, rising sea levels and increased storm damage pose severe threats to large, heavily populated areas, such as Bangladesh and Bengal. We expect the most dramatic human welfare costs to occur in developing countries because the people there have fewer skills and assets, and less access to technology, health care, or civil resources to help them recover from catastrophe.

The scale of these effects is to be measured not in years or decades, but in centuries and millennia. Even a human generation is short by comparison and great care is needed to deal with issues of time preferences and discounting between generations. For example, there is evidence that individuals discount values in the future at rates that falls with the length of the delay, and that discounting between generations is quite different from discounting between years for a single individual. (See for example Weitzman, 1998;

[3] The incidences of "land grabbing" in Africa are also a relevant and telling sign of this issue (see Friis and Reenberg, 2010).

[4] See http://www.zerohedge.com/article/detailed-look-spent-fuel-rod-containment-pools-fukushima.

[5] See also http://www.thebulletin.org/web-edition/op-eds/call-to-resist-the-nuclear-revival.

[6] Ironically, this will probably attract a new wave of oil drilling there, as if we had not learned anything.

Karp, 2005.) Furthermore there may be important changes in relative prices due to changes in economic structure, or different discount rates for different sectors. As mentioned above growth is still possible but the direction and content of growth needs to be controlled to make it compatible with planetary boundaries. This means that we can get richer but relative prices will change considerably, which has potentially very large consequences for intergenerational fairness—or to be more technical, for appropriate discount rates applied to future costs on century-long scales (see for instance Hoel and Sterner, 2007; Sterner and Persson, 2008).

3. Cost efficiency in climate policy: the need for a unique price of carbon

Effective climate policy will be expensive. This does not mean prohibitively expensive or that we should turn away. On the contrary, damages from climate change are likely to be much more costly than abatement, so it makes good sense to invest in avoiding them.[7] Those who oppose mitigation sometimes paint a bleak picture of the results of taxing fossil fuels, in which people in developed countries are deprived of modern comfort and developing countries are deprived of their prospects for economic growth. However, the integrated assessment models that illustrate the costs and benefits of fossil fuels taxation typically assume not only continued welfare but *continued growth* in welfare, even under stringent climate abatement policies. A typical model might show the world economy growing by 2.9 percent *with abatement*, compared to 3 percent in a hypothetical "business as usual" scenario that *leaves out climate damages*. Although this comparison is not appropriate, precisely because the damages are unaccounted for, it is worth noting that here, even when abatement is assumed, world income increases. However, instead of taking, say, 100 years for income to increase tenfold it would take 102 years (Azar and Schneider, 2002). This does not deny that the costs involved are sizeable and thus efficiency in climate policy design itself is an important goal.

Efficiency in climate policy requires the use of market-based instruments (MBIs) that give a single clear price signal to all countries and sectors (Tyrole, 2009). This is particularly true if the costs of abatement are heterogeneous. In such case, the cost of abatement, for instance, through avoided deforestation in one country may be very different from that cost in another country (or in other sectors). If there is a difference, then MBIs can save a large share of total costs by shifting abatement to where it is cheapest. The more pronounced the heterogeneity of the costs, the bigger the savings with MBIs (Sterner, 2003). MBIs also send clear price signals to stimulate research and development of new technologies from which the most significant emission reductions may come.

The most straightforward way to send a unified price signal is with taxes, but it could also come from an international agreement that limits emissions for each country and permits them to trade. This allows for economic efficiency, as well as producing revenue for countries that get a bigger allocation than they use. Just such a grand deal failed in Copenhagen in 2009; instead, we got an agreement—the Copenhagen Accord—based entirely on voluntary participation (i.e., pledges).

Why can this not be equally effective? First, voluntary mechanisms are not an ideal way to provide public goods. We do not organize the provision of public goods based on donations because we know that a tax-based system is, on the whole, more effective. Second, we need a decisive way to make the deal "binding" and the reductions of each country contingent on the participation and ambitious reductions by other countries. This is characteristic of the "public good." Also there are some aspects of a pure global public good but there are also aspects in the climate-energy complex that are more local by nature, such as local pollutants and issues of energy supply security. It therefore seems promising to take an approach that is not exclusively centralized but not exclusively decentralized either, for instance the polycentric approach of Ostrom (2009) emphasizes that a coordination of policies at the local, national and international levels is necessary since these different levels have different potentials and constraints and because climate change is interwoven with many other environmental problems that are more local in character.

