Fondazione Eni Enrico Mattei

NOTA DI LAVORO

29.2010

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SUSTAINABLE DEVELOPMENT Series

Editor: Carlo Carraro

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Summary

Modellers have examined a wide array of ideal-world scenarios for regulation of greenhouse gases. In this ideal world, all countries limit emissions from all economic sectors; regulations are implemented by intelligent, well-informed forward-looking agents; all abatement options, such as new energy technologies and forestry offsets, are available; trade in goods, services and emission credits is free and unfettered. Here we systematically explore more plausible second-best worlds. While analysts have given inordinate attention to which countries participate in regulation—what we call "variable geometry"—which has a strikingly small impact on total world cost of carbon regulations if international trade in emission credits allows economies to equilibrate. Limits on emission trading raise those costs, but by a much smaller amount than expected because even modest amounts of emission trading (less than 15% of abatement in a plausible scenario that varies the geometry of effort) have a large cost-reducing impact. Second best scenarios that see one sector regulated more aggressively and rapidly than others do not impose much extra burden when compared with optimal all-sector scenarios provided that regulations begin in the power sector. Indeed, some forms of trade regulation might decrease the financial flows associated to a carbon policy thus increasing political feasibility of the climate agreement. Much more important than variable geometry, trading and sectors is another factor that analysts have largely ignored: credibility. In the real world governments find it difficult to craft and implement credible international regulations and thus agents are unable to be so forward-looking as assumed in ideal-world modelling exercises. As credibility declines the cost of coordinated international regulation skyrockets—even in developing countries that are likely to delay their adoption of binding limits on emissions. Because international institutions such as treaties are usually weak, governments must rely on their own actions to boost regulatory credibility—for example, governments might "pre-commit" international regulations into domestic law before international negotiations are finally settled, thus boosting credibility. In our scenarios, China alone would be a net beneficiary of pre-commitment that advances its carbon limits two decades (from 2030, in our scenario, to today) if doing so would make international regulations more credible and thus encourage Chinese firms to invest with a clearer eye to the future. Overall, low credibility is up to 6 times more important in driving higher world costs for carbon regulations when compared with variable geometry, limits on emission trading and variable sectors. In this paper, we have not explored the other major dimension to the second-best: the lack of timely availability of the full range of abatement options, although our results suggest that even this will be less consequential than credibility.

Keywords: Greenhouse Gases, Second-best Regulation

JEL Classification: Q5, Q58

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

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ABSTRACT

Modellers have examined a wide array of ideal-world scenarios for regulation of greenhouse gases. In this ideal world, all countries limit emissions from all economic sectors; regulations are implemented by intelligent, well-informed forward-looking agents; all abatement options, such as new energy technologies and forestry offsets, are available; trade in goods, services and emission credits is free and unfettered. Here we systematically explore more plausible second-best worlds. While analysts have given inordinate attention to which countries participate in regulation—what we call "variable geometry"—which has a strikingly small impact on total world cost of carbon regulations if international trade in emission credits allows economies to equilibrate. Limits on emission trading raise those costs, but by a much smaller amount than expected because even modest amounts of emission trading (less than 15% of abatement in a plausible scenario that varies the geometry of effort) have a large cost-reducing impact. Second best scenarios that see one sector regulated more aggressively and rapidly than others do not impose much extra burden when compared with optimal all-sector scenarios provided that regulations begin in the power sector. Indeed, some forms of trade regulation might decrease the financial flows associate to a carbon policy thus increasing political feasibility of the climate agreement. Much more important than variable geometry, trading and sectors is another factor that analysts have largely ignored: credibility. In the real world governments find it difficult to craft and implement credible international regulations and thus agents are unable to be so forward-looking as assumed in ideal-world modelling exercises. As credibility declines the cost of coordinated international regulation skyrockets—even in developing countries that are likely to delay their adoption of binding limits on emissions. Because international institutions such as treaties are usually weak, governments must rely on their own actions to boost regulatory credibility—for example, governments might "pre-commit" international regulations into domestic law before international negotiations are finally settled, thus boosting credibility. In our scenarios, China alone would be a net beneficiary of pre-commitment that advances its carbon limits two decades (from 2030, in our scenario, to today) if

doing so would make international regulations more credible and thus encourage Chinese firms to invest with a clearer eye to the future. Overall, low credibility is up to 6 times more important in driving higher world costs for carbon regulations when compared with variable geometry, limits on emission trading and variable sectors. In this paper, we have not explored the other major dimension to the second-best: the lack of timely availability of the full range of abatement options, although our results suggest that even this will be less consequential than credibility.

INTRODUCTION

In the ideal world all governments would regulate 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 [Aldy and Pizer, 2009]. Indeed, from the pioneering work in this area to the present day, the standard result from economic models that examine regulation of warming gases confirms that a global approach is the most cost-effective strategy [Manne and Richels, 1992], [Nordhaus, 2005] and [Jacoby at al, 2008]. The benefits of such a global approach are particularly large when countries aim to make deep reductions in emissions, such as implied with increasingly popular goals such as limiting concentrations of CO_2 at 450 ppm or even 350 ppm. Meeting such goals, some of which imply lowering concentrations even below today's levels, is essentially impossible without nearly all nations and sectors participating [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, the real world is not nearly so accommodating. Developing countries have been famously reluctant to accept caps on their emissions. [1] 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 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 will 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. 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 trading systems. 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]. And 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

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[1] For example, see the Indian position on climate change http://pmindia.nic.in/Climate%20Change_16.03.09.pdf

funding in other major international accords such as on protection of the ozone layer [Benedick, 1998] and [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 landscape of fragmented efforts that run at many different speeds [Victor et al., 2005]. This paper explores some economics of the second best and their implications for politics and the design of international treaties and other regulating institutions.

