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Unilateral measures and global emissions mitigation*

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Abstract

In this paper we discuss global climate change mitigation that builds on existing unilateral actions to deliver ever deepening emission cuts over time. A wide array of unilateral environmental measures have been documented. We discuss the rationale for such measures and argue that unilateral initiatives have the potential to generate positive spillover effects both within and across countries. Using a simple dynamic model of learning, we show how global negotiations can accelerate convergence to a global low emissions regime by building on and strengthening the positive spillovers inherent in unilateral initiatives.

JEL Classification: Q54, F53, Q50.

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1. Introduction

This paper studies the interplay between unilateral measures and multilateral negotiation in relation to global climate change mitigation. Although participation and compliance in broadly based multilateral initiatives may be hard to achieve, there are numerous unilateral initiatives already underway to cut emissions. We begin by documenting the extent, form and variety of unilateral measures, at national/regional/urban/individual levels, to combat climate change and achieve significant emissions reductions. These are, at first sight, hard to rationalize on grounds of narrow self-interest since the benefits accrue to others and we discuss their rationale. We then discuss global climate change mitigation that builds on existing unilateral actions to deliver ever deepening emission cuts over time via a process of global learning and cumulative participation.

Any broadly based global cooperation that requires nations to commit to emission cuts beyond what nations are unilaterally willing to undertake is thus unlikely to be stable (i.e. immune to deviations by a nation or a coalition of nations). A notable feature of the Kyoto Protocol has been that enforcement mechanisms have been effectively absent, with no penalties on non-compliance or non-participation. By delaying participation or by not complying with a global agreement to cut emissions, a deviating country or coalition of countries can continue capture the short-term benefits from continuing with high carbon economic activities but pass a significant portion of the costs to others (other countries, future generations)[1]. A multilateral accord may thus only be the repackaging existing unilateral measures.

We argue that there is a case for examining how global policy should be designed to build on existing unilateral initiatives to cut emissions as they have the potential to generate positive spillover effects both within and across countries. We suggest that multilateral negotiations can actually build on unilateral measures by concentrating on spillovers and developing a new global Intellectual Property (IP) regime fostering innovation and technology transfer. There is a danger of slowing the pace of emission cuts if unilateral measures are held on to as multilateral bargaining chips. The challenge is to shape the global regime to accelerate and strengthen multilateral agreement to cut emissions by building on the externalities generated by existing unilateral measures.

A simple dynamic model is constructed which demonstrates that while a country, as a whole, may be unwilling to commit to broad based multilateral initiatives to cut

[1] A number of papers have pointed out the limitations of mulilateral cooperation due to free riding in the presence of negative externalities (see, for instance, Shapley and Shubik (1969), Starrett (1973)).

emissions, agents within countries may still be willing to undertake a variety of unilateral initiative to cut emissions. We also show that social learning, over time, can result in a greater proportion of individuals switching to low carbon activities over time than is the case where it is absent. Single countries on their own may never get to the point of switching completely to low emission activities but a suitably designed learning process which creates and strengthens positive spillovers across nations is more likely, over time, to deliver a global switch to low emissions.

Drawing on these results, we discuss how policy design affects global learning by impacting both the structure of interaction between countries and the rate of convergence to a global low emissions regime. We argue that policy should build on the positive externalities involved in unilateral emissions reduction by developing a platform for exchange of information, a stable market for innovation that lowers the relative cost of cutting emissions and new global IP regime involving subsidized technology transfer of low carbon activities with the aim of altering the participation constraints of relevant economic actors (agents/firms/institutions/countries) over time.[2]

The remainder of the paper is structured as follows. Section 2 discusses the current use of unilateral measures; section 3 examines various rationales for unilateral measures. Section 4 studies the conditions under which global learning, building on existing unilateral measures can lead to a low emissions world. Section 5 discusses policy implications while the last section concludes.

2. How extensive are unilateral measures on emissions mitigation?

In this section we attempt to document, characterize and discuss the nature and extent of unilateral measures which have been taken world wide towards climate change. In tandem with their participation in global negotiations in the UNFCCC, the major participant countries have also simultaneously launched national action plans for combating climate change which involve extensive use of unilateral commitments. To an extent, these unilateral commitments may represent mechanisms for the implementation of proposed multilateral commitments, but in other ways they are quite different. Thus, in the EU, there is a commitment to a 20-20 program, which involves a 20% reduction in emissions and 20% of energy to come from renewables by 2020. This is separate from multilateral commitments, though the EU has offered to go further to a 30% emissions reduction if

[2] For an initial contribution along these lines see Chatterji and Ghosal (2009).

other entities will match. Similar initiatives can be found in the case of China where there is an extensive commitment to a 20% energy consumption reduction relative to trend by 2020, and also a 20% commitment to renewables.

These forms of commitments, interestingly, also seem to involve deeper commitments by smaller countries. One striking case is Norway, which has committed itself to become a zero carbon economy by 2050 even though they would not be the direct beneficiaries of their own emissions reductions. Also, both New Zealand (via a major reliance on thermal power) and Costa Rica (via major policy initiatives towards preventing deforestation) have openly declared that they intend to be among the most carbon emission reduction sensitive economies in the world, with major reductions in emissions relative to 1990 trends.

All these unilateral commitments are national but, on the face of it, go substantially beyond what countries are seemingly jointly willing to commit to multilaterally. This seems paradoxical since in joint multilateral commitments countries benefit from each others reductions and hence should go further multilaterally. Beyond the multilateral level, there are also many further commitments also being made by sub-national and local levels by governments, community based organizations, businesses, and even by individuals.

Before looking at the depth of mitigation these measures imply it is helpful to clarify these reduction efforts. Direct emissions mitigation is typically the focal point of policy both at national and international levels, and largely in the form of emissions reduction targets and mandates on key carbon emitting industries such as power generation and construction. Carbon trading schemes, cap-and-trade schemes and carbon taxes are also in the direct category. Indirect mitigation occurs in myriad form and is more typically used as a vehicle for unilateral action at a subnational level. Common examples include increasing capacity in renewables and reducing energy consumption through a focus on energy saving techniques and increased efficiency i.e. the use of more energy efficient equipment such as low power light bulbs, new forms of engines and turbines, as well as reduction in energy consumption directly. Forest management and recycling programs also fall under the indirect heading, as well as most private sector measures to reduce carbon emissions. Use of these measures often involves commitments whose implementation are contingent on the availability of appropriate technological innovation.

In addition to the characterization by types, there is also classification by the different levels of government and authority which are involved in these kinds of emissions programs. Some examples of programs undertaken by national governments have already been discussed above but significant programs have also been put in place by state governments and local and city governments. It is not unusual in Europe for individual cities to now have emissions reduction targets by specified dates. These could involve community based programs such as free bicycle plans, such as in Copenhagen, or watershed renewal programmes, such as in rural communities bordering major rain forests as in Mexico, and community information monitoring schemes such as sophisticated software which tracks carbon from individual houses based on lifestyle and energy use (the idea being that increased knowledge will change people's behavior). Commitments are also made at a business level, with new businesses offering what is needed for other businesses, communities and individuals to "go green".[3]: Because of the wider social/political commitment to emissions reduction, it becomes good business to characterize products as emissions sensitive, contributing to significant emissions reductions. Finally, similar actions can be taken at an individual level.

These unilateral actions being undertaken to combat climate change and reduce carbon emissions around the world are both diverse and in constant flux. The examples given in this paper are representative samples of the levels and types of unilateral actions occurring.

2.1. Unilateral Measures by Country

Unilateral measures interact with multilateral negotiations and it can be argued that multilateral commitments will largely endorse, or consolidate, unilateral commitments. At a global level we have discussions under the UNFCCC, which previously produced the Kyoto Protocol and aim at a new (and improved) treaty to be concluded in their 2009 meeting in Copenhagen. At its core, the negotiation is about carbon emissions reduction, although there are separate discussions of adaptation and innovation funds. Talks are also occurring within the G7 and G20 on climate change, but no substantive agreements to act on climate change have yet emerged from these groups aside from resolutions not to interfere with the UNFCCC negotiations. But new unilateral measures, notably by the US and China, have been announced in advance of the Copenhagen negotiations. It is likely that any resulting multilateral agreement would thus largely reflect what countries are willing to undertake unilaterally. But such commitments could be interpreted as a way of staking out bargaining positions as part of the multilateral negotiation. There is also the issue of whether, by committing to specific unilateral measures, these high emissions nations alter the incentives of other nations to commit to more stringent measures as well.