Consider the viewpoint of country *i*: why make a big pledge of *X* if you can just as well make a small pledge of *x*? The only reason would be if your own large contribution is *matched* with equally sizeable contributions by the other participants, so that the overall collectively produced "public good" (in this case, climate stability) is sufficiently big. In principle, the position of the European Union prior to Copenhagen, which promised 20 percent if other countries did nothing and 30 percent if other countries were ambitious, is one example, but it was seemingly the only example. Had world political leaders truly been driven by a desire to see maximum collective reductions in greenhouse gasses, we would expect to have seen more such tactical bids.

Furthermore, when "pledges" are not binding, there is no guarantee that they will be met. And there is certainly no incentive to over-fulfill a pledge—because there are no abatement credits that can be traded. Thus, a country such as India cannot make money from a pledge system. It has much less (or no) incentive to participate and comply, compared to a system with tradable permits (given the reasonable assumption that India receives more abatement credits than it needs). We noted above that the overall savings to the global economy depend on whether abatement costs are heterogeneous. We do not know the heterogeneity of abatement costs, but since emissions emanate from a wide variety of processes, economic sectors, techniques, and countries, it is reasonable to assume that some heterogeneity exists. Of course, the broader the application, the better.

If we include all gases, sectors, and countries, and if we allow both avoided emissions plus captured and stored gases, then a larger number of potential abatement solutions can compete. The bottom line is, as usual, that the cheapest solutions are implemented first and the early costs are saved by sidestepping unnecessarily expensive abatement options.[8] Searching for a single instrument leads, however, to the next major concern—fairness. Suppose it is more "efficient" (lower costs per unit of radiative forcing avoided) to reduce fuel use in the production of bricks in a small town in Africa than to persuade a rich person in Europe to drive his SUV less. This example may sound overly theatrical, but it captures the heart of the issue. We need to ask ourselves whether such an exchange can ever be ethically justified. We think it could be fair and acceptable if it really is a voluntary exchange, in which the users or producers of the

[7] There is much uncertainty about costs, which complicates the matter. There is, for instance, a low but positive probability of truly catastrophic damage. Assuming some form of risk (and maybe ambiguity) aversion, are we willing to pay to avoid expected damages? And are we also willing to pay some form of insurance premium to avoid even a small risk of really large damages? See Weitzman (2009) for a mathematical formulation of low-probability, high-impact events and implications for climate policy.

[8] Unfortunately, there are also counterarguments to integrating all sectors under one policy instrument. Different rice cultivation methods, for instance, cause widely varying methane emissions. Modifying rice cultivation is probably a cheap way of reducing radiative forcing. However, at present, the uncertainties involved and the degree of complication in monitoring and verifying make it difficult to include this in a carbon-permit market.

bricks are more than sufficiently compensated by the car driver. The beauty of MBIs is that in principle they can achieve such exchanges efficiently and fairly, with limited transaction costs. To do this, however, requires *one policy instrument* or scheme that is broad enough to encompass both the brick maker in Africa and the rich driver in Europe. Designing such an instrument raises tricky issues about fairness in allocation.[9]

4. A fair share in a global deal

Because climate change is global, the policy response must also be global. Policies applied only in individual countries or sectors risk "carbon leakage." Leakage is a term for the potential of carbon emissions to move abroad in response to an increased cost of emitting carbon in a country with stricter policies. A competitive advantage in countries with less strict policies can lead to increased carbon-intensive production in these countries, an idea that is logically straightforward. Policymakers thus worry about pollution havens and the detrimental effects of environmental regulation on competitiveness claimed by industry. There is actually very little empirical evidence that stricter environmental legislation really does induce industry to migrate but we are not sure because environmental regulations to date have imposed only very moderate costs on industry. The shadow prices needed to reduce carbon emissions by 50–80 percent—and eventually eliminate them—will be high and might in principle be a strong incentive to relocate. There can also be general equilibrium effects because tougher climate policies in some countries will tend to depress the global price of fossil fuels, which encourages fossil use in other countries again pointing to the need for climate policy to be global.

A climate treaty must have fairly broad coverage (but this does not necessarily imply that negotiations need to be structured as the COP meetings of the UNFCCC generally are).[10] It does, however, imply deep consideration of fairness and equity issues (Aldy and Stavins, 2010). We, in the wealthy countries, are hampered by our history: a record of broken commitments (such as with development assistance) makes developing countries wary. It is also clear that an overwhelming share of historically accumulated emissions were emitted by developed countries; it is not farfetched to argue that the rich countries should pay some indemnity or pay for adaptation. But, their responsibility cannot end there. In spite of all the discussions since 1992, and except for a very small number of nations, the richer countries not only continue to emit greenhouse gases, but at a rising rate! Now, a new and complicated conundrum confronts developing countries, in which the rich countries appear to be in a considerable hurry to bind them into agreements that might their limit future growth and prosperity.