We look at the implications of three 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 world. When we vary geometry we divide the world into three crude categories—the most enthusiastic (and richest) nations that act first, 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. As we explore variable geometry we also examine the impact of 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.

The second departure envisions different *trade* constraints, ranging from limiting the maximum amount of trade to including the possibility of different *sectors* joining at different times, which we contrast with the all-sector vision of the ideal 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.

These are gross simplifications, to be sure, but they are useful for our purposes. Indeed, the real world of greenhouse gas diplomacy is evolving in this way. Ever since the United Nations Framework Convention on Climate Change (UNFCCC) was crafted in 1992, every major international effort to regulate emissions, such as the G8 efforts to craft a long-term strategy for protecting the climate, has underscored that reluctant developing countries would be expected to adopt emission caps only long after the industrialized world "takes the lead" and tightens limits on itself [UNFCCC Article 1, 1992; G8 communique, 2009]. Moreover, as a practical matter, some sectors are likely to be regulated earlier than others. Efforts to reform the Kyoto Protocol's Clean Development Mechanism (CDM), for example, include attempts to create incentives for sector-wide policies. In essentially every country, some emitting sectors are easier to regulate than others [e.g., Rai and Victor, 2009].

In addition to varying geometry and trading constraints we also explore a third aspect of the real, second-best world: *credibility*. When policies are highly credible then investors can make reliable plans. 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 [Philibert, 2007]. Very few studies have looked at the effect of policy anticipation on the costs of climate change regulation. The most recent ones are [Blanford et al, 2009] and [Bosetti et al 2009b] and they both assess the negative effect of myopic behaviour on latecomers as well as on climate agreement early participants. In [Paltsev at al, 2009], the focus is more on the effect of policy credibility on the banking of carbon permits, with conclusions that underscore the adverse economic effects of incredible policies. 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 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 risk-averse long-term investments [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 not very strong.

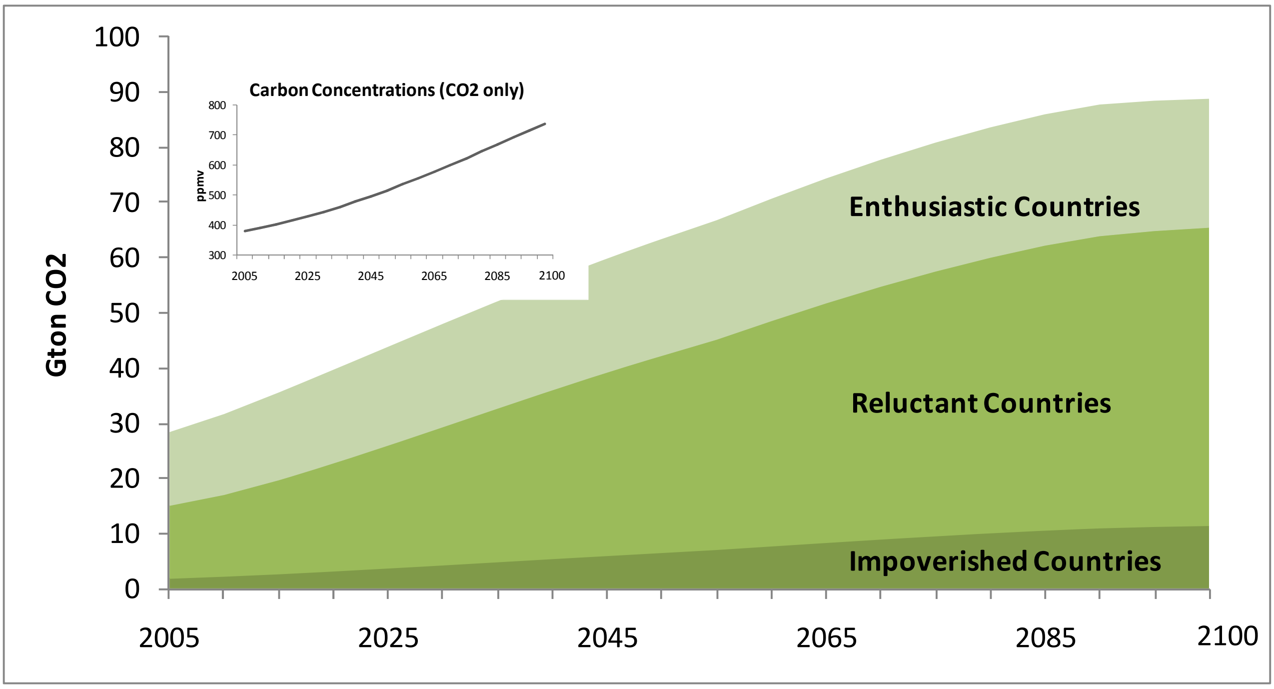
To examine this second best world—where geometry, sectors and credibility all vary—we use the WITCH model [Bosetti et al, 2006]. WITCH is a climate-energy-economy model designed to assist in the study of the socio-economic dimensions of climate change. It is structured to provide information on the optimal responses of every government, linked through the world economy, to climate damages and to identify impacts of climate policy on global and regional economic systems. (A thorough description and a list of related papers and applications are available at www.feem-web.it/witch.) The handling of geometry and sectors in such models is widely familiar. Credibility deserves a word. The key attribute of the WITCH model for our analysis is that it assumes governments and firms are smart and well-informed and thus forward-looking. If policy is credible then governments (and firms) anticipate its arrival. We vary the time horizon over which investors can look to the future as a proxy for credibility. When credibility is high the investor can see to the distant horizon and anticipate, 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.