[3]Recent estimates set the "green" industry worldwide at roughtly 360 billion USD, with estimates that this could grow rapidly to 650-750 billion USD by late 2015. See http://english.cw.com.tw/article.do?action=shpw&id=10399&offset=0.

In addition to the examples of country level unilateral action already mentioned (New Zealand and Costa Rica), a number of national governments and industries, particularly in Europe, are pushing for renewable energy in all its forms and renewables are gaining ground relative to other forms of power production, albeit from a very small base. For instance, Denmark stands out as the wind power capital of the world, especially notable since the push for the development of wind power there predates the Kyoto Protocol. Germany and Spain have subsidies for the installation of solar capacity, and solar energy is purchased by the national grid at a subsidized rate.

In some nations there is also a push towards increasing capacity in the generation of nuclear power in addition to renewables. For example, in the UK, the national government, as part of its unilateral measures to cut emissions and achieve energy security, has supported a new generation of nuclear power stations[4], even though a nuclear path is a somewhat controversial move for at least two reasons. First, there is no reliable method for safely disposing of nuclear waste and second, given the large start-up costs involved, investment in nuclear power may crowd out investment in other forms of green power generation and use such as energy efficiency and renewables. Another concern is that current estimates of the supply of nuclear fuel predict only another 100 years before global stocks are depleted. Thus, if low or zero carbon power generation techniques do not become sufficiently commonplace in the intervening time, then nuclear proliferation may only put off the climate crisis, not solve it.

In the developing world, countries such as China have adopted a 20-20-20 plan – to reduce emissions intensity per unit of GDP by 20%, as well as achieving 20% renewable energy, both by 2020. A significant step towards this is the phasing out of older inefficient coal plants. India, as part of its National Action Plan on Climate Change, is actively seeking to alter its energy sector to one that is 'green' via improved efficiency, renewables (and nuclear power), attempting to forge a 'green' development path which will take environmental considerations into account with spillovers on other industries.

Sweden, Finland, the Netherlands and Norway have all imposed carbon taxes which have been in place since the 1990s. In South Africa, enforcement of existing environmental law has been an issue and hundreds of new environmental enforcement agents have been trained to ensure prescribed forest preserving environmental measures are implemented. In Brazil, there is a goal of 7000 MW of renewable energy capacity by 2010 and a substantial increase in the production of ethanol. Ecuador's 2007 Yatsuni-ITT proposal, which seeks to preserve rainforest despite the oil below and to slowly wean Ecuador off

[4] http://news.bbc.co.uk/1/hi/uk_politics/7179579.stm

oil dependence is indicative of the direction their government is taking. These actions seemingly directly benefit individual countries little relative to the effort involved.

Many of these national level unilateral actions, while reducing CO_2, also serve more local climate needs (adaptation-based projects), adding a self-interest based element to proposed actions. For instance, in Spain, as part of a push to halt desertification there, a government led plan to plant 45 million trees over 4 years is underway[5]. This serves to reduce carbon emissions and lessen the country's Kyoto shortfall but the need to halt desertification is the primary driver. A similar effort, with salt-resistant plants and de-salting plans as the weapons of choice, is underway against the more saline-based desertification progressing in Australia[6]. As an example of what may occur globally as extreme climate impacts occur, in the Maldives, the current president has set up a sovereign wealth fund specifically to buy a new homeland, should the islands become inundated[7] via sea level rise saying, "We can do nothing to stop climate change on our own and so we have to buy land elsewhere. It's an insurance policy for the worst possible outcome". Thus, the phenomenon of unilateral actions in regards to CO_2 reduction and similar issues can be in the self-interest of countries and can simply reflect behavioral response to specific climate damage.

Examples of country-level unilateral initiatives are summarized in Table 1 below.

(TABLE 1 HERE).

2.2. Unilateral Measures by Territories, States and Provinces

Unilateral measures are also evident at the subnational level. At the state and inter-state levels of government in the US we see multi-state agreements such as the Mid-West Greenhouse Gas Reduction accord, the Regional Greenhouse Gas Initiative, the Western Climate Initiative and the Western Governors' Association – Clean and Diversified Energy Initiative. On the face of it, these initiatives are reactive to the US rejection of the Kyoto Protocol. Setting restrictions on CO_2 emissions by specified dates is the content of all of these save the Clean and Diversified Energy Initiative, which sets a 30000 MW production goal by 2015 for renewable energy among member states as well as more long term goals. Many of these agreements are not confined to the US. Several Canadian provinces have also signed onto some of these agreements, Ontario and Alberta for the most part. Within

[5]http://www.abc.net.au/news/stories/2008/09/13/2363739.htm

[6]http://www.planetark.org/dailynewsstory.cfm/newsid/37246/story.htm

[7]http://features.csmonitor.com/environment/2008/11/11/faced-with-rising-sea-levels-the-maldives-seek-new-homeland/

Canada as well, there is a cap and trade plan being negotiated between Ontario and Quebec, two of the top three emitting provinces.

Individual state efforts in North America have the common thread that nearly all states and provinces have programs designed to improve energy efficiency, although direct emissions reduction efforts are the most common activity. With a large amount of carbon emissions originating in the power generation sector and North America having the most energy intensive economy (per capita) globally, these two activities seem to be both technical and political 'low-hanging fruits'. The US states of California and Florida are notable for efforts to improve energy efficiency and CO_2 emissions reduction in numerous areas including all of industry, transit/ autos and households, as well as opening the market and experimenting with all types of renewable energies. Further north in Canada, British Columbia is notable as the first province to independently impose a carbon tax on itself.

In Australia, New South Wales has a $63 million (AUD) plan to overhaul the homes of 220 000 low income families to improve energy and water efficiency as a response to the likely increased energy costs associated with Australia's commitments under the Kyoto Protocol. Most other Australian provinces are also improving energy efficiency and some, such as Queensland, are also actively and independently funding research into renewable energy. Queensland's program has already provided over $7 million (AUD) to numerous projects on renewable energy production and efficiency improvements.

In China and India, where provinces, by and large, follow the mandates from the national level, regional initiatives already exist (such as solar power and bio fuel projects in Karnataka[8]). One striking case is within Brazil where, somewhat in contrast to the national policies for increasing ethanol and biofuel production, some states, particularly Amazonas, have shifted to rainforest preservation, going from handing out chainsaws for free to 'promote development' to now adopting the motto that 'the forests are worth more standing than cut down'[9]. In Russia on the other hand, perhaps due to the fact that it easily meets its Kyoto targets due to negative growth in the 1990's, provincial unilateralism is muted and mostly limited to data and information gathering[10].

Tables 2 and 3 summarize examples of these initiatives.

(TABLE 2 here.)

(TABLE 3 here.)

[8] http://www.thehindu.com/2009/06/05/stories/2009060559100500.htm

[9] http://www.sds.am.gov.br/dsv/download/img_download/20071226155008Relatorio%202.pdf

[10] http://earth.esa.int/workshops/envisatsymposium/proceedings/posters/3P9/463731fr.pdf

2.3. Unilateral Measures by Cities

City level emissions mitigation efforts tend to lend equal weight to adaptation and mitigation, usually blending the two in proposed plans. In New York City for example, a major initiative is underway to improve energy efficiency and reduce emissions of all sorts including a 30% reduction in greenhouse gas emissions from the city. The focus is on replacing older infrastructure with new and more energy efficient technology which will also prepare the way for any water, food, or natural disasters to be dealt with, and also to replace existing cars with more fuel efficient ones and to increase the number of trees and parks within the city. Toronto, Canada has also engaged in energy efficiency upgrading for many of its buildings and infrastructure projects. Otherwise the plan of action is very different, with Toronto seeming to prefer development of local sources of renewables over the larger infrastructure upgrading projects and promoting green roofs heavily. Munich in Germany has a plan very similar to Toronto's, with the added financial innovation of weather derivatives regarding the weather's favorability for generating renewable power in order to help manage the risks involved[11]. Similarly, London, UK, has a plan that focuses most heavily on energy efficiency upgrading, with projects on renewables.

