Politics and Economics of Second-Best Regulation of Greenhouse Gases: The Importance of Regulatory Credibility

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Compared with economically ideal policies, actual limits on global warming gases are likely to be "second-best" in many ways. Most studies focus on "second-best" approaches such as delaying emission controls in developing countries, constraining international emission trading, or regulating gases piecemeal by sector rather than equally across the whole economy. We show that another second-best approach—lacking of regulatory credibility—imposes up to six times the extra costs on the economy when compared with all other "second-best" factors combined. When regulatory rules are not believable then firms and other agents become short-sighted and unable to make optimal investments in research and development as well as long-lived technologies. Although analysts have largely ignored this issue, low credibility is commonplace when governments tackle international problems because international institutions such as treaties are usually weak and fickle. Governments can help solve credibility problems with strategies such as "pre-committing" regulations into domestic law that is usually more credible than international commitments. We show that China, for example, can justify unilateral, emission controls because such pre-commitment would encourage Chinese firms to invest with a clearer eye to the future.

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INTRODUCTION

In the ideal world all governments would control greenhouse gases from all sectors of their economies as soon as possible. That ideal outcome would give firms time to anticipate regulation. It would also help prevent "leakage" of emissions that would occur if emission-intensive activities shifted from tightly regulated sectors and countries to the more lax zones [e.g., Aldy and Pizer, 2009]. Indeed, from the pioneering work on the economics of regulating greenhouse gases to the present day, the standard result confirms that a global, economy-wide and long-term approach is the most cost-effective method for controlling warming gases [Manne and Richels, 1992], [Nordhaus, 2005] and [Jacoby at al, 2008]. The economic benefits of this approach are particularly large when countries aim to make deep reductions in emissions, as implied with increasingly popular goals such as limiting concentrations of CO_2 and other warming gases at 450 ppm or even 350 ppm. Indeed, meeting such goals is essentially impossible without immediate and comprehensive limits that cover nearly all nations and economic sectors [Clarke et al. 2009, Bosetti et al. 2008, Edmonds et al. 2007, Keppo and Rao, 2007, OECD Policy Brief, 2009].

While the ideal world is elegant and efficient, the real world is not nearly so accommodating. Developing countries have been famously reluctant to accept caps on their emissions. Efforts to entice them by offering more generous caps—so-called "headroom allowances"—are exciting for theorists to discuss, but have been politically impossible to achieve in real diplomatic discussions. The experience with Russia (which was given a particularly generous cap to entice its participation in the Kyoto treaty) suggests that providing generous caps to reluctant treaty members may actually be counter-productive [Victor, 2001]. Even if some kind of headroom deal were crafted with the developing countries, practical and political difficulties make it doubtful these countries would participate in economy-wide limits on emissions right from the outset. Rather, they would allow regulation, first, in particular sectors where they are confident of their ability to administer emission controls; other, less well-regulated sectors would be brought into a regulatory scheme later on [Victor, in press]. That sectoral approach reflects not only the interests and capabilities of these countries, but also those of the more advanced nations that hope to link their emission trading schemes to the many low-cost opportunities for emission controls in the developing world. They will be wary about allowing trading links to sectors that are impractical to monitor and enforce [Rai and Victor, 2009; Wagner et al., 2008]. Even in those sectors where regulation is feasible, developing countries will demand delays and compensation before they impose limits on their activities, just as they secured delays and special funding in other major international accords, such as on protection of the ozone layer [Benedick, 1998; Parson, 2003].

The ideal world of greenhouse regulation is one of a seamless regulation that spans all sectors globally. The real world is a messier second-best landscape of fragmented efforts that run at many different speeds [Victor et al., 2005; Richels et al., 2009]. This paper explores some economics of the second-best scenarios and their implications for politics and the design of international treaties and other regulatory institutions.

We look at the implications of four large departures from the ideal world. In one, *countries* join global regulation at different times and with different levels of effort—what we call "variable geometry." Variable geometry contrasts with the global geometry of the ideal first-best approach to regulating global warming gases. When we vary geometry we divide the world into three crude categories—the most enthusiastic (and richest) nations, the reluctant (rapidly developing) nations that make the next move, and the impoverished countries that don't emit much and have much higher priorities than global efforts to dampen climate warming.[1] Variable geometry leads to higher costs because it allows for more leakage.

Second, we examine limits on emission trading, which are also abhorred by analysts living in the first-best world but likely to arise in the real, second-best world. In the first-best world emission trading lowers compliance costs, especially because it allows for trade in credits between industrialised countries, where abatement costs are generally high, and developing nations, where abatement opportunities are often more abundant. In the second-best world much trading occurs through offsets that are devilishly difficult to administer [Victor, in press]. Trading limits make regulation more expensive because it reduces the range of compliance options.

The third departure envisions applying regulation to different economic *sectors* with differing degrees of stringency and timing. We implement this second-best constraint by limiting emission trading between sectors, in contrast with an all-sector, fully fungible emission trading scheme that is typical in a first-best world. When we vary sectors we divide industrial emitting activities into two categories—electric power (which is generally easier for most countries to regulate, especially as much of the world's electric power is run by state-owned companies) and non-electric (which includes highly decentralised emissions sources such as in buildings and industries that governments often struggle to regulate). A sectoral approach is more costly than ideal economy-wide regulation because, like limits on trading, it shrinks the array of compliance options available to firms and countries.

These are gross simplifications, but they are useful for analytical purposes. Indeed, the real world of greenhouse gas diplomacy and regulation is evolving in these second-best directions. Ever since the United Nations Frame-

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[1] In the real world, membership in these categories varies as countries learn about climate dangers and come under varying degrees of political pressure to act or drag their feet. For simplicity, for the modelling runs in this paper we assume the enthusiastic countries are OECD countries; reluctant countries represent Brazil, China, India, Transition Economies and Oil Exporting Countries (i.e., the so-called "BRIC" nations plus oil exporters); the countries we call "impoverished" span Africa and South East Asia. Our classification is for the ease of modelling and broadly corresponds with real government negotiating positions but is not intended to disparage or exalt any particular country.

work Convention on Climate Change (UNFCCC) was crafted in 1992, every major international effort to regulate emissions—not only the legally binding efforts under the UNFCCC but also the many non-binding attempts such as through the Group of 8 organisation of industrial economies—has underscored that reluctant developing countries would be expected to adopt emission caps only long after the industrialised world "takes the lead" and tightens limits on itself [UNFCCC Article 1, 1992; G8 communiqué, 2009]. Many countries are now considering various limits on the use of international offsets and reforms to the Kyoto Protocol's Clean Development Mechanism (CDM) that would treat countries and sectors differently. Every major country that has attempted to regulate emissions has adopted approaches that vary by sector. For example, the EU's Emission Trading Scheme (ETS) covers only industrial sources; other sources, such as transport and buildings, are regulated with different instruments. Developing countries are also exploring policies that would vary by sector, not least because some emitting sectors are easier to regulate than others [e.g., Rai and Victor, 2009].