It is risky to commit to given emissions reductions because abatement costs are not well known. This is particularly true for countries expecting rapid economic growth. The difference over a 50-year period between 2.5 percent and 1 percent growth is a factor of 2. Between 5 and 10 percent growth, the difference is *tenfold* in gross domestic product, which—in the hypothetical case of constant energy intensities, for example—means 10 times the energy demand.

A worldwide agreement on emissions reductions is essentially an agreement on emissions. Considering that emissions reductions will be expensive, the rights to emit will be very valuable and we will need to develop an allocation mechanism. A number of possible mechanisms have been proposed, but we only focus on two here: grandfathering and equal per capita allocation. They best exemplify the conflict of interest between rich and poor countries.

4.1. Grandfathering

As applied to greenhouse gas emissions, grandfathering means that future emissions allowances for any agent should be a proportion of past emissions. This approach heavily favors countries with historically high emissions and penalizes low-emitting countries. The United States emits some twenty tons of carbon dioxide per capita per year and European countries around seven tons, while poor countries, such as India and most countries in Africa, only emit one ton. When we speak of grandfathered "rights," we also use the term "prior appropriation." Perhaps the best-known historical application of prior appropriation lies in the water usage laws in the western United States, where usage rights and priorities are granted according to when an individual first put the water to beneficial use. In other words, "once a priority user, always a priority user," even if to the detriment of others.

A direct application of grandfathering in the climate context is equal percentage reductions, which is the starting point of many climate negotiations including the Kyoto Protocol, as well as more recent negotiations. At first glance, equal percentage reductions or grandfathering may seem to be a fair and "natural" principle, like a flat tax rate. Under grandfathering, those who emit more do, in fact, have to abate more (in tons)—but—they still get to emit more and thus use more of the global atmospheric commons. If a rich country today uses 10 times as much carbon as a poor country, and both are forced to reduce by the same x percent, then the inequity will be exactly conserved. The rich country will always get 10 times more of the resource than the poor country will get.

The Kyoto Protocol was essentially the result of negotiations that took grandfathering and equal percentage reductions, in particular, as their starting point.[11] Developing and intermediate countries appealed to a concept of fairness based on equity and were exempted from numerical emissions targets, as a result. Even though grandfathering is unfair, the outcome that resulted from these negotiations is also untenable in the long run because the exempted countries have no ceiling. In addition, developing countries' economies are not given any incentives to save and they do not get the opportunity to sell emissions rights to rich countries. Thus it is easy to conclude, as many have, that it makes more sense for developing countries to get generous permits than to be exempted from participation.

4.2. Equal per capita allocation

Alternatives to grandfathering include allocation based on endowment and need. Countries that have large hydropower resources or plentiful gas resources find it easier to emit less CO_2 than those whose only energy endowment is coal. Those with a very cold climate may argue that they need more energy for heating. Such arguments quickly become overly complex. A more tractable principle is equal per capita allocation. In its simplest

[9] Note that this initial allocation of rights is intended to make an instrument politically fair and acceptable. It should not influence where actual abatement is carried out. (This should be decided by comparing marginal abatement costs.)

[10] COP=Conference of Parties (the "supreme" body of the convention); UNFCCC=UN Framework Convention on Climate Change.

[11] In reality, the emissions reductions were not equal, but the inequalities did nothing to even out carbon intensities—to the contrary! Australia, with a high-emissions intensity, was allocated an increase of 8 percent, while Canada and Japan were required to reduce by 6 percent, the United States by 7 percent, and Europe by 8 percent. The European Union received the biggest reductions, not because they had high emission intensity, but simply because they were keen on pushing through the deal!

form, each individual in a jurisdiction receives one equal unit of benefit. The concept of "one person, one vote" is an excellent illustration and underlies many democratic principles.

Another illustration is the allocation of oil revenues in Alaska. Twenty-five percent[12] of Alaskan state oil revenues are paid into a fund, whose dividends are distributed on an equal per capita basis to all citizens living in the state. At the macro level, equal per capita allocation means that country allocations depend only on population. This approach for distributing a windfall profit appeals much more to poor countries than to rich ones.

4.3. The appeal of these mechanisms

Both grandfathering and per capita allocation can muster some logical and intellectual appeal. Both can be defended passionately for a wide variety of countries and socioeconomic or political contexts. Proponents of grandfathering say it has already been tested in early permit-trading schemes, such as sulfur trading in the United States, and of course is a key component of the Kyoto Protocol. Often, it seems to be taken for granted. In the run-up to Copenhagen, countries compared their percentage reduction offers as if grandfathering were a given. Equal per capita allocation, on the other hand, has its own considerable pedigree and its appeal to fairness.