We begin by describing two baselines—a standard "business as usual" scenario with no regulation and then a "first best" scenario in which all countries make comparable efforts to stabilize atmospheric concentrations of CO_2 at 450ppm. This second is blissfully optimal in every way—firms have perfect foresight, all governments participate, all sectors are included, and unfettered trade allows equalization of costs. The rest of the paper wreaks havoc on that optimal world.

NO POLICY AND POLICY BASELINES

We are interested in understanding just how bad the second best could become. Thus we start with a baseline run that projects emissions in the canonical "business as usual (BAU)" world that has no new regulation. Figure 1 shows this BAU scenario for the three categories of countries we will examine.

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., 2009).



Then we calculate an optimal path of effort to stabilize CO_2 concentrations at 450 parts per million (ppm). For this paper we focus only on fossil fuel CO_2, but we are mindful that others sources of CO_2 as well as other gases also warm the planet. Including those other gases would make our 450ppm CO_2 optimal scenario similar to a 550ppm all-gas scenario. (Including forestry policy could allow another 20 ppm CO_2-eq of industrial emissions by the end of the century.) With the climate module in WITCH, this 450ppm CO_2 world is equivalent to 550ppm with all gases included. [2] 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 aerosols the expected average warming is about 2.5 degrees of warming above pre-industrial levels. (We do not, address black carbon and its potentially large but uncertain warming properties.) This scenario is thus 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 350ppm. [Monastersky, 2009] Such aggressive scenarios are impossible to achieve with second-best policy that excludes some countries and sectors according to most models, such as for example [Clarke et al, 2009]. The rest of this paper examines scenarios that all deliver the same stabilization at 450ppm CO2. In order to account for the reduced abatement by reluctant and impoverished countries prescribed by second best features, the burden of the enthusiastic countries is adjusted to keep global emissions unchanged.

To explore the second best we start with an optimal first best world. In that world, abatement effort is allocated across countries on the basis of equal marginal costs.[3] Figure 2 shows the optimal level of abatement in this first best world, and Table 1 provides an insight on the specific effort required in this world for each of our three groupings of countries in each of the two main sectors that will be of interest (electric and non-electric).

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., 2009).

[2] Non-CO2 gases emissions of CH4, N2O, SLF and LLF are modeled 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).

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

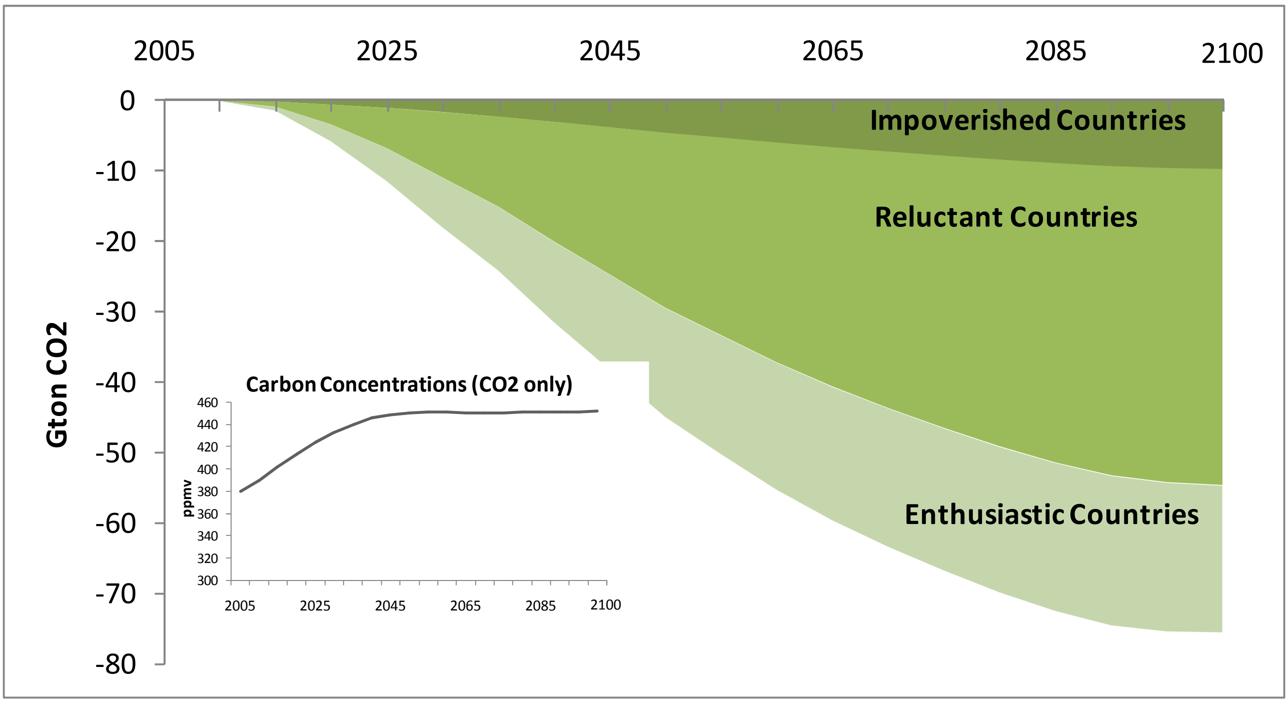


Table 1 Emission reductions to achieve 450 ppm.

