Global Climate Change: Elements of a Mitigation Strategy
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Climate Change: Status of the Scientific Debate:

The scientific debate about climate change is not "over." No scientific debate ever is, in the sense of eliminating all uncertainty. But certain basic points are now known with overwhelming confidence. The earth's climate is changing. The rapid changes of the past few decades are extreme relative to our knowledge of past natural climate variability, except for a few sudden shocks at the end of ice ages. Human emissions of greenhouse gases – mostly CO_2 from burning fossil fuels, plus a few other CO_2 sources such as deforestation and a few other gases – are the major cause of the recent changes. The changes will continue and are very likely to continue at an increased rate. And the impacts of the changed climate, which are already starkly evident in some forms and some places – particularly in Arctic regions – are also likely to grow strongly.

Although the details of impacts are less well known than the basic science of climate change, present knowledge suggests that 21st-century climate impacts are likely to range from the merely inconvenient to the seriously disruptive in places that are rich, temperate, and well governed. Places that lack one or more of these advantages face more serious impacts, which could readily compare to – and indeed be accompanied by – those of major depressions, epidemics, or wars. Changes near the top end of what is presently believed plausible, including abrupt changes such as large-scale disruption of continental glaciers or ocean circulation, could bring impacts that bad or worse to any country, no matter how rich and currently fortunate. Remaining scientific uncertainties – e.g., exactly how fast will the climate change, and what the actual impacts will be – merely modify this basic picture. Those who continue to claim that recent changes are overwhelmingly natural-caused, that future changes will be small, or that their impacts can confidently be known to be small or even beneficial, if not themselves liars or cranks, have been naively misled by those who are. For all competent and impartial observers, the time for arguing about the scientific case for the seriousness of the climate-change risk has past. We know enough to make a compelling case for action. The only question is what action.

What to do about it – Why mitigation is the major early requirement:

Action on climate change includes some combination of two major components – conventionally called mitigation and adaptation – plus a third approach, geoengineering, to be held in reserve. **Adaptation** measures seek to adjust human society to the changing climate, e.g., by building seawalls or planting drought-resistant crops, to reduce harmful impacts. We will probably have to do a lot of adaptation, because we have long missed the chance to keep climate changes small. But with a few important exceptions – e.g., long-lived climate-sensitive investments, and places where serious impacts are already occurring – the required adaptation efforts are not immediate, but are spread over the time horizon of expected climate impacts, a few decades and longer. Adaptation is an essential part of our response to climate change, but not the most urgent part.

Geoengineering involves actively manipulating the climate system to offset the climatic effects of greenhouse-gas emissions, for example by injecting reflective aerosols into the stratosphere or positioning shields in space to shade a small fraction of the sun's disk. While there are no serious proposals to do such things in the near term, it is increasingly clear that these options need to be studied for their effectiveness, cost, and especially their potential risks – one does not actively manipulate planetary-scale processes lightly. The main reason these must be considered is that it might be possible to implement them faster than other responses. They can consequently provide insurance against the prospect that we badly fail to solve the climate-change problem or are unlucky in how big, fast, and bad climate change turns out to be. If climate changes are looking really bad in 2050, it might be attractive to have a technical response that can arrest or even reverse changes within another decade or so – although even in that case, the international political and legal problems would be severe.

This leaves mitigation – measures to reduce the human causes of climate change by limiting the greenhouse-gas emissions that are responsible. These come mostly but not entirely from fossil-fuel combustion, with a secondary share from deforestation. Mitigation is the only response that limits the environmental risk of climate change without potentially creating new ones, but it takes a long time to make a difference. A vigorous program of mitigation starting now would start to have a discernible effect in slowing climate change in 30 to 50 years. Unfortunately, we have very limited ability to wait to learn more about how bad climate change will be before starting to make such efforts, because any such delay will just push the effect still further into the future. This is a main reason that mitigation is the top item on the climate-change policy agenda, and also the most contentious. Figuring out how to limit future emissions is a hard problem – a hard technical problem to determine how to do it effectively at reasonable cost, and a hard political problem to distribute the resultant burdens – on which little progress has been made despite more than 20 years of analysis and argument.

The Scale of the Mitigation Problem: Stabilization objectives and requirements for non-emitting energy.

The Framework Convention on Climate Change states the objective of mitigation policy aptly: to stabilize the concentrations of greenhouse gases in the atmosphere at a level to avoid dangerous anthropogenic interference with the climate system. Limiting climate change requires stabilizing the atmospheric concentrations of greenhouse gases. This is a much more demanding requirement than stabilizing human emissions of these gases, a weaker goal with which it is sometimes confused. Atmospheric concentrations are a stock, like a nearly full bathtub, to which our emissions are an added flow, like a running tap. To stretch the analogy, stabilizing atmospheric concentrations – stopping the bathtub from overflowing – requires cutting global emissions sharply, eventually to nearly zero.

