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Unilateral measures and emissions mitigation*

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Abstract

Do unilateral measures to cut emissions provide an adequate foundation for global climate change negotiations from a post-Copenhagen perspective? We document the extent and variety for unilateral measures. In a formal model, we examine the conditions under which global learning, by building on the positive spillovers generated by unilateral measures, delivers cumulative emissions reduction over time. Using our results, we analyze the key features of a global policy regime builds on unilateral measures to accelerate convergence to a low carbon world.

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1. Introduction

The Copenhagen Accords[1], while non-binding, sets out the foundation of a framework for the unilateral actions of all the parties relating to mitigation and adaptation related activities. Do such unilateral measures provide an adequate foundation for global climate change negotiations from a post-Copenhagen perspective?

This paper studies the interplay between unilateral measures and multilateral negotiation in relation to global climate change mitigation from a post-Copenhagen perspective. We, first, document the extent and variety of existing unilateral measures and in a model of global learning, examine the conditions under which global negotiations, building on the positive spillovers generated by such unilateral initiatives result in cumulative emissions cuts over time. Based on our results, we develop a policy proposal that addresses the obstacles if further global negotiations, building on the Copenhagen Accords, have the potential to achieve the goal of a 2°C cap on temperature rise[2].

We note that participation and compliance in a broad-based multilateral initiative that aims to go further than what individual countries are unilaterally willing to commit may be hard to achieve. Any broad based global cooperation that requires nations to commit to emission cuts beyond what nations are unilaterally willing to undertake is unlikely to be stable (i.e. immune to deviations by a nation or a coalition of nations). By delaying participation or by not complying with a global agreement to cut emissions, a deviating country or a coalition of such 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): free riding in the presence of negative externalities limits the scope of multilateral cooperation in the presence of weak property rights (Shapley and Shubik (1969) and Starrett (1973) were among the first to make this point).

Although multilateral cooperation has been a hard to achieve, a number of unilateral initiatives are already underway to cut emissions. We begin by documenting the extent, form and variety, some at a national level but mainly at a subnational (regional/urban/individual) level, of existing unilateral measures. Examples of such unilateral measures include community based programs such as free bicycle plans, such as in Copenhagen, Denmark, or watershed renewal programmes, such as in rural communi-

[1] The text that came out of the Copenhagen meeting hosted by the United Nations Framework Convention on Climate Change (UNFCCC) in December 2009 is referred to as the Coppenhagen Accords.

[2] As set out in the reports of the IPCC. A more ambitious target 1.5°C cap has been recently suggested by the low-lying island states in Copenhagen.

ties bordering major rain forests as in Mexico. As such unilateral measures consist of a mix of local adaptation together with increasing capacity in renewables and the reduction of energy consumption either directly and indirectly (via energy saving techniques, infrastructure renewal and increased efficiency).

If a city introduces a raft of measures to induce more use of public transport and some of these measures are successful[3], 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 economic actors in other countries and not just within the borders of the country where the innovation takes place.

Switching to low carbon activities requires the spread of low carbon technologies[4] primarily in energy, infrastructure, transport and industry and effective innovation in these technologies in one nation or region will generate positive transnational externalities (Human Development Report (2008)).

A case in point is the argument 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 a real incentive for the development of substitutes to CFCs (Benedick (1998)). Thus, although there is a difference in scale, the events surrounding Montreal Protocol may be taken as a precedent for the potential of such a mechanism.

The point is unilateral commitments induce innovation, by creating a market for such innovations, in technologies that could lower the cost of switching to low carbon economic activities across different locations[5].

The positive spillovers generated by such unilateral initiatives, we argue, can be the starting point for a new global policy initiative that enables a process of global learning, both within and across countries, that delivers ever deepening emissions cuts over time. We build a formal model where we analyze the conditions under which learning results in global adoption of low carbon technology in finite 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 evolving over strongly connected nations will results in all countries switching to low emissions in finite time.

Drawing on the results of the model, we discuss how policy design could affect global learning by impacting both the structure of interaction between countries and ensure

[3]It is worth noting that even failure can generate useful information.

[4]Technology is defined broadly here to include not only process and physical tech innovations but also the associated behavioral/ cultural changes that go along with those innovations

[5]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.

integrated convergence to a global low emissions regime. Our results suggest that key features a successful policy that builds on unilateral initiatives via global learning will have to include developing a platform for exchange of information and subsidized monitoring, strengthening spillovers across subnational actors in different countries and a new global IP regime involving subsidized, targeted technology[6] transfer of low carbon activities.

We critically examine a specific policy document presented by the G77 and China in Copenhagen under paragraph 11 of the Copenhagen Accords which also addresses similar issues. This proposal sets out a fast-track process for the diffusion of relevant technologies to either high emissions areas or those places were adaptation is already becoming a critical concern. Building on our results, in section 4 below, we critically examine this proposal.