We also explore a fourth and much less studied aspect of the real, second-best world: *credibility*. When policies are highly credible then investors can make reliable plans; in turn, the cost of emission controls is lower than it would be otherwise because new technologies can be ordered and installed with the normal turnover of the capital stock [e.g., Philibert, 2007]. Very few studies have looked at the effect of policy anticipation on the costs of climate change regulation. The few exceptions include [Blanford et al, 2009] and [Bosetti et al 2009b], both of which assess the negative effect of myopic behaviour on latecomers as well as on climate agreement early participants. A study by [Reinelt and Keith,2007] has examined the consequences of regulatory uncertainty on incentives to invest in carbon capture, which is one widely discussed technological option that could help societies lower emissions. Still other studies have looked at how credibility affects markets. An analysis by [Paltsev at al, 2009], for example, has explored the effect of policy credibility on the banking of carbon permits, concluding that incredible policies have adverse economic effects. Despite these few exceptions, studies of global warming regulation have not given much attention to why anticipation would vary and the practical implications for policy. And no study, until the present one, has sought to quantify and compare the importance of many different second-best factors on economic outcomes. As will be clear, we suggest that credibility is paramount. Indeed, while this topic is rarely discussed among analysts of climate policy, this is a long-standing topic in other fields of regulation and regulatory risk. Studies of foreign investment, for example, have shown that countries that have more credible regulatory policies tend to be more attractive locations for investors who are risk-averse and fear that unpredictable changes in regulatory results will lead to expropriation of their fixed assets [Vernon, 1971; Woodhouse, 2006]. The daily business of diplomats, such as those crafting global warming treaties, is a constant fretting about credibility because international legal mechanisms, on their own, are usually not very strong. Credibility is a scarce resource in international law.

AN INTEGRATED ASSESSMENT MODEL

To examine this second-best world—where geometry, trading rules, sectors and credibility all vary—we use the WITCH model [Bosetti et al, 2006].[2] WITCH is a regional integrated assessment model that is designed to analyse optimal responses of world economies to climate damages and to identify the impacts of climate policy on global and regional economic systems. It is a hybrid of "top-down" (macroeconomic) and "bottom-up" (technology) assessment models. Its top-down component consists of an inter-temporal optimal macroeconomic growth model in which the energy input of the aggregate production function has been expanded to provide a bottom-up like description of the energy sector. The bottom-up attributes include detailed treatment of investment and operating costs, performance and learning curves for major clusters of energy technologies. World countries are grouped in twelve regions that strategically interact playing a Nash game; countries make regulatory decisions optimising their own welfare in light of expectations of what other nations will do. Countries signatories of climate agreements are also subject to external constraints such as binding limits on emissions. Emissions calculations from the economic model are provided to a climate module that projects concentrations of warming gases and climatic effects.

A model with dynamic and strategic features and detailed representation of energy technologies is particularly useful for analysing climate change policy because deep cuts in emissions require development and deployment of new technologies over a long time horizon. WITCH includes mitigation options in both the power generation sector and in other major parts of the energy system, such as transportation. Mitigation options in the power sector include nuclear, hydroelectric, integrated gasification combined-cycle coal plants with carbon capture and storage (CCS), and renewables. In the non-electric sector options include advanced biofuels. In all, the model includes more than ten mitigation options in the energy sector, including both substitution and fuel switching. The model includes endogenous improvement in energy technology—spending on R&D leads to improved performance of technologies. The model also distinguishes between innovation in existing, near-commercial technologies and investment in "breakthrough" innovative technologies with zero carbon emissions. (We model these technologies, which do not exist today, as a generic portfolio rather than picking particular winners. Through R&D investments one or the other potential alternative will become available at a competitive cost in the future.) This approach allows for some detail in the discussion of technological change while avoiding attempts to estimate the detailed choice of energy technologies far into the future

[2] A thorough description and a list of related papers and applications are available at http://www.witchmodel.org.

when such projections from today's vantage point would be meaningless. WITCH includes two breakthrough technologies, one in the electric and one in the non electric sector, that necessitate dedicated innovation investments to become economically competitive, even in a scenario with a climate policy. We follow the most recent characterisation in the technology and climate change literature by modelling the costs of the breakthrough technologies with a two-factor learning curve in which their price declines both with investments in dedicated R&D and with technology diffusion. Similar approaches are also reported, for example, in [Kouvaritakis et al., 2000] and [Klassen et al, 2007].

For our analysis, a key attribute of the WITCH model is the ability to adjust the extent to which governments and firms are forward-looking. If global policies such as binding limits on emissions and concentrations of warming gases will be credibly enforced then each region's policy maker (and by implication, firms that follow the dictates of the policy maker) can reliably anticipate the arrival of policy mandates. Anticipation allows firms and governments to invest in new energy technologies in a manner consistent with the commercial life-time of the energy stock, penetration limits of carbon free technologies, and the gestation from investment in R&D until tangible improvements in the performance of new technologies appear. In the real world, policy makers and firms are more myopic—in part because international policies are difficult to enforce and no government or firm wants to invest massively in pursuit of a policy that could change—especially if the changes lead to a more lax regulation that makes heroic investments in new technologies less valuable. WITCH allows us to mimic that myopia. By shortening the time horizon over which investors are free to respond optimally to the future policy we proxy decreasing levels of policy credibility. When credibility is high the investor can see to the distant horizon and anticipate, today in 2010, a policy that formally takes full effect in 2030. When it is low, the future is cloudy and anticipation is reduced to 15, 10 or 5 years ahead of the policy, while precedent decisions are forced to be in line with a business as usual scenario.