In China, Shanghai has invested 80 billion Yuan (11.6 billion USD) in environmental protection projects. The city, which is near to sea level has increased plant and tree coverage to help ward off erosion as the threat of flooding increases and is also intensely focused on upgrading and installing infrastructure to ensure the city's water supply. The plan also provides incentives for promoting green industries within and around the city and also has a goal for decreasing the volume of vehicles on the roads by 65%.[12] Sydney, Australia is focusing on water infrastructure upgrading, but other types of infrastructure are secondary to the drive towards making the city carbon neutral via energy efficiency and renewable energy policies and related projects by 2020[13].

A common thread in these unilateral emissions reduction initiatives (direct and indirect) is seen here in the form of a focus on renewables, energy efficiency upgrading and infrastructure renovation at a city level within the global sphere. On the other hand, more so than at high levels of government, a clear focus on adaptive measures is also interwoven into these policies.

[11] http://www.munichre.com/en/ts/innovation_and_insurance_trends/windmills_against_climate_change/default.aspx

[12] http://en.chinagate.cn/development/environment/2008-12/15/content_16950071.htm

[13] http://www.sydneywater.com.au/EnsuringTheFuture/ClimateChangeStrategy/Ensuring_the_Futire_-_Climate_Change_Strategy_-_Feb_2008.pdf#Page=1

Table 4 presents examples of various city-level initiatives.

(TABLE 4 here).

2.4. Unilateral Measures by Businesses and Joint Public-Private Partnerships

Unilateral measures are also being implemented by businesses and joint public- private partnerships. While efforts similar to those mentioned above are ongoing in Mumbai (India) and in Moscow (Russia), unlike in most large cities around the world, most of the efforts in these cities are often better described as business ventures rather than government efforts. This is because the deployment of Clean Development Mechanism (CDM) related projects in these cities has tended to overshadow the need for explicit climate change legislation in favour of legislation to manage a proliferation of CDM projects. These often take a form similar to other city efforts, focusing on renewables, energy efficiency upgrading and infrastructure renovation, but with CDM projects subsidized due to the carbon credits generated. These are not managed fully within the public sphere, nor are they specifically limited to one city's boundaries[14]. This makes CDM a common mechanism for the emergence of private-public partnerships in those areas where CDM projects are valid.

One such project, for example, is the eco-friendly train project in Mumbai, where the aim is that long term infrastructure viability will be maintained and government expenses will be reduced by partnering with business to reduce train energy usage by over 30%. Such projects take the place of pure public sphere efforts with the objective of greater cost efficiency for government and higher profit for business from the government. This does, however, come with a greater degree of risk in terms of a project's success or failure, particularly when the project relies on unproven technological innovations that reflect the desire to mitigate carbon emissions.

In some cases, CDM funding builds on existing locally owned private sector initiatives such as the previously mentioned Karnataka Renewable Energy Project[15]. While such

[14] http://www.articlearchives.com/energy-utilities/utilities-industry-electric-powerity/1816583-1.html and

http://www.14000.ru/projects/city-climate/leaflet0908e.pdf and http://bangalorebuzz.blogspot.com/2006/12/emission-cuts-to-augur-well-for-bmtc.html

[15] Ravikiran Power Projects Private Ltd, Monitoring Report: 7.5 MW Grid-Connected Biomass Power Project (UNFCCC Ref. No. 0971), Version: Ravikiran / 001, dated 4 September 2008 ('Monitoring Report'), p. 8, available at: http://cdm.unfccc.int/UserManagement/FileStorage/13KBH5NLQM60FOWXY9PZ8J47TCISAD, accessed on 31 March 2009

projects reflect an incentive to further local development goals (regardless of whether those goals are intrinsically eco-friendly or not), the underlying incentives (driven by CDM) still shape the projects so that they are ‘greener’ than what would likely occur otherwise. However, that the requirement of “additionality” in CDM funded projects is hard to verify in practice[16].

There are also large scale public-private partnerships, where the financial input of CDM and similar incentive mechanisms is either less significant or does not apply. In the current global economy, when large businesses partner with governments at a national or regional level, funding for large-scale experimental projects becomes possible. In the United Arab Emirates, construction is underway for what is claimed will be the world’s first zero carbon city (while in operation; construction is still just as carbon intensive). This is notable for several reasons. First and foremost, the UAE is a country largely dependant on production and sale of fossil fuels (mostly oil) and this project represents a change from the status quo. Second, the scale of investment, which is roughly around $22 billion USD, makes it one of the most expensive green projects in the world. Third and finally, a key priority is given to profitability, in the hopes that this will signal to others that similar projects can be profitable in other areas of the world as well[17]. The embryonic city, which lies near Abu Dhabi, has infrastructure designed to encourage energy saving and estimates are that it will use 75% less power than a conventional city of the same size, and all energy that is used will be generated using renewables[18].

Similar to this, a retro-fit for Dongtan in China is in the works in association with the Shanghai Industrial Investment Corporation. With a retro-fit, zero carbon may not be possible and so the project has been called building an ‘eco-city’, with an emphasis on emissions reduction, efficiency upgrading, new city planning models, infrastructure and architecture. The aim is that Dongtan will be transformed to use natures resources as efficiently and effectively as possible in the hope that this will ensure the city’s long term survival and prosperity in environmental as well as economic terms[19].

Business involvement in emissions mitigation also partly reflects the perceived profitability of going ‘green’. For example, in Dubai, a company called Dynamic Architecture[20]

[16] We discuss the shortcomings of CDM as a funding mechanism for technogy transfer in greater detail in Section 5.1.

[17] This is an example of the demonstration effect, a point that we will come back to later on in the following section.

[18] http://www.dailygalaxy.com/my_weblog/2008/05/the-worlds-firs.html

[19] http://www.arup.com/newsitem.cfm?pageid=7009

[20] http://www.dynamicarchitecture.net/home.html

is working on redefining skyscraper construction in terms of efficiency and also in terms of self-sustainability, suggesting new building methods as well as making skyscrapers into wind power generating plants, able to power themselves and several city blocks at a fraction of the cost and construction time of a more traditional skyscraper. Another example is Interface Carpets, a carpet manufacturer that boasts the so-called 'greenest CEO in the world', Ray Anderson. Carpet making is oil and carbon intensive and Mr. Anderson has managed to reduce carbon emissions in their process by 82% over the past 12 years in absolute tonnage, while at the same time doubling profits. Approximately, this is the reduction goal for the whole world set out for the long term under the UNFCCC negotiations to keep warming at 2 degrees. Thus a case study of this company makes for a good example of how to reach that goal. Perhaps even more significant, it stands as a signal that the stated international goal is reachable even for fossil fuel intensive industries – and at a profit as well[21].

Similar businesses are growing on a global scale and a large subsection of them, mostly from developed countries, attend the annual 'Clean Equity'[22] conference in Monaco, where green industry leaders mingle to share ideas and network with each other. Here gather companies developing greener cars, better batteries, better solar cells, consultancies offering services on how to green your business, concept businesses for launching new geothermal, wind and solar energy ideas, companies selling green gimmicks[23] and several other types of green companies.

Perhaps somewhat counter-intuitively, oil companies have also embraced the statement that going green is profitable. This is embodied in the US Carbon Action Partnership (USCAP)[24]; a large group of oil companies, mining companies and other heavy emitters who are essentially calling for regulation to be placed over them in terms of carbon emissions, calling for significant and early action and for the US (home to all head offices of the members) to take an early and significant stance on reducing carbon emissions. While the purpose here is to guide change so that the most profit/ least damage is won, that such an agreement exists at all is indicative how important these companies believe

[21] Mr. Anderson's speech on this at a recent TED conference may be found at http://www.youtube.com/watch?v=iP9QF_lBOyA

[22] http://www.cleanequitymonaco.com/

[23] Things such as this idea from Honda, opening up more car options as your driving gets greener, would qualify as a gimmick. http://earth2tech.com/2009/03/02/upcoming-honda-insight-turns-eco-friendly-driving-into-game/

[24] http://www.us-cap.org/, some members include Shell, Chrysler, DuPont, Dow Chemical, GM, Ford and GE

emissions reduction to be, whether this stems from ecological concerns or worries over their bottom line profit.