How much emissions must be reduced how soon depends on the level of stable atmospheric concentrations we are aiming at, which in turn depends on how much climate change we are willing to gamble on our ability to tolerate. Human emissions since the early 19th century have already raised the concentration of CO_2 from about 280 parts per million (ppm) to 380, and they are presently increasing at 2 ppm per year. Stabilization levels are discussed ranging from 450 to 750 ppm. Many have proposed stabilization goals from 450 to 550 ppm: 550 ppm would roughly double the pre-industrial concentration of CO_2, while 450 ppm would roughly double the equivalent climate effect if human increases in other greenhouse gases are included in the calculation. There is no strong basis for knowing what limit must be met to avoid dangerous anthropogenic interference (or, for that matter, how such interference is to be defined), but many knowledgeable observers get nervous about serious disruptions in contemplating increases beyond 550 ppm.

Emissions trajectories that stabilize concentrations at low costs have a common shape, with emissions initially rising, then turning and declining sharply. This shape tends to reduce costs for four reasons: it avoids premature scrapping of long-lived capital; it allows more time to develop new low-emitting technologies; it allows time for the natural carbon cycle to help remove early emissions from the atmosphere by the time the concentration target becomes binding; and by delaying emission-reduction expenditures, it reduces their present value through discounting. The lower the CO_2-stabilization target, the sooner the reversal and decline occurs. Stabilizing at 550 ppm, for example, requires global emissions, presently around 8 billion tones of Carbon (GtC) to peak at 11 GtC around 2035, then decline to 7 GtC by 2100 and 3 - 4 GtC by 2200. These cuts must be made in the context of a growing world population and economy, so the reductions made by present high-emitting countries must be sharper than this if they are to allow room for emerging economies to grow. What is required to follow these trajectories depends on how emissions would grow on their own and other uncertainties, but any such stabilization trajectory requires deploying quantities of new non-emitting energy supplies that are roughly comparable to the current total world energy supply by the middle of the century.

At one level this problem is simple. Cheap conventional oil and gas production will decline, maybe in a few years, maybe a few decades. Whether we follow high-emitting paths or declining ones that have possibility of stabilizing at some reasonable level depends on which way the global energy system goes afterwards. If we move to conventional use of coal or high-carbon synthetic fuels from coal or unconventional sources, we are very likely to track high emissions scenarios, with no prospects of stabilizing atmospheric concentrations this century or next. If we move to non-carbon primary sources – or more precisely, non-carbon-emitting primary sources – there is a good chance of following something like a stabilization trajectory.

The major non-emitting options are well known, and include efficiency improvements in energy use; renewable energy sources such as wind, solar, and biomass; nuclear power; and technologies for carbon capture and underground sequestration, which allow continued use of carbon-based fuels without emitting CO_2 to the atmosphere. Note that Hydrogen is not on this list because it is the answer to a different question. Hydrogen is an energy carrier, like electricity or refined liquid fuels, not a primary energy source. Whether a hydrogen economy helps or hurts the pursuit of climate stabilization depends on whether you make the hydrogen from greenhouse-emitting primary energy sources (e.g., from coal or oil sands), or from non-emitting ones. While there are some ways that shifting to hydrogen as an energy carrier might ease the shift toward lower emitting primary mix, you cannot count on this.

Except for small niches – of which the biggest now is wind power in the best sites – all these energy supply options presently cost more than conventional fossil fuels. This is why the bulk of new energy investment worldwide is going into conventional sources, especially coal power for electrical generating stations. There are large prospects for technological advances that will reduce costs in all these categories, but achieving these will require a combination of major investments in R&D, demonstration-scale projects, and early market roll-out of new technologies to move down learning curves. At present, neither investment in non-emitting sources nor the RD&D are occurring at anything like the required rate. And they will not occur without credible policy-driven market signals to motivate them.

The scale of development and deployment of these options to move toward stabilization is enormous. While it is possible to identify presently available technologies with which it would be technically feasible to achieve much or all of the required shift over 50 years, it is not possible to predict the actual mix of solutions – whether currently known or to be developed – that will work. Many options could experience major technical breakthroughs that would make them claim large shares of the required transition – a perennial favorite to bet on is a large, perhaps hundred-fold drop in the cost of solar photovoltaic cells – but there is no basis for predicting which if any of these options will benefit from such breakthroughs. The history of technical innovation would suggest there are likely to be a few winners and many losers – roughly equal shares to multiple technological directions is surely the least likely outcome. But we can't try to pick those few winners in advance, because we have no way of knowing which ones they will be.