To begin the analysis we develop two baseline scenarios. One is a standard "business as usual" (BAU) scenario with no regulation (figure 1). Then we limit emissions such that all countries make comparable efforts to stabilise atmospheric concentrations of CO_2 at 450ppm. We call this scenario the regulated baseline and show the regulatory efforts on figure 2 with details in table 1. For simplicity we concentrate here on fossil fuel CO_2, which is the most important human-emitted warming gas and also the one for which WITCH (like nearly all integrated models) has the finest resolution on abatement options. We are mindful that other sources of CO_2 as well as other gases also warm the planet. Including those other gases and sources would make our 450ppm CO_2 optimal scenario similar to a 550ppm all-gas scenario.[3] We focus on the 450ppm CO_2 goal because

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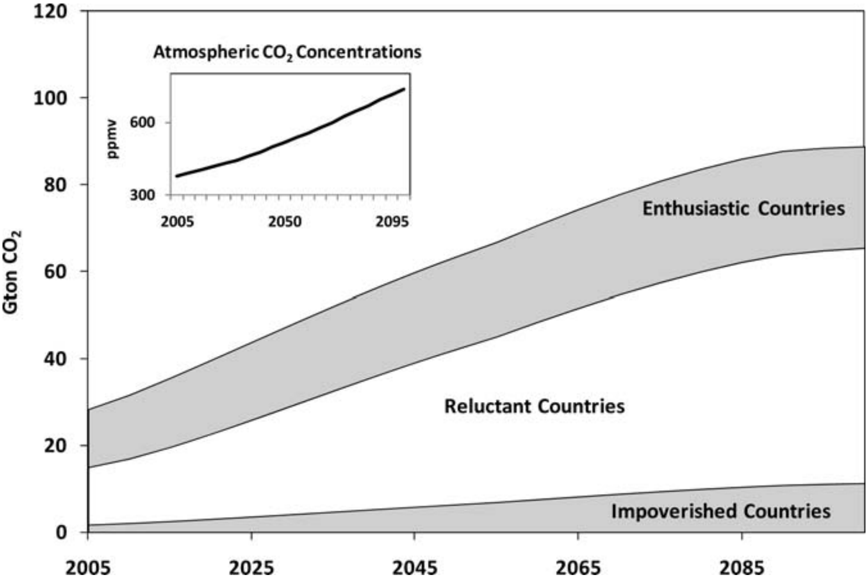
[3] The resulting radiative forcing is equivalent to about 3.5 watts per square meter; when the warming effects of all the gases are included, and there is some accounting for the cooling effects of

Figure 1: The Reference ("Business as Usual") Projection from WITCH



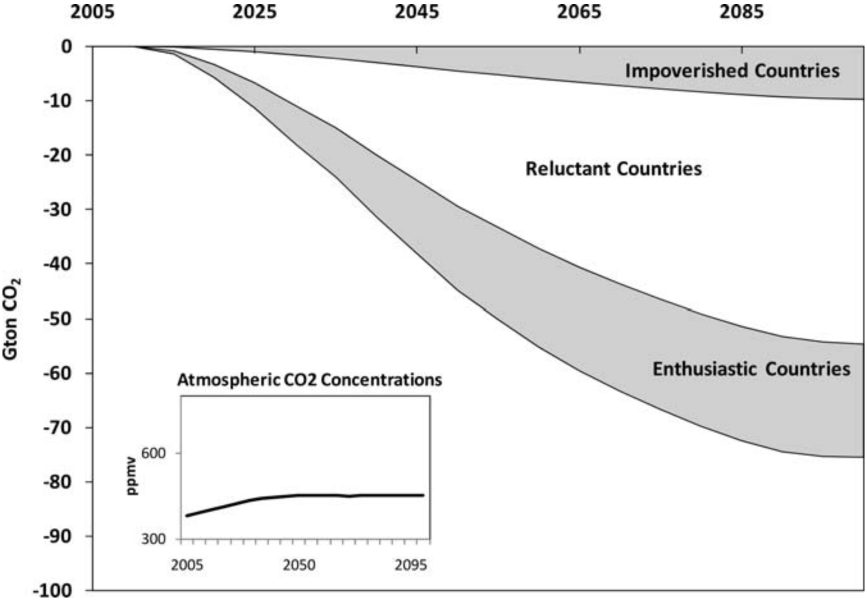
We include only emissions of CO_2 from burning fossil fuels and project for three politically-informed groups of countries: the enthusiastic (rich, industrialized) nations, the reluctant nations that are fast-growing yet wary at present to spend their own resources on emission controls, and the impoverished low-emission countries that have other priorities for the coming decades and are not immediately essential players in emission controls. The inset shows projections for CO_2 concentrations (including land-use emissions, per the standard WITCH assumptions reported in Bosetti et al., 2009c).

it is widely discussed and has been the subject of extensive modelling and thus our results can readily be compared with others. We do not claim that this goal aligns the costs and benefits of climate regulation, which is an important and controversial matter, but not the focus of the present analysis. This scenario is less aggressive than some of the scenarios that are now popular—among climate modelers and activists, if not real politicians who might implement them—such as stabilising concentrations at 350ppm. [Monastersky, 2009] Most models find that such aggressive scenarios are impossible to achieve with second-best policy that excludes some countries and sectors, such as for example [Clarke et al, 2009].

The regulated baseline shown in figure 2 and table 1 is a "first-best" response. Costs are minimised because policy makers and firms have perfect

aerosols, the expected average warming is about 2.5 degrees of warming above pre-industrial levels. In WITCH, non-CO2 gases emissions of CH4, N2O, SLF and LLF are modelled explicitly. SO2 aerosols are assumed to have a direct cooling effect on temperature. Baseline projections of non-CO2 GHGs are based on EPA regional estimates (EPA, 2006). Our analysis excludes forestry options, but including them would allow another 20 ppm CO_2-eq of industrial emissions by the end of the century. WITCH does not include black carbon and its potentially large but uncertain warming properties.

Figure 2: Abatement Efforts in the "First Best" World of Optimal Regulation



Main chart shows emission levels (below the BAU scenario in figure 1) for each of our three groups of countries. The inset shows the resulting stabilization of CO_2 concentrations (including land-use emissions, per the standard WITCH assumptions reported in Bosetti et al., 2009c).

foresight; all governments on the planet participate; regulation applies to all sectors with equal marginal effort; and unfettered trade in goods and services as well as emission permits allows equalisation of costs. In this first-best world where emission permits trade freely, abatement effort is allocated across countries on the basis of equal marginal costs.[4] The cost of a first-best policy, measured as the present value of Gross World Product (GWP) losses compared with the BAU scenario, is 1.58% (using a 5% discount rate, a widely used rate for comparing costs and benefits over time).

FOUR DIMENSIONS OF THE SECOND-BEST

The rest of this paper examines scenarios that all deliver the same environmental outcome as the regulated baseline—that is, stabilisation at 450ppm CO_2—while wreaking havoc on the first-best assumptions.

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[4] This assumption is not needed for optimality, as trade would equalise marginal abatement independently of the initial allocation, but we make it to minimise the flows of emission permits when the market equilibrates. Our view is that large permit flows are politically not sustainable and thus our scenario is designed to reflect one that is as close to likely political outcomes as possible.