2.5. Unilateral Measures by Individuals

Individual actions are also having a significant impact on climate change mitigation. Recycling is increasingly becoming common across the globe. In many developing countries, recycling is a source of livelihood for the urban poor[25]. Compact florescent bulbs are also becoming more commonplace every day, with LED technology, perhaps even more efficient, progressing apace. Ultimately, the goal is to make households as energy efficient and carbon free as possible. For the dedicated, this may involve purchasing for energy efficiency, while installing home-based solar or wind power systems. If individuals have the will, funds and supporting legislature this set of behavior is becoming a global commonality. Individuals also influence higher levels of governance, businesses and whole groups of other individuals. In simpler terms, these individuals attempt to shift culture more towards the 'carbon free' mentality. Some who have put notable effort into this include significant political figures such as Al Gore and Arnold Schwarzenegger of the US, Nicholas Stern of the UK and Chancellor Angela Merkel of Germany. Some celebrities and other well known people, with varying degrees of effectiveness, have also advocated climate change action and left a mark, albeit a smaller one. These include David Suzuki, Sir Paul McCartney, Jimmy Buffet, Celine Dion, Keanu Reeves, Alanis Morrissette and countless others, a large number of them well known internationally.

Of other individuals, completely unknown before the climate change issue arose, there are many who have had impact. Some are inventors and some are orators, but the former need help from the business sector to have an impact, in general (and thus may be said to have already been covered in the previous section), while orators tend to act on their own. Perhaps one of the most effective orators is Greg Craven. Using Youtube as his initial medium, this small town physics & chemistry teacher has created, first an ominous initial statement on climate change entitled "The most terrifying video you'll ever see" which has since generated several million hits, followed by a carefully planned and thought out 7 hour long series of videos entitled "How it all Ends" that expands on the initial message, responds to critiques, and discusses and explains the science climate change for the average person in a way that cuts through all the media sensationalism and confusion. His argument for action on climate change was so compelling that several international news stations from around the world became interested and he has also seemingly been

[25] http://www.guardian.co.uk/environment/2007/mar/04/india.recycling

contacted by a lead author of the Stern Review. His stated intent is to make his message 'go viral' via as many media formats as possible and change mainstream culture in regards to views on emissions and climate change in general. These examples illustrate the point that individuals can, and do, influence large groups of people via existing social networks and, through them, seek to alter the mainstream culture enough to influence higher levels of authority and government.

3. The Rationale for Unilateral Measures

A number of the examples discussed in the preceding section can be rationalized as being in the short-term self-interest (adaptation to the local impacts of climate change, ensuring energy security, halting the process of desertification, local development needs) of certain nations/regions/institutions (for future reference, "entities") with the secondary benefit of lowering emissions. Nevertheless, the full range of unilateral measures being undertaken cannot seemingly be solely explained by perceptions of narrow short-term self-interest especially for smaller countries or cities or individuals as participation in emissions reductions initiatives generate little or no direct private benefit.

One potential explanation is in terms of collective identity. Certain forms of collective identity can be self-enforcing in that conditional on other individuals accepting the same collective identity, it is in the self-interest of any one individual not to deviate, a point emphasized by Olson (1971) in his work on collective action. To the extent to which "going green" is viewed as an essential part of the collective identity in a given entity, individuals in that entity will undertake unilateral measures to cut emissions[26].

A different rationalization of unilateral initiatives lies in "rule utilitarianism" (Harsanyi (1977)) where individuals act to conform to a specific rule given that some group of other individuals also conform to the relevant rule. Unilateral measures in a given entity can be rationalized if each individual in that entity finds its optimal to cut emissions given that all individuals in that entity conform to the rule of cutting emissions[27].

[26] We can formalize Olson's argument as follows. Let G denote an entity where membership entails an individual commitment to cut emissions. Consider an individual i who obtains a benefit b_i from group membership. Let c_i denote the cost of cutting emissions to individual i. Then, as long as $b_i - c_i > 0$, individual i will cut emissions to signal alleigance to the collective identity of the group.

[27] Applied to our context, rule utilitarianism may be formalised as follows. Assume that each individual in an entity has a common set of actions $A = [0, 1]$ (where 0 corresponds to low emissions and 1 to high emissions) and wishes to maximize a common utility function (which could be weighted sum of utility functions of individuals belonging to the group) over the set of action profiles. Under rule utilitarianism, each individual i, $i = 1, ..., n$, an action $a_i \in A$ to maximize $U(a_1, ..., a_i, ...a_n, \mathbf{a})$ s.t. $a_j = a_i$, for all

There are also arguments that unilateral measures can make sense in terms of the demonstration effects involved. By undertaking unilateral measures certain entities demonstrate not only the feasibility of collective action and their awareness of the potential threats to other entities but also lower the cost of cutting emissions for all other entities as well[28]. Therefore, even if it isn't in the direct short-term interests of certain entities to cut emissions, by anticipating that such activities will generate a similar response from others, such entities will undertake unilateral measures. Thus Heal (1993) argues that as one country undertakes even limited emission cuts it incurs a variety of costs (e.g. R and D investments, retooling) that are "sunk" in nature. However, once the new low carbon technology has been developed, it can be made available to another country at a relatively lower cost. Moreover, given the larger market, there are greater private incentives to innovate in both countries leading to deeper emission cuts within the two countries and at some point, inducing emission cuts by a third country and so on. The general point is that as one country cuts its emissions, the marginal cost of cutting emissions for other countries may fall as well thus making emission cuts more worthwhile in these latter countries.

In related vein, it can be argued that the initial commitment to cut 50% of CFCs in the Montreal protocol was critical to its success as it lowered the costs of making even bigger reductions by providing an incentive for the development of substitutes to CFCs (Benedick (1998)). The difference between this and the scenario described above is one of scale, thus the events surrounding Montreal Protocol may be taken as a precedent for the potential of such a mechanism.

In an influential contribution, Pacala and Socolow (2004) have argued that implementing a series of "stabilization wedges"[29] will place the world, approximately, on a path to

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$j \neq i$, j belonging to the group, and $\mathbf{a}$ is the action profile chosen by individuals outside the group. This formalization is useful in the context of the following section's model.

[28]A simillar point has been made in a model of farsighted network formation in Dutta, Ghosal and Ray (2005).

[29]These are, by 2054, 1. double vehicle fuel efficiency, 2. reduce the use of vehicles by half, 3. reduce all building and appliances emissions by 25%, 4. double our efficiency in obtaining energy from coal, 5. replace 1500 GW of coal based energy with natural gas, 6. introduce carbon capture and storage to power plants totalling 800 GW coal or 1600 GW gas, 7. use CCS at 500 MtC/ year coal based H2 power plants (or half that if gas is used), 8. use CCS at coal-to-synfuel production plants of total capacity of 30 million barrels per day (assuming CCS is 50% efficient – ie – 50% waste carbon is fed back into the system), 9. replace 700 MW of coal power with nuclear, 10. replace 2000 GW of coal power with 2 million 1 MW (peak) wind turbines, 11. replace 2000 GW of coal power with photovoltaic technology, 12. Add 4 million 1 MW (peak) wind turbines for production of H2 based vehicle fuel, 13. increase ethanol production by a factor of 100 for vehicle fuels, 14. halt tropical deforestation, plant 2 times as

stabilizing CO_2 levels. Arguably, a more grass-roots approach would be required in any attempt to go further than stabilizing emissions. If a highly industrialized nation (or an entity within it) implements some of these wedges within its borders, other nations (and entities within it) can learn from its experience and use the innovations (be they policy based or technological) stimulated by such an attempt. For example, if a city introduces a raft of measures to induce more use of public transport and some of these measures are successful, other cities elsewhere in the world can learn from its experience and implement similar measures. At a national level, reducing the cost of generating electricity by wind/solar power potentially benefits many countries and not just the country within whose borders the innovation takes place. Such unilateral commitments induce innovation in technologies that lower the cost of switching to low carbon economic activities by creating a market for such innovations. The argument is thus that there can be significant positive transnational externalities involved in any unilateral initiative[30].