Grandfathering benefits those countries with large emissions or high fossil fuel use, while equal per capita allocation benefits low-income countries that use little fossil fuel. Table 1 shows the percentage of global carbon emissions from fossil fuel and population for the largest countries.

The United States emits 20 percent of the world's carbon dioxide with only 5 percent of the world population. Its fossil-based carbon dioxide emissions per capita are 20 tons of carbon (tCO_2/capita), roughly four times higher than in China (5 tCO_2/cap) and twice that of many European countries. If emissions allowances were allocated by grandfathering, the United States would receive 20 percent of the global total, compared to an equal per capita allocation, which would give it only 5 percent. Consider the consequences for the United States if the whole world reduced emissions by 50 percent. With grandfathering, the US allocation would be reduced by 50 percent, whereas with equal per capita allocation its allocation would be reduced by almost 90 percent.

Any efficient and rational scheme allows trading, so countries do not need to reduce actual emissions by these exact percentages—we are speaking here of allocations. The point is that the allocations can generate substantial flows of revenue. For India, the consequences are somewhat opposite those for the United States. With a per capita allocation, it gets a share equal to its population (17 percent), whereas with grandfathering it only receives 5 percent. If the whole world reduces emissions to half, the Indian allocation would still allow for large domestic increases if the allocation was based on per capita equity. For India, the difference between grandfathering and per capita allocation is 12 percent points! If, one day, we limited fossil carbon emissions to 4 billion metric tons (Gt) globally, the difference between the two allocation mechanisms means a difference of 0.5 Gt of carbon, or almost 2 Gt of CO_2. If the price of CO_2 is US$50–$100 per ton, this difference is worth $100–$200 billion per year.

5. Enclosing the environment

Consider the ecosystem services provided by the world's atmosphere when we decrease CO_2 and other climate gasses. We can think of this as a highly valuable, natural resource that will probably be regulated someday. Its value is so large that it will take decades to agree on how to allocate rights to it. For example, the League of Nations first debated the partial enclosure of ocean resources in 1930, but could reach no agreement. In 1945, the United States unilaterally appropriated its continental shelf and other countries soon followed suit. The UN brokered formal negotiations between 1973 and 1982, resulting in the treaty known as the "Law of the Sea," which entered into force in 1994, 64 years after the initial effort. If it takes 30 years to negotiate property rights to the atmosphere, we can have a viable, all-inclusive, and binding agreement by the mid-2020s. This may be quite an optimistic scenario, but it puts current negotiations into perspective. It is also sobering, since an agreement to start reducing emissions in the year 2020 will be too late to reach a target of keeping warming to 2°.[13]

Table 1
Global emissions of CO_2 and world population.
Source: Carbon Dioxide Information Analysis Center (CDIAC) of the US Department of Energy.

Country	Emissions (%)*	Population (%)
China	22	20
United States	20	5
European Union	14	7
India	5	17
Other	39	51
World	100	100

* CO_2 emissions from the burning of fossil fuel only.

However, we can make a case for some cautious optimism. This issue is clearly not as easy as phasing out ozone-depleting substances, inscribed in the Montreal Protocol (which only concerned a small number of countries and producers and minor rents), but it need not be as complicated as global nuclear disarmament, the land conflicts of the Middle East, or the rights of immigrants from low-income countries in the United States and the European Union. Seen in the context of long-term economic growth, the costs are breathtaking but quite manageable.[14]

Of course, the perceived urgency of climate change and its position on the policy agenda will depend on a number of factors in each individual country. Some of the most important factors are the following:

1. The expected damage or the size of the risks incurred.
2. The ability of the country to deal with shocks.
3. The salience of other current problems in the country concerned.
4. The role of special interest groups (for instance coal mining, aluminum smelting, tourism etc.) that might domestically argue either in favor or against action on climate change.

It is difficult and inappropriate to generalize but it is becoming clear that many developing countries will be particularly worried about climate change because of the factor 2. To some extent this

[12] The remaining 75 percent finance the state budget, which also benefit Alaskans, although in less direct ways.