Table 1: Emission Reductions to Achieve 450 ppm

Table shows BAU emissions and percentage cumulative reductions in emissions (2015 to 2100) below BAU for our optimal ("first best") stabilization scenario.

		Enthusiastic countries (OECD countries)	Reluctant countries (BRICs, Transition Economies and Oil Exporting Countries	Impoverished countries (Africa and South East Asia)	Total
Cumulated Emissions Total (Gt CO_2)	BAU baseline emissions (Gt)	1907	3448	666	6020
	Regulated baseline emissions (Gt)	595	1049	191	1834
	Difference (percent)	–69%	–70%	–71%	–70%
Cumulate Emissions Electric Sector (Gt CO_2)	BAU baseline emissions (Gt)	734	1636	323	2694
	Regulated baseline emissions (Gt)	137	240	52	428
	Difference (percent)	–81%	–85%	–84%	–84%
Cumulate Emissions Non-Electric Sector (Gt CO_2)	BAU baseline emissions (Gt)	1173	1811	342	3327
	Regulated baseline emissions (Gt)	458	809	139	1406
	Difference (percent)	–61%	–55%	–59%	–58%

Variable Geometry

The first element leading us away from the first-best is geometry of participation. To simplify matters, when varying geometry we divide the world into three categories of nations that roughly correspond with political interests and administrative capabilities. The "enthusiastic countries" are mainly the richest

Table 2: Second Best Assumptions on Variable Geometry

Country	Target	Example
Enthusiastic countries (OECD countries)	Immediate target. Allocation proportional to effort in first best case.	For US. By 2025 30% below baseline and 24% above 1990 levels. By 2050 77% below baseline and 49% below 1990 levels.
Reluctant countries (BRICs, Transition Economies and Oil Exporting Countries)	Target in 2030. Allocation proportional to effort in first best case.	China. By 2050 70% below baseline and 108% above 1990 levels.
Impoverished countries (Africa and South East Asia)	Target in 2050. Allocation proportional to effort in first best case.	Sub-Saharan Africa. By 2050 75% below baseline and 61% above 1990 levels.

industrialised nations that are under growing internal pressure to spend their own money on slowing global warming and to help other countries make efforts as well. Next are the "reluctant" countries whose emissions are high (and growing rapidly) but have other political priorities. With economic growth their interests are shifting in the direction of making some effort to control emissions, and their national administrative systems are varied in their ability to regulate a pervasive pollutant such as CO_2. Some sectors are difficult to regulate; others are easier in part because governments themselves own most of the relevant infrastructure and thus can regulate it more readily, such as in the electric sector [Victor and Heller, eds., 2007]. Last are the "impoverished" countries that have generally low emissions and much more immediate troubles than global warming (table 2). These countries' emissions stay relatively low, although some of these countries are prodigious clearers of land clearers (a source of emissions we exclude from the present analysis). This three-category approach follows Victor (2007), which explains the political and administrative logic in more detail and is modelled by [Bosetti et al. 2009a]. There is a burgeoning literature on the geometry of participation, and much of it explores scenarios with similar attributes [See, e.g., Bosetti et al 2008; Edmonds et al., 2007; Keppo and Rao, 2007, Clarke et al 2009, Jacoby et al, 2008].

Table 2 reports assumptions for a plausible scenario that includes this variable geometry. The reluctant nations begin regulating after a two-decade delay; the impoverished nations follow another two decades later still, making no effort before 2050. For simplicity's sake, we assume that this second-best geometry converges to the first-best global approach after 2050, at which point all nations make an effort based on equal marginal costs. This assumption of ultimate convergence may be naïve. Africa was deeply poor a century ago and might still rank among the impoverished in 2100, making little effort to regulate its emissions. But our concern here is the transition until 2050 in a world where countries move at different speeds. Indeed, over such long time horizons differences are unlikely to be permanent. In 1950 Japan and much of central Europe were among the poorest nations in the modern economy; today they are rich and in the lead on greenhouse gas regulation. Similarly, by 2050 many of today's emerging tigers are also likely to be rich leaders and will accept the regulatory obligations that accompany leadership.

Our results for this simple, variable geometry scenario are similar to those reported in other studies. Assuming immediate and unlimited global trading including offsets, the global cost of variable geometry is nearly the same as in the first-best world because trade allows for easy equilibration of markets and globally least-cost solutions. Of course, the cost for individual regions varies with the assignment of regulatory burdens. In our variable geometry scenario, the cost paid by enthusiastic countries is 8% higher than in our first-best scenario; reluctant countries incur a 5% extra burden; and the impoverished countries are 49% better off because they sell surplus permits and investment opportunities in offsets to the other countries that have tighter regulation.[5]

Trading and Offsets

Our assessment of geometry hinges on the heroic assumption that international trading will be free and efficient. As a practical matter, full-blown emission trading requires countries to agree on emission caps, which has proved extremely difficult politically. And thus most of the benefits of trading hinge on the first-best assumption that offsets will be widely available. Yet in the real world there is growing evidence that offsets markets are not working well and are encumbered with transaction costs—problems evident especially in the world's largest offset market, the Kyoto Protocol's CDM [e.g., Wara and Victor, 2008].

To mimic these second-best constraints we add limits to international trade. As a practical matter, those limits could take the form of bans or other constraints on trade between regions, which could reflect the desire to limit the flow of capital and to force regulation to occur within particular countries. For example, in the Kyoto negotiations many interest groups were wary about allowing too much (or even any) international trade in emission credits because that would allow the rich industrialised nations to avoid obligations to act at home. Trade limits could also include extra costs, such as explicit taxes—for example, the tax on the CDM that has generated a small pool of money to fund adaptation projects—or perhaps high transaction costs from tight regulation of offset programs to ensure that offsets are genuine. In limiting total trading, we restrict

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[5] These changes are all net present value with the standard 5% discount rate. In our regulated baseline scenario we allocated emission credits to equalise marginal cost. In the variable geometry scenario we assigned more burden to the countries that care most about the problem and have the greatest resources to address it, even though this convenient political attribute requires accepting greater financial flows across countries as the tightly regulated countries purchase offsets from more lax zones.

trading to no more than 15% of a country's compliance effort—a scenario we will call "15% cap". In adding transaction costs, we envision that efforts to reform the CDM create a much tighter administration that imposes a $10 per ton CO_2 extra cost. (That number is at the high end of current estimates for administrative costs but not implausible.)

Because the results from these constraints are most interesting when combined with other second-best constraints we report them later.