A critical issue relates to both the size and form that these emissions reductions take. On the one hand, one could argue that these actions are often largely symbolic and undertaken for political reasons foremost, or one can argue that there is more substance involved. In the OECD, Europe and in large population, rapidly growing developing countries over 50% of industrial emissions are accounted for by 3-4 industries (power generation foremost), and hence attempts to cut emissions and/or the adoption of open technology standards in these key sectors will be seen to have a significant potential impact on overall emissions within these countries. Switching to low carbon activities requires technologies that relate primarily energy, infrastructure, transport and industry (Human Development Report (2008)) and clearly effective innovation in these technologies in one nation or region will generate positive transnational externalities.

It follows from this that even if a majority of entities in a nation do not find it in their self-interest to cut emissions, a minority of entities might. Thus, *even if a given country is not willing to commit to emission cuts as part of a multilateral negotiation process, a positive fraction of entities within each nation might be willing to cut emissions and thereby reduce the costs involved in future multilateral agreements.*

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much new trees (300 Mha worth of land), and finally, 15. practice conservation tillage on all farmland globally 10 times as much as currently practiced. SeFor further information on Socolow wedges refer to http://carbonsequestration.us/papers-presentations/htm/Pacala-Socolow-ScienceMag-Aug2004.pdf

[30] The scope of such positive externalities may, however, be limited by issues of technology transfer and absorptive capacity across locales in the face of binding political and cultural constraints.

4. Unilateral Initiatives, Learning and Global Convergence to Emissions Cuts

In this section we present a simple dynamic model which demonstrates how social learning which builds on unilateral initiatives could deliver a switch to a global low emissions regime over time. We show that while single countries on their own may never get to the point of switching completely to low emission activities, a suitably designed learning process with strongly connected countries (which will be made precise below) can, over time, deliver a global switch to low emissions. Subsidized targeted technology[31] transfer may be a vehicle to alter the participation constraints of countries over time. We, then, use the model to discuss how policy can affect the rate of convergence to a global low emissions regime.

4.1. The dynamic model of learning

We consider discrete time intervals which go from $t = 1, 2, \ldots$. There are $N = \{1, ..., n\}$ countries. Each country consists of a number of individual entities of mass $m_i > 0$[32]and the total mass across countries is $M = \sum_i m_i$. At $t = 1, 2$, $e_{i,j}^t \in \{0, 1\}$ denotes the emissions of greenhouse gases by individual j belonging to country i so that at any $t, e_{i,j}^t = 0$ corresponds to adopting low carbon activities while $e_{i,j}^t = 1$ corresponds to persisting with a high carbon activities. Let $e_i^t = \int_j^{m_i} e_{i,j}^t dj$ denote the total emissions of country i in period t. Let $E^t = \sum_i e_i^t$ denote the total emissions at time t.

Let a fraction γ_i^t (respectively, $1 - \gamma_i^t$) of individuals j in country i have preferences and incentive to cut emissions unilaterally (respectively, continue with high emission activities). We assume that once a switch occurs from high to low emission activities it is irreversible. We do not impute any particular motive to such individuals who want to cut emissions unilaterally but several possibilities are evident in the preceding sections.

We will assume that $\gamma_i^1 = \gamma_i < \frac{1}{2}$, $\gamma_i \geq 0$, for all countries i with strict inequality for some countries i. We assume that that underlying preferences (which we do not explicitly specify) are such that it is globally efficient to set $e_i^t = 0$ for all i, t.[33]

[31]Technology is used here to include not only process and physical technological innovations but also the use of existing technology which lowers emissions, such as a switch away from small inefficient coal burning power plants to larger more efficient plants using non coal fuel.

[32]We interpret m_i as the size of country i. This is used as an approximate measure of a country's ability to influence carbon levels. Formally, we assume that nation i consists of a set of individuals i of Lebesgue measure m_i.

[33]The divergence between private payoffs and global payoffs is assumed to reflect the wide-spread negative externalities (the medium term damage caused by global warming) resulting from continued

We assume that in each country i at each t, individuals decide, via majority voting, between two alternatives: (i) all individuals within the country switch to zero emission activities or (ii) only those individuals who voluntarily choose to do so switch to low emission activities. Therefore, a country i will commit to cut emissions to zero in period t (and in all subsequent periods) iff $\gamma_i^t \geq \frac{1}{2}$. Otherwise, the emissions level in country i at t is given by $e_i^t = (1 - \gamma_i^t)m_i$.

We assume that the there is some underlying process of social learning within each country i that works as follows. A unilateral commitment by a group of individuals within country i at each t to cut emissions in any time period stimulates innovative activity that lowers, over time, the relative cost[34] of adopting low carbon activities for other individuals both within country i and across all other countries $j \neq i$. Such an effect relies on the design of appropriate policy mechanisms that maximize the impact of positive technological/institutional externalities to facilitate innovation, technology transfer and adoption of low emission activities both within a country and across countries. This will be the focus of the discussion on policy below.

The fraction of individuals within a given country i who are willing to cut emissions unilaterally is an increasing function of the number of other individuals globally who have undertaken unilateral commitments to cut emissions. We allow for inertia in learning so that at each t, not all individuals within country i who benefit from switching actually do so- this could be due to a variety of factors such as habit formation, lack of awareness and information etc.

Formally, the evolution of γ_i^t within each country i over time is described, for $t \geq 2$, by the system of difference equations :

$$\gamma_i^t = \min\left\{\gamma_i^{t-1} + \lambda_i\left(G_i\left(\sum_j \rho_{i,j}\gamma_j^{t-1}\right) - \gamma_i^{t-1}\right), 1\right\}, i = 1, ..., n \qquad (1)$$

where λ_i, $0 < \lambda_i \leq 1$, is a measure of inertia within country i, $G_i\left(\sum_j \rho_{i,j}\gamma_j^{t-1}\right)$ denotes the proportion of individuals in country i for whom it becomes a dominant action to cut emissions at t given that a proportion γ_j^{t-1}, $j = 1, 2, ..., n$ of individuals in all countries have already cut emissions at $t-1$ and $\rho_{i,j}$, $0 \leq \rho_{i,j} \leq 1$, captures the spillover from country j to country i, with $\rho_{i,i} = 1$. We assume that $G_i(x) = 1$ for all $x \geq 1$. Note that (1) is a system of difference equations that cannot, in general, be reduced to a collection of uncoupled difference equations, one for each country i.

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high emission activities.

[34]These costs could be financial costs, lowering the relative costs in terms of the effort or time sacrificed to do the 'green' thing i.e. making it easier in terms of the physical and cognitive effort involved to do the 'green' thing rather than the more carbon intensive equivalent action.

The spillover effects across countries, for any one country i, are captured by the term $\sum_j \rho_{i,j}\gamma_j^{t-1}$. Specifically, both the sign i.e. whether or not $\rho_{i,j} > 0$ and the magnitude of $\rho_{i,j}$ for a pair of countries i, j will be a consequence of the use of appropriate policy mechanisms that build on positive technological spillover across countries.

We assume that the map $G = \{G_i : i \in N\}$, $G : [0, n]^n \to [0, n]^n$, is continuous and increasing on $[0, 1]^n$: learning within and across countries is complementary. In effect we assume that all internal and external learning will cause an increasing proportion of individuals within a country to cut emissions (or at least, any negative influence is always overridden by the positive influences)[35].

Will each country eventually be in a position to commit to cut emissions? We say that country i is connected to country j if $\rho_{i,j} > 0$. Define a directed graph over N where the vertices are individuals and an arc (i, j) exists iff i is connected to j. A path in a directed graph is an ordered collection of arcs and vertices in which all vertices are distinct. A directed graph is strongly connected if for every pair of distinct if for every pair of distinct vertices (i, j) there exists a path connecting i to j. We say countries are globally strongly connected if the associated graph is strongly connected.

An example of a scenario where countries are globally strongly connected is when $\rho_{i,j} > 0$ for all $i \neq j$. A different scenario where countries are globally strongly connected is one where $\rho_{i,1} > 0$, $\rho_{1,i} > 0$ but $\rho_{i,j} = 0$ for $i \neq j$ whenever $j \neq 1$.