[13] Unless the rate of reduction is very high and/or the climate sensitivity is lower than currently expected, it will be hard to reach a 2° target if we start in 2020 (Levin and Bradley, 2010; UNEP, 2010; Rogelj et al., 2010; Stigson, 2010)—even though this goal is specifically mentioned in the Copenhagen Accord. Rogelj et al. (2010) called the pledges "paltry," saying that they may even lock the world into paths leading to more than 3° of warming. Meeting the 2° will require dramatic cuts between 2020 and 2050. The authors lamented the fact that ambitious goals for 2050 were dropped, apparently in the last minute, from the Accord. The advantage of discussing a vision for 2050 makes fairness issues seem more tractable in the long run (Guesnerie and Sterner, 2009).

[14] According to the Stern Review, costs are on the order of 1 percent of GDP. In the context of decades of growth at a few percent per year, this is quite small.

is also true of factor 1 (at least for small island states and countries that are already experiencing pressure due to water scarcity and heat and where these factors are expected to get worse). Factor 3 has some tendency to operate in the opposite direction. For Sweden the prospect of climate related disease, refugees, property loss and loss of life may seem more dramatic than for a country that already experiences great hardship today. The fourth factor cuts across the categories of rich and poor; but it is logical to think that some low income countries with large reserves of fossil energy are less inclined to discuss climate policy because they have powerful elites making money from selling fossil fuel. The picture is thus very mixed and it is inevitable that different countries will make different judgment concerning the urgency of climate policy.

This factor likely explains some of the reticence that some countries have shown in climate negotiations. However the reticence can also be largely tactical. Since there is an inevitable struggle over the allocation of rights as we have discussed—and over "side payments"—it is in such a situation not tactical to appear very keen on getting a deal. On the opposite, in a struggle over shares in a negotiation it may generally be a good bargaining strategy not to appear very interested. It is possible if not likely that some of the disinterest shown by both India, the US and many other states is in fact part of the negotiation process.

6. Technology policy

Traditional analysis of climate economics assumes the main market failure is the existence of external effects, such as carbon emissions, unmanaged common property resources, or the atmosphere, in this case. There is, however, at least one additional, important market failure, namely, the disincentive to research and development (R&D) that is created by poor tenure security of intellectual property (Jaffe et al., 2003). Considering the gravity of climate change, companies should be doing more research into solutions—but they do not, simply because they know that there would be no way to fully capture the reward on major innovations. Governments should come up with strong incentives for R&D to compensate for this lack of incentives.[15] There are numerous possible solutions, although none is perfect. For example, drastically increasing public funding for such R&D is a possibility. But here again, the countries involved face a problem of joint action, both to create proper incentives for R&D and to deal with the fact that countries vary widely in terms of their most pressing domestic needs and priorities. An international treaty to stimulate R&D for new, climate-friendly technologies will likely be much easier to implement than a treaty aiming to reduce fossil fuel use, but fairness concerns are critical here as well and will need to be dealt with in any global technology-focused agreement. For example, technology-transfer agreements can create financing flows from developed to developing countries while protecting international licensing and patent agreements.

An international research agreement is, however, far from sufficient. In the absence of a strong price signal, research will typically not be targeted to produce practical results for current or expected price levels. In the energy sector, advantages to scale are prominent, as are "learning by doing" and technical progress. A combination of these factors can effectively create "lock-in" situations, where the barriers to entry are high. Policies, such as feed-in tariffs or subsidies to production, can be more effective than just research grants. On the other hand, this presents a considerable challenge to policymakers because it can be perilous to pick winners and subsidies can easily become self-perpetuating. The problems are compounded by the fact that the energy sector is characterized by agents with market power, as well as the power to lobby.

[15] It is an attribute of this problem that potential "solutions" can be as distinct as carbon capture and storage, fusion, hybrid rice, social engineering to make domestic fuel taxation politically acceptable, or the fertilization of the seas with iron shavings.

7. Green growth

The challenges and opportunities we have discussed so far combine to give us one broad message: that we face a special period in history. The development of an international climate policy amounts to the creation of property rights to the atmosphere—sometimes referred to as an "enclosure" of this resource. The creation of such an expanse of property, plus the shift in developmental paradigm, will take time to accomplish. One fundamental obstacle is agreeing how to share costs. To overcome this, we must address certain dilemmas that affect the range of available policy options:

- We are in a considerable hurry to start reducing emissions, but a global treaty implies large transfers of wealth and complex fairness issues that will take a long time to resolve, and their size hinges partly on the availability of new technologies.
- A global treaty would, of course, be easier to achieve if there were sufficiently good "clean technologies" available. However, there is no strong incentive to develop such technologies *before* we have affirmed property rights that put a price signal in place, as they would be under a binding and global treaty.
- To demonstrate that reductions are possible, someone must go first. However, with the prevalence of grandfathering, proactive behavior not only goes unrewarded but may actually be punished.