Table shows 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)
Power Sector	76%	83%	82%
Other Energy Sectors	57%	52%	57%

The cost of such an optimal policy—what we also call the "first best world,"--measured in the loss in Gross World Product (GWP) compared with the BAU scenario, is 1.58% using a 5% discount rate.

THREE DIMENSIONS OF THE SECOND BEST

Now we turn to the various aspects of second-best policy.

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: The "enthusiastic countries" are mainly the richest industrialized nations that are keen to spend their own money on slowing global warming. Next are the "reluctant" countries whose emissions are high (and growing rapidly) but have other political priorities. Last are the "impoverished" countries that have generally low emissions and much more immediate troubles than global warming (table 2). This approach follows Victor (2007) and the modelling of those scenarios by [Bosetti et al. 2009a].

Our simple categories are rooted in these countries' political and administrative context. The "enthusiastic" nations are under internal political pressure to spend their own resources to control emissions while also shifting some resources to other countries to help them with the task (and also help them adapt to the unwanted effects of a warming world). These countries' preferences for controlling emissions stem from their high wealth (which makes the public prize environmentalism and other amenities), democratic governance (which makes leaders attentive to public pressure) and free press (which shines a spotlight where government choices and public sentiment diverge). High wealth usually correlates with competent public administration, which makes it possible for government to implement broad-based emission cuts that the public demands.

The "reluctant countries" are all headed in that same direction, although at present they are much less keen to devote their own resources to slowing global warming. Their decisions to regulate emissions will reflect not simply internal pressure (which might be a long time coming) but also external pressures from enthusiastic nations that are keen to solve global problems and know that their efforts will fail without efforts in tandem by other large emitters. Over time these nations will become less reluctant as higher wealth leads these societies to put more of a value in the amenity of a clean environment, as they learn more about the harms that will befall them if world emissions go unchecked, and as the enthusiastic countries threaten them with punishments such as trade sanctions if their behavior stays uncooperative. These countries are usually in the midst of building a modern public administration, but those efforts are uneven in outcome. Thus usually in some sectors of the economy the government is firmly in control and able to implement central policies; in others regulation is more akin to the wild west. Governments, knowing that their administrative abilities are limited, often try to assert direct control over key sectors of the economy through state ownership—which is one reason why most vital hydrocarbon resources and electric power systems in these countries are owned by governments themselves. Government ownership, often, translates into more direct and effective administration. [Victor and Heller eds., 2007]

And last, we call the rest of the poorest countries "impoverished." They are so poor that for the foreseeable future these countries will not be willing or able to control emissions. Emissions from the impoverished countries will also stay relatively low, although some of these countries will see high emissions from land clearing that is often associated with poverty and poor governance. (In the simple analysis here, we exclude that source of emissions.)

Table 2. Main countries in each category and the timing of their contribution to the stabilization effort. (As with our first-best scenario, this allocation is based on the most efficient (cost-minimizing) allocation of effort while minimizing the international flow of emission credits. The real world will see many more complications in setting national emission targets.)

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.

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 sake, we assume that the second best world converges immediately to the optimal solution after 2050. After this ultimate convergence all nations make a comparable effort. This assumption of ultimate convergence may still be a naïve one. 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. (The discount rate, in addition, reduces the present importance of events in the distant half of the century.) The second best is a world of transition at multiple speeds as big emitters become wealthier and more capable. The policy implications of second best analyses related to the speed of that transition and the kinds of instruments that could help accelerate or direct the transition. But it is not a world of permanent differences. 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. 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].

Our results for this simple, variable geometry scenario are similar to those reported in other studies. Assuming immediate and unlimited global trading including offsets—that is, countries not facing a binding target are allowed to trade any reduction in emission with respect to their baseline emission path—global policy costs are basically the same as in the first best world because trade allows for easy equilibration of markets and least-cost solutions. Of course, the cost for individual regions varies with the assignment of regulatory burdens. In our variable geometry scenario, the enthusiastic countries pay 8% higher cost than in our first best scenario; reluctant countries incur 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. This variation simply reflects that in our first best scenario we allocated emission credits according to marginal cost while the variable geometry scenario is politically and administratively more realistic in assigning 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. When geometry is variable the enthusiastic nations must spend more so that the overall world emissions stay in line with the goal of stabilizing concentrations at 450ppm CO2.

Trade and Sectors

Next, we add an additional aspect of the real world: limits on trade. As a practical matter, those limits could take the form of bans or caps 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) trade because that would allow the rich industrialized 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 intended to fund adaptation projects—or perhaps high transaction costs from tight regulation of offset programs to ensure that offsets are genuine [e.g., Wara and Victor, 2008]. We look at both of these. In limiting total trading, we impose a 15% cap. And in adding costs, we envision that efforts to reform the CDM create a much tighter administration that imposes a $10 per ton extra cost. (That number is at the high end of current estimates for administrative costs but not implausible.)

We also explore limits on trade that might take the form of regulations that vary by sectors. Indeed, a few analysts have examined such scenarios, often focusing on the electric power sector [Sawa 2008]. Such sectoral approaches are important to analyze 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, even in countries with highly advanced systems of regulatory administration policy instruments often vary across sector. In the EU, for example, a market-based emission trading scheme regulates industrial emissions while governments and industry associations are regulating emissions from buildings and most of transportation with wholly different policy instruments [Ellerman et al, eds, 2007].