Estimates of the cost of making the transition to atmospheric stabilization vary widely, from a few tenths of a percent to several percent of future GDP lost. This is substantially bigger than the cost of any other single environmental issue addressed to date, but clearly manageable in aggregate for rich industrialized countries, particularly in view of the large GDP growth projected over the 21st century. (In fact, these costs are comparable to the total estimated cost of all environmental compliance in industrialized countries today.) For a low-income country pursuing a development takeoff, these costs are clearly much more onerous. The two big uncertainties in these costs arise from different assumptions about how easily innovation brings down the costs of non-emitting energy systems, and different assumptions about how mitigation policies are enacted. On the one hand, if mitigation policies stimulate major cost-reducing innovations – as they have on many other environmental issues, though not all – then total costs could be lower, down to barely noticeable. On the other hand, current cost estimates assume optimal cost-minimizing worldwide policy to meet a given emissions constraint, with flexibility to make cuts indifferent places, at different times, and through reductions of different gases, so marginal mitigation costs are equalized. Less efficient and less flexible policies could raise the cost of stabilization at any specified level several times.

Policies:

Most of the required R&D to develop low-emitting energy technologies, and virtually all the investment to deploy them, will be done by private firms, not governments. The job of policy is to motivate these private decisions. A big increase in energy R&D is part of the solution, some of which will need or greatly benefit from public-sector subsidies, partnerships, and research programs. But the main motivation for the required private-sector investments must come from policies that make it profitable to reduce emissions – or that create a strong expectation that it will be profitable to do so over the relevant commercial lifetime of investments or technology development being undertaken now.

The design of these policies must be addressed simultaneously at the national and international levels: neither of these levels of response can be effective without consideration of, and contributions from, the other. This note briefly considers some issues on the boundary between national and international policy, but principally examines issues in the design of mitigation policy at the national level.

Market-based environmental policies such as emissions fees and tradable emissions permits possess several general advantages over other, administrative and directive forms of regulation, principally greater cost-effectiveness and incentives for innovation. These general advantages are even more important in greenhouse-gas mitigation than other environmental issues because the potential costs are so high. An idealized, pure market-based greenhouse emissions policy might impose a tax on the carbon content of fossil fuels where they are extracted (at the oil well or the coal mine) or imported. The price increase resulting from the tax would then follow the fossil energy through the economy, raising the cost of all goods in proportion to their use of greenhouse-emitting energy and so providing incentives to shift to lower-emitting alternatives throughout the economy. An idealized tradable-permit system would operate in an equivalent way. Extracting or importing carbon-based fuel would require a permit for the expected emissions when the fuel is burned, and the cost of acquiring the permit would track the use of fossil energy through the economy in the same way. In either case, a credit would be generated – the tax rebated or a new emissions permit granted – when a unit of fossil fuel is put to a use that avoids the expected CO_2 emissions, such as petrochemical manufacture or combustion from which the carbon is sequestered in a stable long-term reservoir. Various hybrid policies that combine elements of emissions taxes and tradable permits are possible, of which the most widely proposed is a permit system with a safety valve, a maximum permit price at which additional permits will be issued.

Could actual mitigation policy in any real country take such an extremely simplified form? Even in real economies, these policies have several important advantages. They spread the burden of mitigation effort broadly across the economy, bringing benefits of both increased cost-effectiveness and limiting opportunities for gaming. In addition, because it does not matter (in theory) where the initial burden of regulation is placed, such policies can be implemented to reduce administrative burden – e.g., targeting points of fossil-fuel extraction or import that may number in the hundreds or thousands as in the descriptions above, rather than points of combustion and emissions that number in the millions. In contrast, narrowly targeted regulations, e.g., ones that target only certain types of emitting facilities or facilities over a certain size, may be easier to enact politically but can be less effective, administratively cumbersome, and generate rampant gaming, as facilities are re-labeled, re-defined, or re-designed to move outside the boundaries of the regulation.

Real Mitigation Policies – Issues to Consider.

Despite these advantages, no mitigation policy like this would ever be enacted. They must be modified or augmented, for many economic, administrative, and political reasons. First, policies must consider certain characteristics of real economies (e.g., trade, capital age structure) that are not considered in the simple analyses of these idealized policies. Second, policies must be responsive to the political and economic setting in which they operate, in terms of its particular economic structure, technological strengths and weaknesses, legal and policy traditions, and configuration of political interests. The trick of successful mitigation is to design policies that are both technically and economically sound – and consequently effective and reasonable in cost – yet are also politically feasible, and so capable of being enacted. While the details of how to achieve this depend strongly on the particular jurisdiction, a few issues have to be considered in any attempt to enact serious mitigation policy.