More generally, when countries are globally strongly connected, between any two countries i, j, there is a chain of countries $k_0 = i, ..., k_M = j$ with $\rho_{k_t,k_{t-1}} > 0$.

Suppose the set of countries is globally strongly connected with $\gamma_i > 0$ for some country i. Consider the map $G = \{G_i : i \in N\}$ where $G : [0, n]^n \to [0, n]^n$[36]. Note that by construction $G_i(x) = 1$ for all $x \geq 1$, $i = 1, ..., n$. Therefore, the vector $(1, ..., 1)$ is always a fixed-point of G. Note that $G_i\left(\sum_j \rho_{i,j}\gamma_j\right) > \gamma_i$ whenever $0 < \gamma_j < 1$ for some $j \neq i$ with $\rho_{i,j} > 0$. Whenever $\gamma_i^t > 0$, for some country i at some t, as there is a path connecting each country j to country i, $j \neq i$, there exists $t' \geq t$ such that

[35] The restriction on G is strong but is made for reasons of expositional simplicity. By repeating the argument made below to show G has a unique fixed-point $(1, ..., 1)$, it is easily verified that any fixed-point of G is greater than (in the ussual vector ordering) the vector $\left[\frac{1}{2}, ..., \frac{1}{2}\right]$ as long as G is increasing on $\left[0, \frac{1}{2}\right]^n$.

[36] We assume that all learning within and across countries is complementary so that G is increasing on $[0, 1]^n$: all internal and external learning will cause and increasing proportion of individuals within a country to cut emissions (or at least, any negative influence will tend to be overridden by the positive influences). Our analysis is robust to a perturbation where negative influences dominate positive influences as long as G is increasing on $\left[0, \frac{1}{2}\right]^n$ (i.e. positive momentum) as any fixed-point of G is greater than (in the usual vector ordering) the vector $\left[\frac{1}{2}, ..., \frac{1}{2}\right]$.

$G_j\left(\sum_k \rho_{jk}\gamma_k^{t'-1}\right) > \gamma_j^{t'-1} \geq 0$: $t = t'$ if $\gamma_j^t > 0$ and $\rho_{ji} > 0$, otherwise $t' > t$, $t' \leq t + s$ where s is the minimum number of vertices (the minimum taken across all the paths connecting i to j) between i and j. As $\gamma_i > 0$ for some country i, it follows that $(1, ..., 1)$ is the only fixed-point of G. Let $\{\gamma^t : t \geq 1\}$ denote the sequence generated by an iterated application of the RHS of (1). Then, by continuity of G, for each country i $\sup_t \gamma_i^t = 1$ and as $\{\gamma^t : t \geq 1\}$ is a component-wise increasing sequence, $lim_{t\to\infty}\gamma_i^t = 1$ for all $i = 1, ..., n$.

Let $\hat{t_i} = \inf\left\{t : \gamma_i^t \geq \frac{1}{2}\right\}$. Therefore, for all $t \geq \hat{t}_i$, $\gamma_i^{\hat{t_i}} \geq \frac{1}{2}$: whenever, there are some (however weak) spillover effects in learning across countries i so that all countries are globally strongly connected, eventually a majority of voters in each country i will vote to commit to cut emissions. Therefore, a stable global agreement to cut emissions will emerge at $\hat{t} = \max_i \hat{t}_i$. As the RHS of (1) is increasing in λ_i, $\rho_{i,j}$ and γ_j, $i, j \in N$, for each country i, $\hat{t}_i$ is decreasing in λ_i, $\rho_{i,j}$ and γ_j, $i, j \in N$.

We summarize the above discussion as the following proposition:

Proposition: Suppose learning within each country is described by the map (1), countries are globally strongly connected and $\gamma_i > 0$ *for some country* i*. Then, there exists* $\hat{t}_i$*, decreasing in* λ_i*,* $\rho_{i,j}$ *and* γ_j*,* $i, j \in N$*, such that country* i *will commit to cut emissions for all* $t \geq \hat{t}_i$ *with* $e_i^t = (1-\gamma_i^t)m_i$ *for all* $t < \hat{t}_i$*. A stable global agreement to cut emissions will emerge at* $\hat{t} = \max_i \hat{t}_i$*.*

So far, we have focused on the case of learning with spillovers in scenarios where countries are strongly connected. To understand the importance of spillover effects in driving global learning to the point where countries commit to switching to low emissions, it is useful to consider the polar opposite case, where $\rho_{ij} = 0$ for all $i \neq j$. In this case, all learning takes place within a single country and the evolution of γ_i^t within each country i over time is described, for $t \geq 2$, by the equation:

$$\gamma_i^t = \min\left\{\gamma_i^{t-1} + \lambda_i\left(F_i\left(\gamma_i^{t-1}\right) - \gamma_i^{t-1}\right), 1\right\} \quad i = 1, ..., n \qquad (2)$$

where $F_i(.) = G_i(.)$ on $[0,1]$. Clearly, in this case, (2) is a system of difference equations that can be reduced to a collection of uncoupled difference equations, one for each country i each of which can be analyzed separately.

In this case, will each country eventually be in a position to commit to cut emissions? The answer in general is no. Let $\gamma_i^* = \min\{\gamma \in [0,1] : F_i(\gamma) = \gamma\}$ is smallest fixed point of the map $F_i : [0,1] \to [0,1]$. γ_i^* is well-defined as 1 is always a fixed point of $F_i(.)$ and the set of fixed-points of $F_i(.)$ is closed subset of a compact set and hence, compact. Let $\{\gamma_i^t; t \geq 1\}$ denote the sequence generated by an iterated application of the RHS of (2) with $\gamma_i^1 = \gamma_i \geq 0$ and $\gamma_i^* \geq \gamma_i > 0$. Clearly, if $\gamma_i = 0$, country i never moves away from 0. If $\gamma_i > 0$, then by continuity of $F_i(.)$, $\sup_t \gamma_i^t = \gamma_i^*$ and as $\{\gamma_i^t; t \geq 1\}$ is an increasing sequence, $lim_{t\to\infty}\gamma_i^t = \gamma_i^*$. Therefore, as long as $\gamma_i^* < \frac{1}{2}$ learning within country i will never result in country i, as a whole, switching to low emissions.

More generally, note that it is straightforward to construct examples where $\rho_{ij} \neq 0$ for some $i \neq j$, countries are not globally connected and therefore, $lim_{t\to\infty}\gamma_i^t < \frac{1}{2}$ for all i: simply set $0 < \gamma_1 < \frac{1}{2}$, $\gamma_j = \rho_{j1} = 0$, $j \neq 1$.

In conclusion, our formal analysis suggests that while *single countries on their own may never get to the point of switching completely to low emission activities, a suitably designed learning process with strongly connected nations will, over time, deliver a global switch to low emissions.*

4.2. A new global IP regime: subsidies, spillovers and global learning

We will now discuss how the model results above point to global policy initiatives which can affect the rate of convergence to a global low emissions regime.

How should national and multilateral arrangements be designed in order to effectively build on the positive externalities inherent in such unilateral initiatives?

It bears repeating here that the variety of different unilateral initiatives reflects a heterogeneity of interests, beliefs, motivation at the level of countries, regions and groups. Some unilateral initiatives are driven by perceptions of self-interest (adaptation to the local impacts of climate change, ensuring energy security, halting the process of desertification, local development needs) while others are more globally preventative in nature (general greenhouse gas reduction accords, etc.). Groups within a nation might also undertake unilateral initiatives primarily for signalling collective identity, in which case concepts of rule utilitarianism and demonstration effects come into play.

In theory, although low emissions may not emerge as the outcome of majority voting at a national level (at least in large countries), unilateral measures may well exist at various subnational levels. Moreover, subnational groups are more likely to have the autonomy and resources in initiating unilateral measures in decentralized political systems that empower individuals and communities.