For simplicity, we divide the world into two broad sectors: electricity and the rest. We assume that enthusiastic countries apply regulatory effort across all sectors. But the rest of the world varies its effort. 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 [Victor and Heller, eds 2007]. Thus if the government is under pressure to control emissions it will initially grasps for the levers on emissions that it can control more readily. And because many of these firms are owned by the government itself it is often easier for governments of reluctant nations to manage political wariness about new burdens by concentrating the burden on sectors where the state is more readily in control. 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 summarizes the assumptions we will make across the sectors of each category of nations, which are similar to the delayed scheme presented above. 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 Regulation of Sectors: The Example of Electric Power. 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 along with other sectors of the economy with the same stringency and timing. 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

We show our results in figure 3.

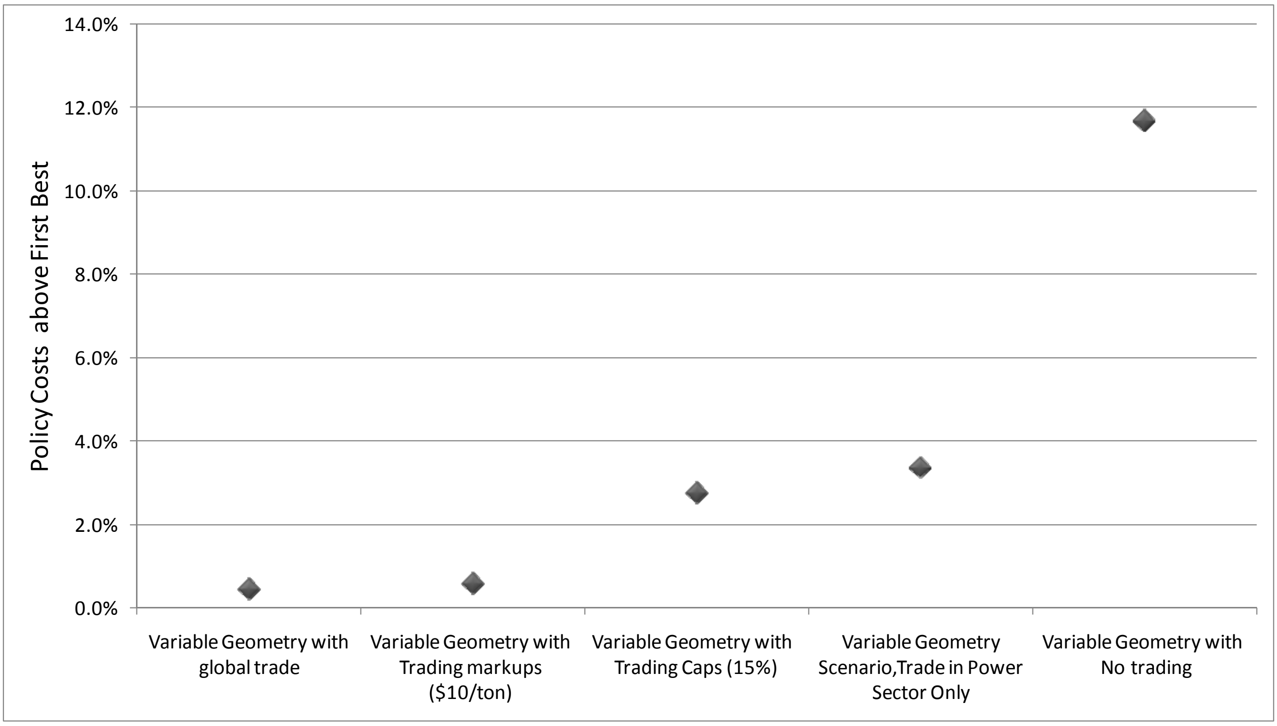
At the far left is a scenario that shows the extra cost in a setting we have already discussed—variable geometry with a global market with no limitation. The second scenario, mimicking the transaction costs associated with buying offsets abroad as a 10$ per ton C markup, imposes only a tiny extra cost on the world economy.

Restricting the maximum share of abatement that can be covered with offsets causes a very modest 3% increase in policy costs. In the short term the increase in costs can be substantial, in 2020 costs are 50% higher. Though policy costs in the first periods of the policy are still very modest, in absolute terms, hence the increment is watered down when looking at the overall policy effect. 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). Restricting permit demand vis a vis an unchanged permits supply decreases carbon permit prices in the first three trade periods. In the same period, trade flows also shrink to 20-40% of what they would have been otherwise. The two effects combined results in very modest financial flows, comparable with the first best case.

These results are consistent with other scholars who have found that so long as some form of trade is allowed for, extra costs imposed by different form of trading constraints are modest. When trade is limited to just the industrialized countries costs increase by just 12%. The effect on global costs of allowing trade in the power sector only is also limited and shows that a power-focused regulation would not impose large efficiency losses. The extra cost, however, is small because most of reduction that would be bought and sold on the market come from the power sector even when all sectors are accounted for, as the non electric sectors (notably transportation) are more costly to regulate. Thus in a final scenario we also restrict such trading with the electric sectors.

When all trading is restricted, the extra cost is 12% higher than in the first best world. This higher cost is greater than the second-best scenario with variable geometry and unlimited trade, but it is still much smaller than the scenario that envisioned loss of credibility. (All three of the scenarios shown on figure 3 assume complete credibility of policy decisions, which is an assumption we relax in the next section.)

Figure 3 Increases in Policy Costs with respect to the first best case given different assumptions about international permit trade. Policy costs are measured as discounted reductions in Gross World output with respect to the baseline, no policy case. Figure shows the increment in policy costs with respect to the first best case. 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; 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; 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 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.