But—and it is a large but—only when we have solved the allocation issues can an international agreement be put in place.

It is here that we must discuss alternative paths. We need new policy that makes it easier to fulfill future national goals for any given country. We need new policy that makes global agreement more likely. This is where "green growth" comes in. Green growth is attractive to *some* businesses, *some* trade unions and *some* environmentalists. Politically, people seem to accept stimuli for green cars and green fuels much more easily than they accept higher fuel taxes, although the latter are considerably cheaper in reducing carbon emissions. Developing countries are more attracted by the idea of green growth and—as particularly relevant in the past couple of years—it fits nicely into the rather dismal state of the business cycle, given the demise of several banks and the near-demise of entire countries, such as Iceland and Greece. The strong threat of a slowdown in global growth makes the lure of green growth all the more attractive. The question, then, is: what makes this a sustainable strategy?

Many environmentalists who believe costs for abatement are small, compared to potential damages, have been severely frustrated by the difficulty of reaching national and international agreements. Some of them suggest we abandon the whole discourse on burden sharing and instead frame the issue "positively," as "competing to be first in the solar age." This appears overly optimistic since the old truth still applies that abatement is only profitable at a global coordinated level not at the level of a single country. However one may also ask who should go first. Frontrunners tend to reap some rewards in terms of setting standards and collecting patent royalties and export revenues. Large countries such as China and the US have the natural advantage of being so large they internalize at least a share of the benefits. They also have reason to think strategically

when it comes to positioning with respect to modern technologies. Ultimately there is also a moral responsibility for the rich countries that account for the largest historical emissions to go first. If they do not- it is very hard to see any other countries taking the lead.

Even prominent heads of state have become enthused. In November 2008, UN Secretary-General Ban Ki-moon, together with President Susilo Bambang Yudhoyono of Indonesia and Prime Ministers Donald Tusk of Poland and Anders Fogh Rasmussen of Denmark, wrote an article appearing in the *International Herald Tribune* and the *New York Times* entitled "Crisis Is Opportunity." They argued that

> we do not need to await the arrival of new technologies, nor need we worry excessively about the costs of taking action. Studies show that the United States could cut carbon emissions significantly at low or near-zero cost, using existing know-how. For evidence, consider how Denmark has invested heavily in green growth. Since 1980, GDP increased 78 percent with only minimal increases in energy consumption. For businesses, such savings translate into profits. Poland has cut emissions by a third over the past 17 years, even as its economy boomed. Today, for example, European companies in the green tech sector enjoy substantial "first mover" advantages, accounting for one third of the world's burgeoning market in environmental technologies.
>
> With the right policies and financial incentives—within a global framework—we can steer economic growth in a low-carbon direction. With the right policies and the right incentives, we can be sure that developed and developing countries alike contribute to the cause of fighting global warming, each in their own way and without compromising every nation's right to development and the economic well-being of its citizens (Ban et al., 2008).

They go on to say that most "forward-looking chief executives know this. That's one reason why business people in so many parts of the world are demanding clear and consistent policies on climate change." In the business sector, one of the most influential organizations is the World Business Council on Sustainable Development. The title of their latest annual report was *The Green Race Is On*, and the "President's Message" started: "we hoped the December climate talks in Copenhagen would deliver a clear new framework to manage climate change. It did not. But, the year did deliver a new sense of the reality and urgency of the energy and climate agenda. *Business leaders realized that they must help lead society toward solutions, stepping into political and diplomatic arenas previously alien to them* [author's emphasis]…" (WBCSD, 2009). At the same time, the Council's own Vision 2050 project began to document the spectacular breadth of business opportunity inherent in pathways toward sustainability (see WBCSD, 2010).

The message that the "Green Race is on" between countries aims to encourage them to embrace a low-carbon economy and become a leading supplier of resource-efficient technologies and solutions. The countries desiring "to win" must transform their own home markets to build competencies and scale and thereby gain comparative advantage. The sentiment conveyed is one of urgency and underscores the risk of missing vital opportunities. WBCSD portrays Japan as a leader in energy-efficient solutions because it grasped the opportunity revealed by the energy crises of the 1970s. It also sees the European Union as the leader today, given its 40 percent market share in green technologies and its plans for a 300 percent increase in R&D for green technologies. Still, the Council voices concern that the European Union is not building its domestic green market fast enough. The Obama Administration is mobilizing US innovation capacity to position itself as the world leader in green technologies. Jeffrey Immelt, chief executive of General Electric, is quoted as saying, "let's not take this growth industry and give it to every other country in the world but the US" (March 3, 2010). The WBCSD, however, thinks that China may emerge as the winner because its next five-year plan focuses strategically on such goals. India, too, is seen as a key supplier of low-cost solutions, based on its own domestic demand from a big and poor population.