Supplement economy-wide market-based policies with targeted initiatives: In real economies, broad market-based policies such as emissions taxes are not uniformly effective across the economy because many decisions with potent emissions effects are driven by other factors than energy prices. For example, building design and construction practices are predominantly determined by building codes. Such decisions create valuable opportunities for sector-specific policies to augment economy-wide market-based policies, e.g., measures targeting the energy efficiency of buildings, appliances, and vehicles, regional planning and zoning, and the major infrastructure investments that interact with these to shape settlement densities and transport demand. In many settings, such policies must be developed by or in collaboration with sub-national governments.

Respect capital lifetimes, but watch out for trickery: Costs of mitigation are much higher if they require premature abandonment of existing capital. This is why market-based policies need to start with modest stringency (just enough to get people's attention), then increase over time in some credible, pre-announced way to allow phased retirement of older, higher-emitting capital stock and orderly planning of new investment and technology development.

Such broad-based policies leave decisions how to treat new and old investments up to the investors. But in some cases, particularly for targeted sectoral policies, there may be reason for policies to distinguish new emissions sources from old ones explicitly. This may be especially crucial when there is a flood of new long-lived investment going into a sector that carry long commitments to future emissions. Motivating changes in the character of these new investments may require strong measures that you don't want to apply to old sources, even ones in the same sector, because their emissions characteristics are largely fixed and the policy would just impose large costs. Examples might include the rapid build-up of coal-fired electrical generating stations underway in China and several other large emerging economies, and the rush of investments now underway in the Canadian oil sands (unfortunately accompanied by a large federal subsidy). In the case of an over-heated gold rush such as the current situation in the oil sands, stringent environmental restrictions on new investments may actually bring broader social benefits, by slowing the rush to a more manageable pace. The risk of drawing such explicit distinctions between new and old emissions sources, however, come from the perverse incentive to stretch out the lifetime of old sources to continue benefiting from the more lenient regulatory treatment – one of the worst unintended consequences of the New Source Performance Standards under the US Clean Air Act. The lesson is that if policies treat existing sources more leniently than new ones, there must be a firmly committed phase-down of that benefit to ensure that the old sources aren't kept running forever, perhaps related to the remaining accounting life of assets for tax purposes.

Beware large transfers, and seek ways to avoid or compensate them: Big transfers of costs and benefits between domestic groups – e.g., between industrial sectors, between regions, or between private firms and the government – are the bane of environmental policy. Any serious mitigation efforts will create serious opportunities to make and lose money, and serious differences in burdens. The major reason that conventional emissions taxes are so rarely enacted at other than trivial levels despite their theoretical advantages lies in the large transfer they imply between emitters and the treasury, even after sources have adjusted their emissions in response to the tax.

Because nations differ in the nature, structure, and regional distribution of their energy economies, the particular distribution of burdens of a mitigation policy is highly specific to each country. Building enough political support to enact mitigation may require manipulating the details of policies to soften the burden on the hardest hit, or crafting national political bargains to compensate the biggest losers through other means. As a practical matter, it may be acceptable to let those whose cooperation is most essential to enacting policy gather some measure of windfall rents. But as ever in policy-making, skepticism is required in assessing claims of how much it hurts. Coal-burning electrical utilities may operate in competitive and regulatory environments that let them pass cost increments through to their customers. Demands to give away the store, for example by exempting emissions-intensive industries from an emissions tax or giving emissions permits for free to current emitters rather than auctioning them, should always be expected and resisted. Giving them all, and auctioning them all, form the endpoints of a bargaining range: the problem is to find some reasonably efficient and politically practical point to land in the middle.

Consider fiscal effects, provide comfort to guardians of the Treasury: Any sensibly designed market-based mitigation policy holds the prospect of large revenue flows to the national treasury, through some combination of revenues from emissions fees and from initial auction or sale of emissions permits. The politics of mitigation policy are likely to be much easier, and the macroeconomic costs of policies reduced, if policies are designed to be revenue-neutral or nearly so through intelligent recycling of these revenues, ideally by reducing some other tax with highest deadweight loss, such as payroll taxes. But treasury officials are justifiably nervous about proposals to replace a secure and well understood revenue stream with an unfamiliar and potentially volatile one. Mitigation policies consequently need to leave room for adjustment and adaptation as experience is gained with both their behavioral and fiscal effects, but not so much as to impair credibility or risk big costs from sudden increases.