Sectors

We also explore second-best policies that might vary by sector. A few analysts have examined such scenarios, often focusing on the electric power sector [Sawa 2008]. Such sectoral approaches are important to analyse because even when governments are keen to regulate emissions due to internal political pressure or external incentives such as carbon credits, it can often be administratively difficult for governments to control activities in all sectors. Moreover, the politics of regulation often vary by sector. For simplicity, we divide the world into two broad sectors: electricity and the rest. We assume that enthusiastic countries require equal regulatory effort in all sectors. But the rest of the world varies its effort by sector. This reflects that in all the largest emerging economies most of the electric sector is controlled centrally and much of the power sector is already regulated for its pollution, whereas more diffused sources—such as buildings and transportation systems—have proved more difficult for states with weak administrations to regulate. When a government is under pressure to control emissions it will initially grasp for the levers on emissions that it can control more readily. And governments keen to earn offset credits will focus on sectors where they can more readily control transaction costs and manipulate policy to maximise offset earnings. These administrative and political insights conveniently align with the fact that the power sector also offers large leverage over emissions, especially as the rapidly growing reluctant countries expand their economies and electrify. Table 3 summarises the assumptions we will make across the sectors of each category of nations, which are similar to our second-best assumptions on variable geometry.[6]

Now we show results that combine these three second-best assumptions (figure 3). At the far left is a scenario that shows the extra cost in a setting we have already discussed—variable geometry with global emission trading. The second scenario on figure 3 mimics the transaction costs associated with a $10 per ton CO_2 administrative markup on international offsets, which imposes only

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[6] In implementing these assumptions we have adjusted the caps (in proportion to the effort for each group of countries under our variable geometry scenario) so that this scenario leads to the same global emissions each period (hence enthusiastic countries make up for any emission excess deriving from the uncapped sectors of the other two groups of countries. This adjustment ensures that all the scenarios yield the same environmental outcome and thus their costs are more readily compared.

Table 3: Second Best Assumptions on Sectoral Regulation

Table shows assumptions for regulation of the power sector and other sectors for each of the three country groupings. In enthusiastic countries the power sector is regulated with the same stringency and timing of other sectors. In the reluctant and impoverished countries other regulations are imposed earlier on the power sector, and comparable limits on emission trading are imposed on the power sector over the same time horizon.

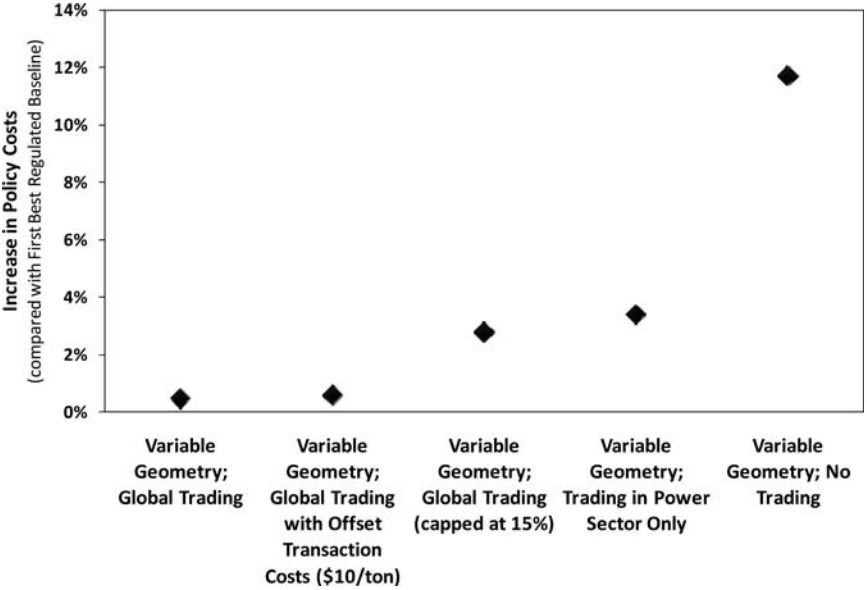
Countries	Target	
	Power Sector	Other Sectors
Enthusiastic countries (OECD countries)	Immediate cap	Immediate cap
Reluctant countries (BRICs, Transition Economies and Oil Exporting Countries)	Starting in 2015	Nothing until 2030
Impoverished countries (Africa and South East Asia)	Starting in 2025	Nothing until 2050

a tiny extra cost on the world economy. That's because the deep cuts in total emissions needed to reach the 450 ppm goal requires many offsets at high cost; the extra administrative burden is not particularly onerous.

Restricting the maximum share of abatement that can be covered with offsets or other forms of emission trading, as shown in the third scenario (15% cap) on figure 3, causes a very modest 3% increase in total policy costs. However, in the short term the increase in costs in this scenario can be substantial; in 2020 total economic costs are 50% higher than the first-best regulated baseline, and the costs for the OECD nations are double those in the first-best world. (However, since early costs are modest in absolute terms the overall impact on total integrated costs is not severe.) In addition, the early increase in efforts is rewarded by a faster technological progress that pays off when, in later periods, the cuts in emission are more substantial (see [DeCian and Tavoni, 2009] for a detailed description of the effects of trade restriction on the cost of climate policy). These results are consistent with those reported by other scholars who have found that restrictions on trade are not too costly so long as they are not so severe to prevent at least some forms of trade—for example the studies by [Jaffe et al., 2005] and [Jaffe and Stavins, 2007]).

The effect of second-best limits on sectors is also relatively small. We implement this approach by allowing trade in emission credits only in the power sector (fourth scenario in figure 3). The small (less than 4%) increase in cost when compared with a first-best regulation reflects that most international trading in the first-best scenario occurs in the power sector; allowing trading in the power sector alone is not a particularly binding constraint. It is much more costly to reduce emissions from the non-electric sectors (notably transportation) and thus they generally offer fewer gains for tightly regulated industrialised countries seeking offsets in less regulated emerging economies. For comparison, we also show an extreme case that restricts all trading (fifth scenario on figure 3), for which total costs are 12% above the first-best regulated baseline. This extreme case also

Figure 3: The Effects of Second-Best Policies in Geometry, Trading and Sectoral Regulation



Policy costs are measured as discounted reductions in Gross World output with respect to the baseline. In figure we look at the relative change of costs with respect to policy costs in the first-best regulated baseline. Starting from left increases in policy cost are reported for cases when variable geometry is assumed and: i) all sectors and all groups of countries participate from the beginning to the global market without limitation. The increase in costs in this scenario is nearly zero but not exactly zero due to fact that the different allocation of allowances induces differences in regional budgets, with intertemporal implications. As an example, the regional budgets available for innovation spending will be slightly different, differences which are propagated by international spillovers ; ii) all sectors and all groups of countries participate from the beginning to the global market but there is a $10 markup on the price of permits to reflect higher administrative costs; for reference, in this scenario the price of emission permits is $ 430 per ton of CO2 in 2050; iii) all sectors and all groups of countries participate from the beginning to the global market but there is a 15% limit on the share of permits (including offsets) over total abatement; iv) only the power sector of reluctant and impoverished countries is linked to the global market, until they get a binding target; v) reluctant and impoverished countries do not participate to the global market, until they get a binding target.

offers a useful starting point for our analysis of credibility, to which we turn in the next section.