What makes an important difference between the different trade scenarios is the magnitude of financial flows across countries. As we have seen, by allowing for a politically more realistic geometry of participation financial flows through the carbon market increase with respect to a first best world. (By assumption, our “first best” world allocated emission targets to minimize financial flows.) One could argue that minimizing financial transfers associated to the carbon market is an important component to keep an agreement simple and enhance its credibility. In cumulated terms over the period 2010-2025 the financial flow is 26% of the unlimited trade case when the power sector is the only regulated sector, and drops to less than 10% when there is a cap of 15% on the share of abatement that can be covered by offsets (very near the first best 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 the trade-offs.

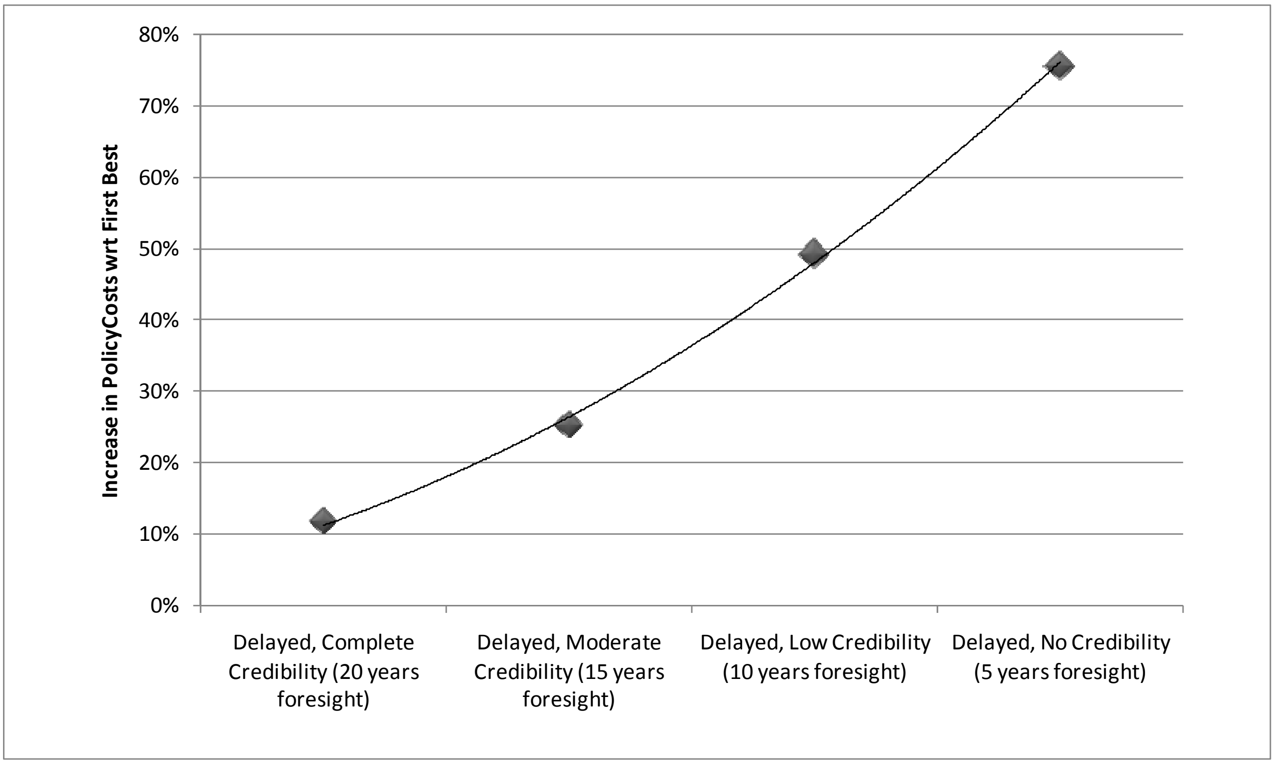
Credibility and Anticipation

Last, 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 these questions [e.g., 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 such reliable guides for investment when compared with the strict system of planning, monitoring and enforcement that is typical of a well-administered system of corporate budget planning or a properly monitored and enforced scheme of national law.

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. Even that pace is running to a fast clock. 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 five years. In international diplomacy the pace is slower.

We show our main results in figure 4. As credibility declines the cost (which we measure as the percentage increase in world regulatory cost compared with the first best scenario) rises sharply. Compared with the second-best characteristics examined so far, the impact of credibility raises costs six fold, which is evident when comparing the left-most point on figure 4 (comparable with the right-most point on figure 3) and the results from the "no credibility" scenario at the right-most point on figure 4. 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 perfect foresight.