The United Nations Environmental Program (UNEP) has launched a special "Green Economy Initiative,"[16] which offers advisory services to governments and corporations. It recommends stimulating development of green industries, such as renewable energy, improved and ecologically sustainable housing, and transport solutions. Also, the next *European Report on Development* (produced by the Overseas Development Institute (ODI), 2012, the German Development Institute (DIE), and the European Center for Development Policy Management (ECDPM)) will focus on green growth, as did the latest *World Development Report 2010* (World Bank, 2010) and OECD's (2009) *Natural Resources and Pro-Poor Growth*.

This is an encouraging news and one understands the temptations for environmentalists and politicians alike, but we also stop to wonder if this growth will be "green enough" or, better still, what policies make this "green" growth sustainable. A simple answer is that the increase in efficiency—in the use of ecologically sensitive inputs or waste products—must be more rapid than the increase in output. More miles driven by more cars can of course only be sustainable if the average emissions per mile go down *faster* than the miles go up.

Look at the transport sector, which has hundreds of studies on vehicle fuel demand (Dahl and Sterner, 1991a, 1991b; Goodwin et al., 2004; Hanly et al., 2002; Graham and Gleister, 2002, 2004). To simplify, we can say that the fuel demand function is surprisingly stable and can be approximated by the function:

$$G = Y^a P^b$$

where fuel demand, G, has an income elasticity of a, which is roughly equal to unity; and a price elasticity of b, which roughly equals -0.7. This means that a 10 percent increase in income, Y, will typically make consumers increase their spending on fuel by around 10 percent. In rapidly growing middle-income countries, the elasticity is sometimes above 1. The price elasticity of -0.7 is a long-run equilibrium value. It does *not* mean that consumption will drop like a stone by 7 percent if the price, P, goes up by 10 percent. Instead, it means that after a full set of adaptations has taken place, then, in the long run, the fuel demand will be 7 percent lower than it would have been otherwise. In the short-term perspective of a year, the fuel demand will only drop by may be 1–2 percent, and even this will not be visible if there is, say, a 5 percent growth rate. The observer will simply see an increase of perhaps 4 percent, (which we can interpret as "1 percent less" than the expected 5 percent).

Now we are equipped to answer the question of how to make growth sustainable. Suppose we want to reduce emissions of CO_2 by 2 percent at the same time we increase income by 4 percent per year. To do this, tougher policies must compensate for the effects of growth. With taxes constant (even if they are high), emissions from the transport sector will increase 4 percent per annum. To combine growth in income and a decrease in emissions, in this particular case, the price must rise by 9 percent per year. Note that 9 percent per year is a very strong policy instrument, which means prices double every eight years! Eventually, prices become so high that the elasticities are unlikely to

[16] http://www.unep.org/greeneconomy/.

be constant over such a broad range of data. One may eventually find that many kinds of alternatives are profitable, such as public transport and solar-powered cars of some form, but that is the purpose of the exercise and, in principle, the elasticities account for all these reactions.

For other sectors, such as construction, industry, and so forth, similar mechanisms are at play, but the elasticities are different. At times, it may be more difficult to replace fossil fuels, in which case, elasticities will be lower. In other sectors, they might be higher and there may also be rapid technical progress in energy-saving. They are however not very likely to be much higher than -0.7 in many sectors, so it is likely that overall fossil prices must rise by at least 10 percent per year to make economic growth of 4 percent feasible. Described here is a demand-side mechanism: eventually, energy prices will be so high that fossil-free alternatives can compete, so the price of energy does not need to rise. Some analysts think technology changes will not be enough and that we need changes in culture or lifestyle. This is no doubt true but it is no reason to change approach because it is exactly the changing relative prices that will provide the best guide and inspiration for the lifestyle changes needed.

Higher fuel prices are not popular and tend to be attacked as regressive. Recent research on this subject suggests that, only in the very richest countries, would there be slight regressivity—and then only of the fuel tax itself. The overall pro- or re-gressivity of a tax reform depends on how the revenue is used. It is straightforward to design a reform with higher fuel taxes that is progressive if the revenues are used to lower other regressive taxes or to support goods and services demanded primarily by the poor. Most significant, in this context, is that in low income countries, fuel taxes themselves are actually quite strongly progressive, even without considering the use of the proceeds (Sterner and Slunge, 2009).