Design policies to motivate innovations, especially those that benefit your own citizens: Broad market-based policies can motivate technological innovations to reduce emissions, provided they credibly commit to a long time horizon of increasingly stringent requirements. This need, together with the need to limit near-term disruption, argues for starting interventions at some modest level (although still strong enough to get people's attention), with a pre-announced schedule of smooth future increases in stringency. But national economies have particular strengths and weaknesses in various resources and technologies relevant to mitigation. Policy details should seek to enhance opportunities for innovations in areas of greatest national promise, to position for competitive advantages in a future, greenhouse-gas constrained world economy. This may imply putting strong positive and negative incentives on the most promising broad areas (e.g., for Canada biomass energy and carbon capture and sequestration are especially promising sectors for technology development; wind and solar are not.), or coupling broad-based mitigation policy with R&D programs targeting the most promising sectors.

Worry about competitive disadvantages, but not too much: If a few nations exercise strong leadership in mitigation and incur significant costs, their producers in higher emitting sectors are likely to suffer significant competitive disadvantages. This is the basis for the widely cited argument that all nations must move together slowly, or else emissions leakage will penalize the leaders and make the endeavor ineffective. This concern must be taken seriously, although it has often been overblown. The seriousness of leakage depends on the aggregate size of the economies that move together, and how fast real investment moves in response to policy-generated differences in returns. Evidence from studies of international taxation suggests this movement is not likely to be as big or as fast as those concerned with emissions leakage suggest.

Moreover, one must think about the competitive effects of mitigation strategies dynamically. Any mitigation regime will evolve in its membership and the terms of its agreements, as other environmental regimes have evolved, perhaps rapidly. Consequently early leaders may only suffer competitive disadvantages for a short time. Nations thinking of taking a leadership position must consider how many can be persuaded to move together – which influences both how effectively they can motivate private-sector innovation, and how severe a competitive disadvantage they will suffer (The more nations move together, the more competitors are under the mitigation umbrella) – and how long they can sustain a position of costly leadership while waiting for others to join.

The crucial linkage between mitigation leadership and costs comes from international trade measures. The cost burden borne by producers in nations doing serious mitigation can be reduced – or rather, shifted from producers to consumers – through trade measures that seek to offset the cost burden at the border, using border trade adjustments or similar measures. In the simplest form, the estimated cost burden from mitigation policies would be rebated to exports and charged to imports. Such measures would both mitigate the competitive disadvantages to producers operating under a mitigation regime, and provide incentives for additional countries to join the regime. They would be administratively complex, but not beyond the capacity of modern IT-savvy governments to do reasonable approximations. Moreover, while some international trade scholars have claimed that such measures would be GATT-illegal, their status in fact appears to be unresolved. European nations are already seriously considering such measures, and some national representatives were threatening them at November's meetings in Nairobi.

Thinking about the competitive burden is also the point where the national mitigation problem connects with the global mitigation problem. Stabilizing atmospheric concentrations requires some specified trajectory for global emissions, but says nothing about the allocation of shares among nations or regions. Explicit allocation discussions have got nowhere, but it is nearly universally acknowledged that the rich countries must make larger and earlier contributions, so that the global distribution of emissions heads toward convergence per capita. No other basis for convergence makes any sense: in particular, allocating emissions per unit GDP would either pose no real limit as the world economy grows, or would freeze in current inequities by limiting growth.

Any North-South group of nations contemplating joint mitigation action must grapple with the distributive implications of their decisions – if not in terms of explicit allocations, then implicitly as they bargain over specific transfers and terms of investment. Even a group of exclusively rich countries trying to exercise mitigation leadership would have to consider global distributive implications, if they attempt to limit competitive disadvantages through trade measures, because they must decide whether the trade measures are applied on the same terms to all exports and imports regardless of the development status of the trading partner. Not addressing this issue would amount to unilaterally imposing an equally stringent mitigation regime on the exporting sectors of developing countries and emerging economies.

This is an enormous problem, but there are two grounds for hope. The first is that a group of leading rich countries could put in place a mitigation strategy that deploys clear incentives and provides a clear signal of seriousness – which has thus far not been achieved – even if the stringency of the policy ramps up gradually from a modest start, to limit the early cost burden. The second is that the very enormity of the required shift in global energy systems means that over a century such extreme decoupling of economic growth from emissions will be required that after the transition there won't be much to fight over. The most serious risk is that fighting over allocations in the interim may seriously obstruct the global problem.