While the total global cost of regulation does not change much across the scenarios shown on figure 3, there are big differences in the magnitude of financial flows between countries. As we have seen, a politically more realistic geometry of participation causes much higher financial flows because the carbon market equilibrates costs. (By assumption, our “first-best” regulated baseline allocated emission targets to minimise financial flows.) The various other second-best scenarios generally reduce financial flows because they impose constraints and extra costs on trading. For example, the cumulative financial flow from 2010–2025 in the power sector trading scenario (the fourth on figure 3) is just 26% that of the flows when trade is unlimited (first scenario on figure 3). And financial flows when there is a 15% cap on trading (third scenario in figure 3) are just one-tenth of the unfettered case. Put differently, limits on trading that have a modest impact on total cost can have a huge impact on reducing politically toxic financial flows. More work is needed to investigate politically realistic, second-best assumptions for trading limits.

Credibility and Anticipation

Finally, we examine the effects of credibility. As with other modelling groups, we use a model that allows agents to anticipate future regulation. Such assumptions envision that the world is filled with all-knowing and capable agents. Those assumptions are familiar in modelling and reality. When a firm develops a complex and long-term plan for expenditure of capital it does not assume that most of its managers are asleep, ignorant or otherwise unable to tune their individual efforts to the common plan. But the assumption that agents can anticipate the future is deeply troubling at the international level. International law is weak and easy to disregard. Often its strictures are vague and hard to translate into meaningful efforts that every country or firm should implement. To be sure, there is a raging debate on the questions of why international law exists and whether it works reliably [e.g., Keohane, 1984; Chayes & Chayes, 1995, Goldsmith and Posner, 2005; Guzman, 2008]. But even the most ardent enthusiasts of international law do not see those regulatory instruments as reliable guides for investment when compared with the strict planning, monitoring and enforcement system that is typical of well-administered corporate budget planning or of a properly monitored and enforced scheme of national law. International laws, to different degrees, are not fully credible—especially when their mandates are inconvenient for powerful states.

To explore the importance of credibility we vary the extent to which the model allows foresight. We start with a standard assumption of perfect foresight. (This assumption is akin to imagining that information about the future is costless to obtain.) Then we make the future progressively cloudier—and more realistic—until we reach a scenario of "no credibility," which allows for a 5-year foresight. Five years is about the shortest practical time horizon for crafting standard international legal instruments—even in treaties where most countries have a strong commitment to serious action to solve a common problem, such as the international agreements on the ozone layer—it requires about five years from the point when a negotiating agenda is set until an agreement is negotiated and entered into force. In Silicon Valley a few teenagers can invent a company in their garage, dominate the world market for their service, and cash out as billionaires within

Figure 4: The Impact of Policy Credibility on Regulatory Cost

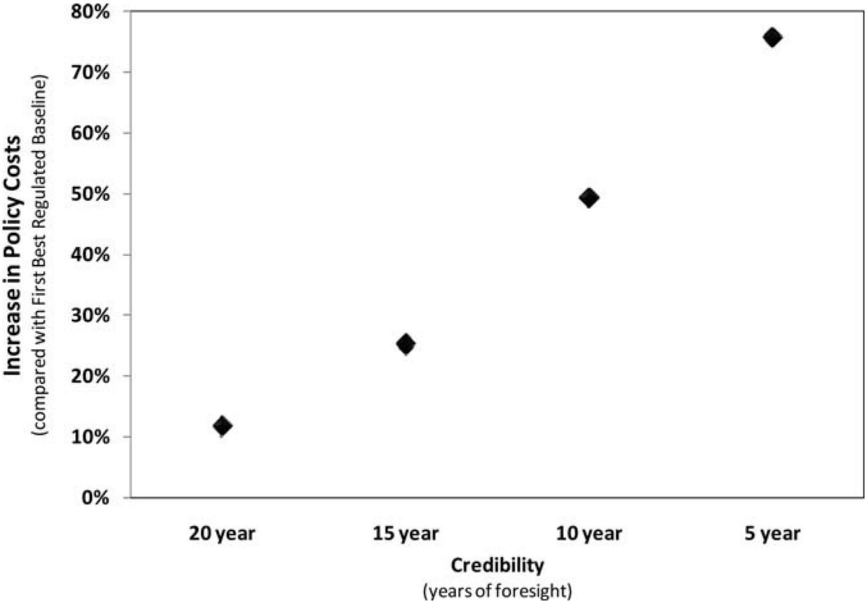


Figure shows extra cost for a complete credibility scenario (left side) and increasingly incredible policies, which we model by shortening the period over which agents can anticipate regulation. The shortest "zero credibility" period is 5 years, which is similar to the period needed to ratify and implement an international treaty that is negotiated with no warning. The "complete credibility" scenario is, for reference purposes, the same as variable geometry, variable sectors, no trade scenario shown in figure 3.

five years. In international diplomacy the pace is slower, it usually takes five years just to agree on the agenda.

For simplicity, we focus on the credibility of the decision to begin regulation; once limits have been imposed on emissions they are credible into the future. Thus for the OECD nations credibility remains high in our scenario because with variable geometry OECD nations already face immediate limits on emissions (see table 2). Myopia has a much stronger impact on reluctant nations.

We show our main results in figure 4. As credibility declines the total world cost of regulation rises sharply. (As with the earlier second-best scenarios shown in figure 3, we examine costs with respect to the first-best regulated baseline.) When all other aspects of second-best regulation are in place and foresight is perfect—shown with the leftmost scenario on figure 4, which is identical to the rightmost scenario on figure 3—the rise in cost is a modest 12% above the first-best regulated baseline. In the extreme situation, where credibility is lowest, the rightmost point on figure 4 is the result, with an increase in total costs of more than 70%. The most striking increases occur when the model is unable to anticipate more than about one decade into the future. This reflects that in the WITCH model (as in essentially all models used to assess the costs of abating warming gases) future costs are discounted, which also discounts the benefits of good foresight. Table 4 shows the effects on different categories of nations.