Although the main result in the formal model suggests that with spillovers all countries will eventually agree to cut emissions down to zero, there still remains the issue of how quickly countries get there. For example, suppose $\lambda_i = 1$ and $\sum_i \gamma_i \geq \frac{1}{2}$: if $\rho_{ij} = 1$ for all countries i, j, then $\gamma_i^t \geq \frac{1}{2}$ for all i and $t \geq 2$. This is clearly a best-case scenario, one where convergence is immediate: $\hat{t} = \hat{t}_i = 2$. More generally, for each country i, $\hat{t}_i$ is decreasing in λ_i, $\rho_{i,j}$ and γ_j, $i, j \in N$. Therefore, policy interventions that increase the values of these variables will increase the rate at which there is global convergence to a low emissions regime.

We argue that subsidies to facilitate technology transfer could be a way of speeding up the convergence to a global low emissions regime. What would be involved would be a new global IP regime a central part of the Copenhagen negotiations on an innovation fund. The idea is that rather than simply support new technologies the fund will also be used to speed up the adoption of existing low carbon technologies. This could take the form of governments in countries either developing new intellectual property or with existing low carbon technology paying a part of the licence fee paid by the users in other countries. The portion involved would reflect the strength of the external effects involved. In addition there should be more public funding for new technology and users in other countries should be directly involved at the development stage.

The design of such a system will have to deal with the question of how much is paid and on what basis is the payment made. What conditions should be attached to these payments? While it is clear that any payments would have to be made conditional on verifiable actions to switch to the use of low emissions technology, the funding mechanism to subsidize technology transfer could usefully build on the experience and the lessons learnt from the operation of the CDM. A key criticism of the CDM has been that the requirement of "additionality" is hard to verify in practice. For example, firms may delay adoption of cost effective low carbon technologies to benefit from CDM or use CDM to adopt technologies that they would have funded from capital markets or internal funds in any case (Olsen (2007), Wara and Victor (2008)). Funding under the scheme we propose could be conditional on countries adopting specific commitments i.e. specific time-bound quantity targets like initially lowering carbon intensity followed by emission cuts, the adoption of low carbon technology standards (such as carbon capture and storage, solar and wind energy etc.) in key sectors such as energy, infrastructure, transport and industry. A portion of the funding should also be reserved for research and development. Decisions on funding individual projects would be taken in the context of an overall carbon reduction plan for the country as whole. Institutional design to ensure timely funding flows, monitoring and evaluation will be essential to the successful operation of such a global fund.

Moreover, such a global funding mechanism will have to build on links (and including any actual and potential spillovers) between countries. For example, the US and the EU are especially important because of their central role in the world economy and their generation of innovation and technology transfer. Others such as China and India are important because of the size of their populations and use of carbon emitting technologies. For example, technology for existing "clean coal" power plants and carbon capture technologies can be developed and further refined in the US and EU with a subsequent (subsidized) transfer to China where it would have a significant impact on cutting emissions. Other interventions may reflect structural similarities, land use patterns, existing patterns of carbon consumption etc. What is needed are platforms where information relating to unilateral initiatives can be exchanged. Subsidies will be varied by characteristics such as the degree of spillover by type of technology and by targeting countries that have the greatest potential to generate spillover effects[37]. The timing of such subsidies is clearly important as is the way in which such subsidies will be phased out. Identifying, quantifying and calculating such spillovers is key to the success of this approach.

In general, measures that reduce emissions inertia within a country and measures that strength the positive spillover effects across countries are both likely to be costly and therefore, with resource constraints, there will be a trade-off between the two. For example, should the UK subsidize measures that improve the energy efficiency of households or subsidize low carbon technologies that reduce emissions in the energy generation? The latter may have a higher potential to generate spillovers across countries while the former will have a bigger impact on reducing inertia in adaptation to low carbon use final demands.

In short, policy needs to be structured so that the cost of switching to low carbon activities falls quickly so that starting from a situation with limited coverage, low carbon activities spread cumulatively over time across localities, entities and sectors.

A new global IP regime and its funding mechanism could stimulate innovative ways to reduce the costs of emission cuts is an integral element in our policy proposal for structuring global climate change negotiations (a point emphasized by Arrow (2007)). To achieve the goal of ensuring that the pace of innovation in low carbon technologies is rapid, such a policy will have supplemented by other measures. Information sharing, incentives, targeted subsidies, carbon pricing that stimulates innovation, lowers inertia and maximizes the impact of spillover effects across countries will be essential. If there is uncertainty over commitments to emission targets and carbon prices fluctuate over time, or are too low or if too many economic activities are excluded from emissions trading, there may be little or no impact on behavior of firms and households. This may discourage innovation (costly investment in the production of new ideas) that lowers the relative cost of low carbon activities. In other words, what is also required are interventions that

[37]This would be due to specific characteristics such as size, influence, technological and innovation capabilities, the degree of similarity with other national economies such as location, patterns of land and energy use, dominance of key sectors, neighborhood effects etc.

establish a stable and growing market for innovation in technologies that lower the relative cost of low carbon activities.

A potential limitation of our proposal is that the process described here may take time to play out and the emission cuts required to stabilize global temperatures may not be delivered quickly. We envisage a process of technology transfer and diffusion that involves chains of innovations and adoption with new inventions based on other low carbon technologies: such a process may require roughly 5-10 years to play out for each innovation, or more if the innovations become controversial in some way. Some of these new technologies will not be compatible with high carbon technologies and entire factories may need to be retooled (thus raising the adoption costs of the new technologies). Although the proposal emphasizes the innovation and subsequent transfer of new technologies, one way to address the above concern is to recognize that emissions reduction can also be achieved by ensuring the spread and adoption of *existing* low carbon technologies within and across countries. For example, households and firms within high income countries can be persuaded to insulate their houses or install solar panels by a combination of subsidies (or low cost loans), and the extension of carbon markets to individual households and small firms/businesses. As already argued, technology transfer across countries (for example, the transfer of existing cleaner and more efficient power generation from coal to China and/or the greater use of carbon capture technologies in power generation) will require a new global IP regime.

The speed of convergence to a global low carbon regime will increase if entities in a given country chooses to cut emissions even when it isn't in their immediate short-run interest to do so, anticipating that such an action would induce an earlier switch by entities in all other countries. Individual entities in countries that (a) create the largest spillover effects, either directly or indirectly, on global learning, (b) are pivotal (i.e. without whom global learning will be delayed substantially), and (c) are willing to bear the costs of being one of the first to switch to low emission activities, are more likely to act in anticipation of inducing an earlier switch to low emission activities by other countries. Moreover, such behavior will be influenced by the strength of the spillovers in learning across countries. For example, if $\lambda_i = 1$, $\rho_{ij} = 1$ for all countries i, j, voters in country i could choose to cut emissions to zero (so that $\gamma_i^1 = 1$) anticipating that $\gamma_j^t \geq \frac{1}{2}$ for all $j \neq i$, $t \geq 2$.

In addition to this, bundling trade and climate change negotiations together could ensure broader participation and compliance in climate change negotiations because the flow of immediate benefits associated with emission cuts (the benefits of lower trade barriers) could alter incentives for countries to participate in global negotiations. However, a necessary condition for such bundling to work is that the *threat* of increased protectionism by low carbon nations be renegotiation proof, a condition (i.e. increased protectionist tendencies) more likely to met by nations already undertaking unilateral initiatives as demonstrated by recent discussion of carbon based border adjustments to address issues of leakage.

5. Multilateral negotiations and unilateral initiatives

How do unilateral initiatives relate to multilateral negotiations? If countries hang on to emissions reduction possibilities as bargaining chips, multinational negotiations can slow the pace of unilateral emissions reductions. On the other hand, multilateral negotiations can be seen merely as a repackaging of unilateral initiatives, many of which are relatively easy to meet due to increasing energy conversion efficiency over time.

There is a significant literature on autonomous increase in energy efficiency over time within the OECD economies since the 1970's[38]. This was about 2% per year in the 1970-1980's as a result of sharp increases in oil prices under OPEC and is now at around 1% per year since the early 1990s (lessened due to relatively inefficient consumer electronics). The IPCC relies heavily on this positive trend continuing in their arguments that the costs of meeting major reductions in emissions intensities are relatively small. Thus, unilateral measures are already assumed in any multilateral agreement in this limited sense.

The issue then is how these autonomous increases in energy efficiency will be affected as a result of the broader scope of unilateral measures which have been taken beyond this. These were not present in the 1970's and 1980's and they will, presumably, accelerate the trend in autonomous increases in energy efficiency. More generally, how much linkage to unilateral actions exists in multilateral agreements, as well as how much potential synergy exists between those unilateral actions within a multilateral context are critical questions to determining the role of unilateralism in a multilateral agreement.