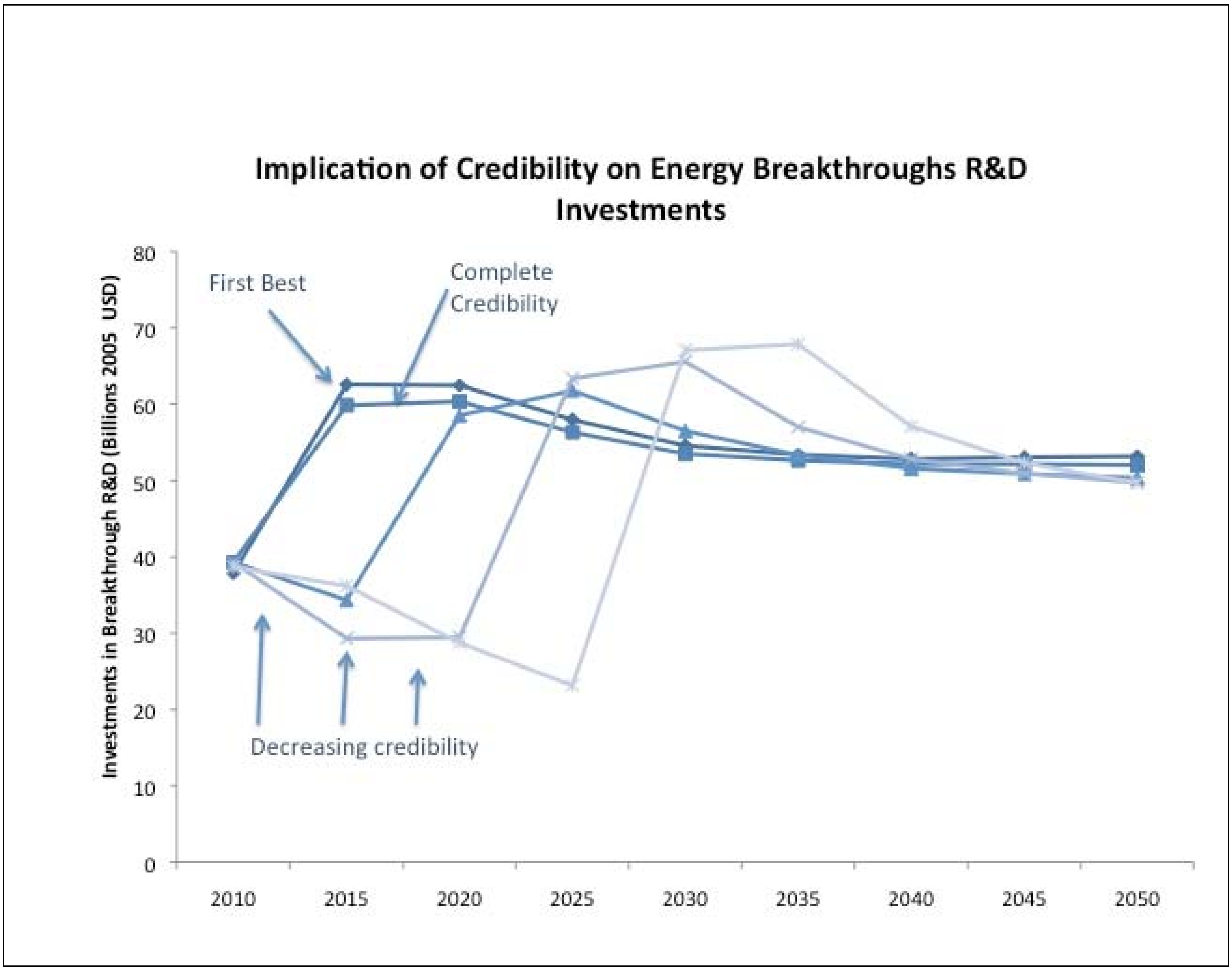
Figure 4: The Impact of Policy Credibilty on Regulatory Cost Figure shows extra cost for a complete credibility scenario (left side) and increasingly incredible policies, which we model by shortening the period over which agents can anticipate regulation. The shortest "zero credibility" period is 5 years, 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.