Even though the OECD nations, themselves, face no decline in credibility they suffer the largest increase in costs. When credibility is low the reluctant and impoverished countries make less effort. Their emissions in the years leading up to the date when they face targets are higher, and the OECD nations compensate for these higher emissions by making more intense regulatory efforts at home and investing more heavily in R&D. Since those higher costs are borne nearer to the present day, their discounted total cost (as shown in table 4) is much higher than the extra but discounted additional costs that reluctant and impoverished nations must pay. The lack of trade in emission credits (as is assumed for all the scenarios in figure 4 and table 4) means that when the enthusiastic nations must make additional efforts, the costs of such efforts arise through regulation at home and through R&D. Even when international trade in emission credits is not allowed, the benefits of R&D still flow through the world market for technology. Interestingly, in both the low- and high- credibility scenarios the impoverished countries are left much better off because our variable geometry puts so much of their burden into the future. That delay in regulatory burden is much more consequential than other factors such as the extra cost they suffer due to low regulatory credibility. When trade is allowed the poorest countries are especially large beneficiaries in low credibility scenarios since a much larger share of abatement effort in the enthusiastic and reluctant nations comes from international trade in offsets.

The lack of foresight is expressed in many ways. One is the impact on spending for forward-looking R&D. Figure 5 reports two kinds of energy R&D: breakthrough R&D (figure 5a), on which governments spend very little unless they face credible emission controls.[7] By contrast, spending on R&D to lower energy intensity occurs in the normal economy already at higher levels because there are many concerns, in addition to global warming, that lead societies to invest in cutting their energy intensity (figure 5b). As policy declines in credibility, global spending on that form of R&D actually increases because its payoffs are more immediate. A society that faces climate policy with very little anticipation must rely on existing technologies to a much greater degree, and the larger stock of those technologies leads to larger general incentives to invest in improvement of energy efficiency. Figures 5a and 5b show results for all countries, but the impact of incredible policies differs. For enthusiastic countries policies are im-

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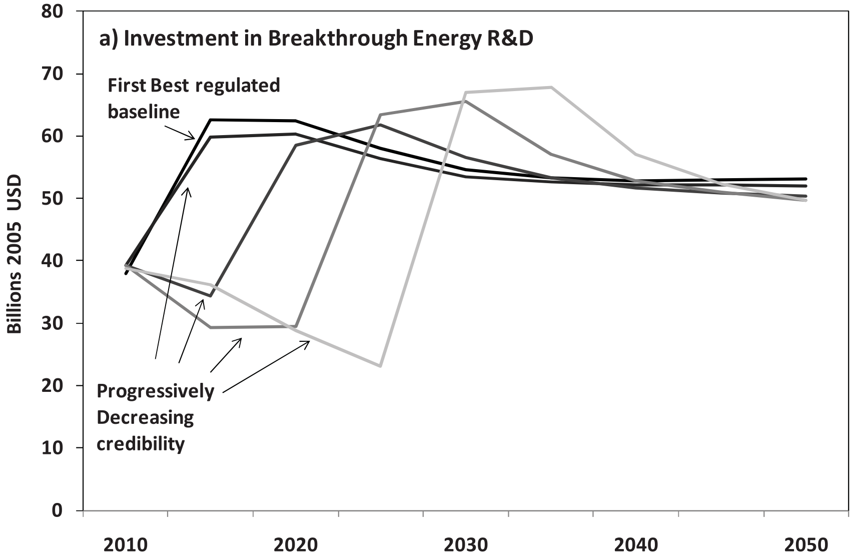
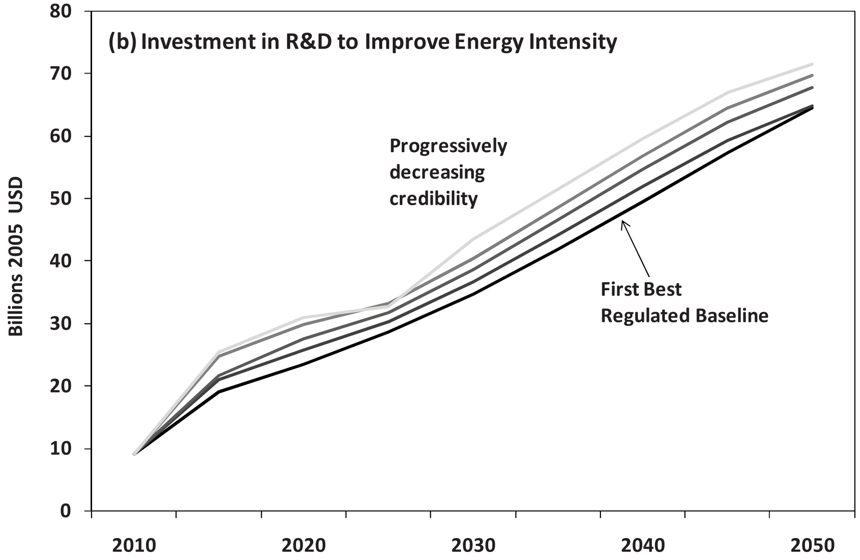
[7] In the long term, innovative breakthrough technologies with low or zero carbon emissions will probably become available. These technologies, which are currently far from being commercial, can be better thought of as a compact representation of a portfolio of advanced technologies that ease the mitigation burden away from currently commercial options and that become available in fifteen to twenty years from now depending on the level of R&D investment.

Figure 5: The Impact of Credibility on R&D spending for Breakthrough Energy Technologies (panel a) and Energy Intensity (panel b)





When policies are not credible governments do not spend money on breakthrough technologies until the policy appears—at which point investment surges, although as credibility declines so does total investment breakthrough technologies. The impact on energy intensity investments is less pronounced and points in the opposite direction. Those investments occur autonomously in the economy and involve technologies with shorter time horizons, which are favored in a world of less credible policy.

mediately credible and thus these nations continue (in fact increase) their spending on all forms of R&D, notably breakthrough R&D. But the reluctant nations make steep reductions in breakthrough R&D (compared with the first-best regulated baseline) when policy is not credible. In practical terms, the modelling effort here suggests that when policy credibility declines more emphasis will be placed on appliances and other quick turnover technologies at the expense of innovation in long lead-time technologies such as solar, nuclear power and other large, costly and technologically riskier options that are profitable only with a patient, long-term perspective.