Fuel taxes represent only one example, albeit an important one. The real cost of the most efficient policy instrument, higher fuel taxes, is limited. However, fuel taxes are not popular and are standardly characterized as costly or difficult. Maybe, if politicians were somehow "obliged" to raise fuel taxes through an international agreement, there would eventually be some "discovery" that the costs are not really so high. Ironically, other instruments, such as banning cars over a certain age or mandating new green cars that run on alternative fuels, for example, are actually much more expensive but often perceived as easier to implement, and such policies are often promoted as part of a "green growth" strategy for political economy reasons.

For instance, the car industry may react positively to this type of instrument. One should be wary in the balance between such instruments because, as we have discussed, the "green car" policy is actually more expensive in relation to gains in abatement. On the other hand, if we want business circles to accept abatement policy, and if we want to promote investments in new green technology, then developing technology instruments of this kind has some merit. However, the policymaker needs to be wily and make sure that there is a palpable tradeoff. If we want a growing economy that is truly green, we must encourage truly green technologies; and policies that promote green growth must also ensure that the technological advance is as big as possible in relation to the resources committed.

8. Discussion

The costs of climate abatement are sufficiently high to motivate industries and countries to focus on efficiency, which implies that we should strive to approach a unique price of carbon and negotiate a global agreement with close to total participation. Global participation in turn requires dealing with ethical issues of fairness and distribution. This challenge, as we have discussed, requires rich and poor countries with diverse interests and urgencies to agree on a single paradigm to, in one way or another, enclose our atmosphere. The positions of, for example, grandfathering emissions rights and distributing them on an equal per capita basis are vastly far apart and we need a policy package that essentially enables some compromise—or else it becomes difficult if not impossible to envision a truly effective solution.

Those skeptical of climate action can also use these arguments pointing to the difficulty of negotiating a comprehensive global deal. It is particularly hard if there are no positive, functioning examples of abatement or low-carbon growth to point to. Thus, we risk a "catch-22": no local action before a global deal and no global deal before all issues of fairness have been ironed out. This will likely be a very long process and different arguments will emerge at different stages in the process. Climate change could dominate national and international discourse throughout this century. In the year 2040, we may well be discussing how to deal with the next step because the actions after 2030 were insufficient. We are just at the beginning and many of the issues under discussion are just first steps. The importance of the cost efficiency of a global treaty and a unique price of carbon are matters of principle, but their practical importance will grow quickly in the later stages of climate negotiations, when abatement costs are really high.

A unique global price of carbon is not quite so imperative *in the first years*. During this initial period, we should perhaps not judge abatement actions primarily by whether they are cost efficient but by whether they nudge the overall process of bargaining and negotiation forward. Good examples are demonstrations of new technology that are likely to be accepted and copied, or that argue for the feasibility of more stringent targets. It will take time before we have a unique price of carbon in the world because it is tied into the difficult questions of how the burdens are split.

In the meantime, we must still reduce emissions, both to reduce pressure on the atmosphere and—perhaps most importantly—to learn more about future abatement technologies and possibilities. Green growth, if taken seriously, can be viewed as a bridge. Today we are seeing a number of initial steps, such as experiments with "green" cars, new fuels, energy efficiency in buildings, solar heating, solar and wind power (in the European Union and the United States), and other clean development mechanism projects for new technology in developing countries. China's five-year economic plan, passed in March 2011, championed energy efficiency and pollution reduction as central to its plan for generating economic growth. It is of course too early to see what the outcome of this initiative will be (and for example the extent to which nuclear energy will play a role) but China's strong investment in the solar and wind sectors clearly demonstrates its belief that economic growth in the coming years will be tied to an emerging low-carbon economy. Also in March of this year, the European Commission released a "roadmap" for a competitive low-carbon EU by 2050, filled with short and long-term investment strategies across virtually all economic sectors. South Korea, Asia's fourth largest carbon polluter, has similarly an initiative to invest over $30 billion in renewable energy by 2015—the list goes on and the United Nations (2011) provides a timely overview of how to provide finance for climate-smart, green growth initiatives. As that report highlights—there is however no point in just providing finance for green growth if it is not tied to other global agreements and plans for mitigation.

Critics may call these actions simply symbolic—and it is true, they are symbolic, as well as embryonic—but they are also learning experiences. Green growth is no panacea: it is a new direction, not merely an instrument. Instead, it will require innovative and stimulating policy directions and goals. All too

soon, we will find that the policies applied in many countries will not be tough enough in the absence of a global international treaty that internalizes the global externalities involved. It is our cautiously optimistic hope that, in the coming years, sensible, green growth policies can help bridge the gap and bring us some steps closer to this necessarily binding global commitment.

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