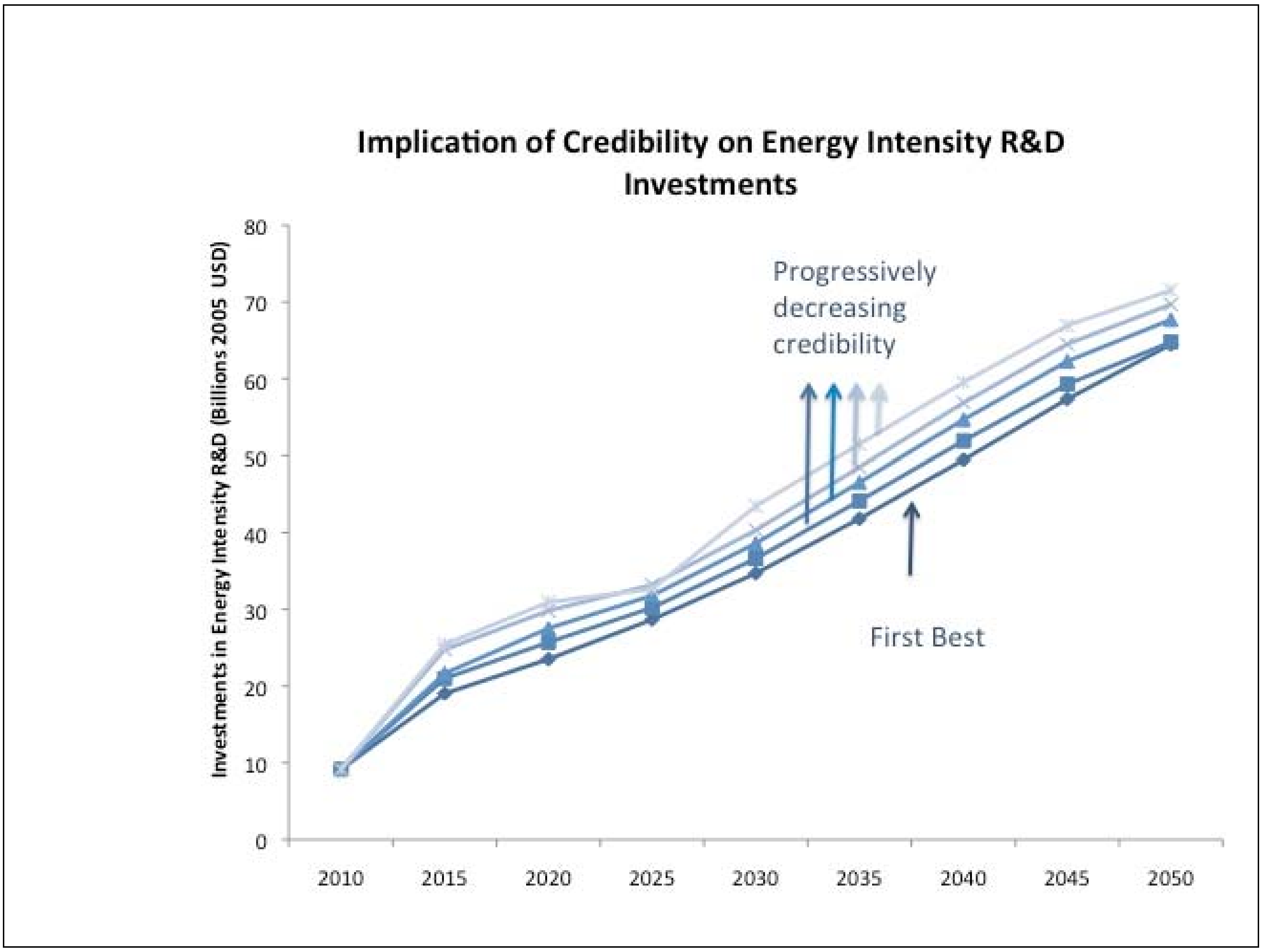


The lack of foresight is expressed in many ways. One is the impact on spending for forward-looking R&D. With less time for anticipation, reluctant and impoverished countries would under-invest in all forms of R&D. The additional effort undertaken by enthusiastic countries would not make up for this on overall energy R&D. Figure 5 reports two kinds of energy R&D: breakthrough R&D (figure 5a), on which governments spend nothing unless they face credible emission controls. [4] By contrast, spending on R&D to lower energy intensity occurs (at a lower level) even in the normal economy where other concerns, such as the economic cost of energy, lead to some policies (figure 5b). Lack of credibility reduces that spending, but not to zero. In figures 5 we report results for all countries, but the impact of incredible policies differs. For enthusiastic countries policies are credible, by definition, from the outset because those countries begin regulation immediately. Credibility is most important for the reluctant players. When the reluctant players under-invest in R&D the enthusiastic countries compensate (because they can internalize some of the extra benefit of more R&D and because they face a tighter target). In the case of breakthrough R&D the extra spending does not exceed the under-investment by the reluctant players. In the case of energy intensity R&D, which has a shorter term payoff and is essential for enthusiastic country to meet their increasingly burdensome target, it does.

Figures 5a (top) and 5b (bottom): The Impact of Credibility on Investment in Breakthrough Energy R&D (panel a) and R&d devoted to 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 total investment (undiscounted) is lower in incredible scenarios than in the credible ones. The impact on energy intensity investments is less pronounced because those investments occur autonomously in the economy and because intensity offers less leverage on emissions than breakthrough technologies.

[4] 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.


Implication of Credibility on Energy Breakthroughs R&D Investments
Investments in Breakthrough R&D (Billions 2005 USD)
First Best
Complete Credibility
Decreasing credibility
0
10
20
30
40
50
60
70
80
2010
2015
2020
2025
2030
2035
2040
2045
2050



WITCH does not explicitly model turnover of the capital stock nor allow for premature retirement of built equipment, but in the real world the absence of foresight may lead to some such retirements (although those are politically troubling). The biggest effects from shorter time horizons are in long-lived technologies that need massive R&D inputs, such as carbon storage.

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 200 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 stabilize 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 to governments from building more effective international regulatory institutions. Variables such as the investment in international institutions might be added explicitly to integrated assessment models as an endogenous factor. 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 Kyoto and Copenhagen treaties—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.

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 scenario, 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. Less able to do that at home they are more likely to buy credits overseas. 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. 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 in costs compared with our "no credibility" scenario), but those extra costs are outweighed by 1.6 trillion in benefits between 2030 and 2050 due to country's early preparation.

Table 4. Change in Policy Costs for the three groups for different policy credibility.

The first two rows report the change in policy costs for the three groups of countries when variable geometry, without any trade and different levels of policy credibility substitute the first best setting. The third row reports the differences in present value Gross World Product between the two credibility cases.

	Enthusiastic countries (OECD countries)	Reluctant countries (BRICs, Transition Economies and Oil Exporting Countries)	Impoverished countries (Africa and South East Asia)
Variable Geometry, Complete Credibility (Increase in Policy costs wrt First Best)	33%	10%	-49%
Variable Geometry, No Credibility (Increase in Policy costs wrt First Best)	114%	75%	-47%
Efficiency Gains from Credibility (trillions of 2005 USD, discounted 5%)	9.4	11.9	0.1

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 mobilizing 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 as "second best." But the second best is a world of reality. 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 arbon market. For cuts in emissions much deeper than those analyzed here, such second best geometries might be more important. But in the politically more plausible scenarios of stabilizing CO_2 at 450ppm, variable geometry inflates cost by about one-tenth when compared with an ideal world effort.

We also find that second best policies that target only particular sectors may also be much less inferior than commonly thought. Regulatory efforts that target the power sector in emerging countries rather than pursuing the more difficult administrative task of controlling all sources of emissions in those countries also have a modest impact on total costs.

By contrast, the ability of firms and governments to anticipate credible regulations has a massive impact on cost. This aspect of the second best is most troubling because it is particularly hard for governments to have a big impact on the credibility of international laws and institutions that require national consent before they enter into force and are difficult to monitor and enforce.

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 recognize 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 best 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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(lxxxvi) *This paper was presented at the Conference on "Urban and Regional Economics" organised by the Centre for Economic Policy Research (CEPR) and FEEM, held in Milan on 12-13 October 2009.*