A full discussion of ways to boost credibility is beyond the scope of our essay. One strategy involves shifting from global negotiations, which are often ponderous because it is hard to get all the world's nations to agree on anything, to smaller "clubs" [e.g., Sebenius, 1983; Kahler, 1993]. Another is to invest heavily in building institutions that make it easier for countries to negotiate commitments, monitor behavior, and stabilise expectations [e.g., Keohane, 1984]. Such strategies require the investment of time and other resources; extensions of the research presented here might explore the gains obtained by governments from building more effective international regulatory institutions and how the cost of such efforts compares with other credibility-enhancing strategies. Variables such as the investment in international institutions might be added explicitly to integrated assessment models as an endogenous factor and coupled to game-theoretic analysis of individual country behavior since the presence of capable institutions makes it easier for countries to enter into reliable contracts. Indeed, legal scholars have rested on such arguments when explaining why rational countries might bind themselves to international strictures (e.g., Chayes & Chayes, 1995; Guzman, 2008). The experience so far with the diplomacy under the UN Framework Convention on Climate Change—where there has been much proclamation about the dangers of global warming but not much real investment in building capable institutions—suggests that most governments don't yet take these issues seriously.

For illustration, we briefly examine one strategy that might boost credibility: pre-commitment. One difficulty with all the strategies already mentioned is that they require collective action and formal negotiations. Pre-commitment is something that a country can do on its own—much like tacit bargaining in arms control where a country can boost the credibility of efforts to cut arms by unilaterally cutting arms on its own [Downs and Rocke, 1990; Schelling, 1963]. A country could, by similar logic, boost the credibility of international warming regulations on its own soil by committing to cut emissions even in advance of a binding international obligation. If such actions increased credibility—by making firms within a nation's borders more likely to anticipate future international regulations and by making those regulations more likely—then pre-commitment (as we will call it) could be in a country's narrow self-interest even without formal cooperation by others.

Table 4: Change in Policy Costs for the Three Groups for Different Policy Credibility

This table reports increase in costs (compared with the first-best regulated scenario) for two variants of the scenario with variable geometry, sectoral regulation and no trade. The first variant shows the increase in cost with complete credibility (equivalent to the left-most point in figure 4) and the second variant shows no credibily (equivalent to the right-most point on figure 4). The third row reports the differences in present value Gross World Product between the two credibility cases.

	Enthusiastic countries	Reluctant countries	Impoverished countries	Total
Complete Credibility (Increase in Policy costs compared with First Best)	33%	10%	–49%	12%
No Credibility (Increase in compared with First Best)	114%	75%	–47%	76%
Welfare Gains from Credibility (trillions of 2005 USD, discounted 5%)	9.4	11.9	0.1	21.3

To provide a sense of what is at stake, in table 4 we report the savings to our three groups of countries for different degrees of credibility. Compared with the first-best regulated baseline, the impoverished countries are always made better off because our variable geometry scenarios allows them to wait to undertake any action until 2050. However, credibility implies almost no efficiency gains for them as the higher flexibility is traded off with fewer gains from international trade after 2050. When rules are less credible firms are forced to scramble to find emission reductions. A less efficient system also implies higher carbon permit prices, which sellers enjoy.

Ironically, then, the countries that have lowest emissions—which are also most vulnerable to changing climate—may have perverse incentives to undermine long-term credibility of international institutions. But for the enthusiastic and reluctant countries—which are the nations that must agree for any climate pact to be effective—there are massive gains in efficiency from a more credible policy. We do not report results for individual regions here, but the numbers for China are illustrative of our general argument. By anticipating the target by two decades rather than one decade, for example, China saves up to 1.2 trillion of USD in discounted terms (in 2005 dollars) over the next 40 years. That net savings comes in the form of higher near-term costs (prior to 2030 China's pre-commitment incurs an extra 0.4 trillion USD in costs compared with our "no credibility" scenario, the right-most point on figure 4), but those extra costs are outweighed by 1.6 trillion USD in benefits between 2030 and 2050 due to the country's early preparation. Of course, China may also suffer losses from pre-commitment if other countries do not follow, and future work should examine how those competitive losses compare with the gains from higher regulatory credibility. For a large country such as China pre-commitment probably would carry extra benefits of raising credibility (and encouraging pre-commitment) for other countries. As often happens with international cooperation, the actions of a single powerful player or club helps set the tune for others.

SOME CONCLUSIONS

As the world's politicians have turned from theoretical discussions of cutting warming emissions to practical realities of how to craft effective diplomatic deals, the analytical community is also mobilising itself to examine the economics and politics of those diplomatic arrangements. We are an idealistic community of analysts, and thus we disparage the real world deviations of policy makers and diplomats as "second-best." But the second-best is a world of more likely futures. We have explored the political economy of that real, inferior world.

We find that the aspect of the second-best that has commanded most analytical attention—variable geometry—has strikingly small effect on the overall economic efficiency of a global warming regime as long as there is a global carbon market. Limits on emission trading and extra costs from trading raise the total cost of meeting the 450ppm goal, but they also have a modest impact. We also find that second best policies that target only particular sectors may also be much less inferior than commonly thought, provided that sectoral approaches begin with a focus on the power sector and there is some opportunity for trading within the sector. For cuts in emissions much deeper than those analysed here—which seem unlikely since few nations are on track to implement the substantial changes implied by limiting concentrations at 450 ppm—such second-best features might have a bigger impact on total costs.

By contrast, the ability of governments and firms to anticipate credible regulations has a massive impact on cost. Ironically, the least developed countries have a strong incentive to make international regulations incredible, since they are major beneficiaries when other countries are forced to purchase emission credits rather than make reductions at home. The biggest losers from low policy credibility are reluctant nations whose obligations to cut emissions are substantial yet distant in the future. Using the example of China we have shown that such countries have a strong interest in making international rules more credible by pre-committing themselves with early, strict national policies that alert firms to the need to prepare.

Our analysis is simple and has not turned over many important stones. We have not explored the well-worn question of fairness, although by varying geometry we recognise that less wealthy countries will delay their participation. Allocations with attention to fairness can have a big impact on results for individual countries, but we find that our main results—including our central finding about anticipation of credible policies—is robust at the global level for which particular national allocations do not much matter. The further we depart from ideal world allocations of the effort, the larger the importance of mechanisms such as emission trading to improve efficiency. However, a larger carbon market and greater financial flows across countries might decrease the political feasibility of international agreements. For this reason an additional issue that should be investigated in greater detail is the size and type of trade restrictions that could reduce these transfers. And while that issue is important, our preliminary analysis here suggests that it will pale in importance to the credibility of policies. Finally, when looking at more stringent climate targets than the 450 ppm CO_2 investigated here, then all second-attributes of policies seem likely to be even more important—and, in the extreme, can make certain emission and concentration goals infeasible to obtain.

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