The spread and acceleration of unilateral measures in the ways we describe also makes it easier to negotiate multilaterally beyond this view of energy efficiency already present in multilateral negotiations. If multilateral commitments are to be largely met through unilateral processes, or are to some extent shaped by existing/ planned unilateral actions, then commitments taken on by negotiators involve little additional cost.

But broadly, the question is whether unilateral measures can be considered to be an engine for reduction in carbon emissions and how this engine will produce negotiated multilateral commitments in terms of both potential synergies and relative effectiveness. Our

[38]http://www.iea.org/Textbase/Papers/2008/Indicators_2008.pdf

analysis implicitly assumes unilateral measures will play a large part in any future multilateral agreement, if one should come about. Under this view, a multilateral agreement should build on national (and more local) efforts to promote the development and spread of effective unilateral actions by strengthening the spillovers across nations and result in a process of social learning that delivers a global switch to a low emissions regime.

6. Concluding Remarks

In this paper we discuss both the size and extent of unilateral commitments to reduce carbon emissions which are being taken in countries around the world and especially in the OECD. The question is whether such initiatives are the most significant part of the global effort at mitigation, or whether they represent symbolic and in some ways naïve commitments which offer no serious possibility of major emissions reduction. If this is the case, other mechanisms of either accommodation to adaptation or mitigation of emissions will need to be resorted to. If unilateral measures are seen to be significant in reducing emissions, then the implications for policy become clear. Building on unilateral measures via global learning through a new global IP regime provides the route for any future multilateral agreement, preemptively dealing with much of the additional cost involved in a multilateral agreement.

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Table 1: Examples of Country-wide Unilateral Measures

Country/Region	Type	Actions/Goals
EU	General emissions reduction/ Renewables	20% emissions reduction by 2020 / 20% of region powered by renewables by 2020
China	Energy efficiency/ Renewables/ General emissions reduction	20% improvement in energy efficiency relative to trend / 20% of region powered by renewables / reduce emissions intensity per unit of GDP by 20% - all goals to be achieved by 2020
Norway	General emissions reduction	Zero carbon economy by 2050
New Zealand	General emissions reduction	10-20% below 1990 levels by 2020, specific plan outlined for achieving this
Costa Rica	Reforestation / Emissions reduction	No set goal, 1986-2006 added +30% forest cover to the country / zero carbon economy by 2021
Denmark	Renewables	user and prominent exporter of wind power turbines to the rest of the world
UK	Emissions reduction	4 new nuclear power stations being built
India	Energy sector reform	Comprehensive efficiency and renewables (and nuclear) energy plan, attempting to create 'green' development path
Brazil	Renewables/ alternate fuels	7000 MW production goal for renewables in 2010 / substantial ethanol production increase
Ecuador	Forest preservation	Rainforest sitting on top of oil field protected due to legislature
Spain	Halting desertification	4 year program to plant 45 million trees near desert edge underway
Australia	Halting desertification	Bio-engineering salt resistant plants and building desalination plants to combat desertification
Maldives	Adaptation measure	Sovereign wealth fund created to purchase new home should country be permanently flooded

Table 2: Examples of Interstate Unilateral Measures

Regions/Provinces/ States (country)	Type	Actions/Goals
Rural communities in Southern Provinces (Mexico)	Watershed Renewal/ Preservation	Payment to farmers for preserving and maintaining forest area deemed ecologically critical (Up to roughly 40 USD/ hectare/ year)
Iowa, Illinois, Kansas, Michigan, Minnesota, Wisconsin (US) and Manitoba (Canada)	General emissions reduction/ cap and trade system	Midwest greenhouse gas reduction accord – works similarly to the EU model for emissions reduction/ trading, only on a shorter 30 month timescale – mandates group and individual reduction targets for this time
Connecticut, New Hampshire, Delaware, New Jersey, Maine, New York, Maryland, Rhode Island, Massachusetts and Vermont (US)	General emissions reduction/ cap and trade system	Regional Greenhouse Gas Initiative – cap power sector emissions at 188 million tons immediately, tightened by 10% by 2018 – member policing of each other – pure auctioning ETS, with offsets allowed
Arizona, California, Montana, New Mexico, Oregon, Utah and Washington (US), British Columbia, Manitoba, Ontario and Quebec (Canada)	General emissions reduction/ cap and trade system	Western Climate initiative – cap and trade approach modeled in phases as in the EU, focus on all institutes emitting over 25,000 tons of CO2 annually, target is 15% emissions reduction from base year 2005 by 2020, enforced on a firm by firm basis rather than standard state basis.
Western Governors Association member states (US)	renewables	Clean and Diversified Energy Initiative – 30000 MW capacity goal in renewables for the group by 2015, 20% group energy efficiency improvement goal by 2020

Table 3: Examples of Individual State Unilateral Measures

Province/ State (country)	Type	Actions/ Goals
Almost all Provinces (Canada) and States (US)	General emissions reduction/ energy efficiency	Goals vary by state/province but most have a minimum of at least 10% improvement in energy efficiency and emissions reduction by various means by 2020
California (US)	Various – focus on renewables and integration of them into infrastructure	Samples - Global Warming Solutions Act of 2006, Alternative and Renewable Fuel and Vehicle Technology Program, Solar Water Heating and Efficiency Act of 2007, The Clean Car Law, and an 80% GHG reduction target by 2050 from base year 1990
Florida (US)	Various – focus on decentralizing power grid through renewables	Samples – 40% reduction target from base year 1990 by 2025, 80% by 2050, creation of Florida Climate and Energy Commission to oversee policy, banning of common energy saving devices prohibited, Florida Climate Protection Act, tax break for residential property with installed renewable power generators, Florida Energy Systems Consortium created to encourage R&D
British Columbia (Canada)	Carbon tax	Revenue neutral tax easing in from a $10 CAD carbon price equivalent tax in 2008 to a $30 one in 2012, specific goods taxed by average carbon content
New South Wales (Australia)	Energy efficiency / adaption preparedness	$63 million (AUD) program to help 220 000 low income households incorporate new technology into the home for improved energy and water efficiency
Queensland (Australia)	Renewables & efficiency R&D	$7 million (AUD) into various projects aimed at developing renewable technology and upgrading energy efficency
Karnataka (India)	Renewables	A ‘100 000 solar roofs’ project centered around,

		but not limited to, the Bangalore area. To be achieved by 2013.
Amazonas (Brazil)	Rainforest preservation	Moved in opposition to Federal ethanol production mandates, halted practice of handing out chainsaws to ‘promote development’, adopted clear preservationist stance

Table 4: Examples of City-Level Unilateral Measures

City	Type	Actions/Goals
Copenhagen (Denmark)	Emissions & pollution reduction	City wide public bike system
New York City (US)	Adaptation measures / emissions reduction/ energy efficiency	Major infrastructure project – estimated 30% reduction in emissions. Project includes improving city forest cover (erosion concern), reworking of electrical grid and building codes for energy efficiency, replacing all aging water pipes with focus on durability, and mandates on increased minimum allowable fuel efficiencies for cars
Toronto (Canada)	Energy efficiency/ renewables	Infrastructure upgrading for durability, updating building codes for energy efficiency, green roof promotion, large number of wind power generators added, both on land and over water
Munich (Germany)	Energy efficiency/ renewables / financial innovation	Infrastructure and building code upgrades (similar to NYC and Toronto), wind power generators added, weather based derivatives designed to manage wind power financial risks of variable winds
London (UK)	Renewables/ energy efficiency	Major infrastructure and building code upgrades for energy efficiency, various wind and solar projects
Shanghai (China)	Energy efficiency/ emissions reduction / green industry promotion	80 billion Yuan for tree & foliage planting & water infrastructure upgrading, revamped tax structure to encourage green industry, plan for removal of 65% of vehicle traffic in the city
Sydney (Australia)	Renewables/ energy efficiency / emissions reduction	Carbon neutral goal by 2020, energy efficiency and water infrastructure upgrades, building code revamped for energy efficiency and carbon neutral goal