The remainder of the paper is structured as follows. Section 2 documents the variety and extent of existing unilateral measures; section 3 sets out the model under which global learning, building on existing unilateral measures, leads to a low emissions global paradigm; section 4 discusses how aspects of this model could be usefully applied to the post-Copenhagen process going forward, 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 worldwide towards climate change. In tandem with ongoing global negotiations, 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 other entities will match. Similar initiatives can be found in the case of China, where there are extensive commitments to a 20% energy consumption reduction relative to 2005 by 2020, a 45% reduction in carbon emissions relative to GDP by 2020 and also a similar 20% commitment to renewable energy. These forms of commitments, interestingly, also seem to involve deeper commitments by smaller

[6]Technology is defined broadly here to include not only process and physical tech innovations but also the associated behavioral/ cultural changes that go along with those innovations

countries. One striking case is Norway, which has committed itself to become a zero carbon economy by 2050.

These unilateral examples are national but, on the face of it, go substantially beyond what countries are seemingly jointly willing to commit to multilaterally; and beyond the national 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. 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, as in Copenhagen, Denmark, or watershed renewal programmes, as in rural communities bordering major rain forests as in Mexico, and community information monitoring schemes as in sophisticated software which tracks carbon from individual houses based on lifestyle and energy use (the idea being that increased knowledge will change people's behaviour). Commitments are also made at a business level, with new businesses offering what is needed for other businesses, communities and individuals to "go green"[7]. 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

In practice, national unilateral measures seemingly almost inevitably interact with multilateral negotiations. This is quite evident in the recent Copenhagen Accord document, which relies quite heavily on unilateralism to achieve any sort of emissions reduction. Many countries developed/ announced unilateral measures in the lead up to Copenhagen and, while such commitments could be interpreted as a way of simply staking out bargaining positions, the argument we put forward is that, by including them in the Accord, it increasingly causes the Accord to become a viable basis for an effective global climate change adaptation/ mitigation framework. A matter of particular interest, which we will come back to in the next section, is the question of whether, by committing to specific

[7] Recent estimates set the "green" industry worldwide at roughly 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.

unilateral measures in the Accord, such nations positively alter the incentives of other nations to commit to new or more stringent measures – in essence causing a snowballing race to zero carbon on a wide scale. But, for now, we examine the breadth and scope of such unilateralism that currently exists.

In addition to the examples of unilateral action already mentioned, 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. Similarly, New Zealand has developed a major reliance on thermal power.

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[8]. 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 currently known 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 will only put off the climate crisis, not solve it.

In the developing world, China has adopted a 45-20-20 plan to reduce emissions intensity per unit of GDP by 45%, as well as achieving 20% renewable energy use, both by 2020. A significant step towards this is the phasing out of older inefficient coal plants, as well as an accompanying planned 20% improvement in energy efficiency by 2020. 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.

Similarly in the US, the focus is on the Waxman-Markey Bill, which sets out a 17% emissions reduction relative to 2005 by 2020 and an 83% one by 2050 through an emissions trading system and numerous related R&D, public awareness and institution creating

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

projects. More recently, the Senate version of this, the Kerry-Boxer Bill, sets out goals of a 20% and 83% reduction respectively for these dates, although it enjoys much less support.

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 environmental measures are implemented. In Brazil, there is a plan dubbed the PROINFA plan, which aims to provide 10% of Brazil's production and consumption of energy by 2022 through renewables. Also there is Ecuador's 2007 Yatsuni-ITT proposal, which seeks to preserve rainforest despite the oil below and to slowly wean Ecuador off 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 carbon, 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[9]. 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[10]. 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[11] 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 that cannot be explained by short-run self-interest is likely to be limited in duration should climate change worsen and as more specific climate 'damage' occurs.

This sampling of national unilateral initiatives is summarized in table 1.

(TABLE 1 HERE).

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

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

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

2.2. Unilateral Measures by Territories, States and Provinces

Unilateral measures are also evident at the subnational level. At the state and interstate 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 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.

Even in China and India, where provinces, by and large, walk in step with the mandates passed down from the federal level, some regional initiatives already exists (such as solar power and bio fuel projects in Karnataka[12]). One striking case is within Brazil where,

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

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'[13]. In Russia on the other hand, perhaps due to the fact that it trivially met its Kyoto targets, provincial unilateralism is muted and mostly limited to data and information gathering[14].

Tables 2 and 3 summarize the unilateral initiatives discussed above.

(TABLE 2 here.)

(TABLE 3 here.)

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. 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[15]. 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 floods increases and is also intensely focused in 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

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

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

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

and also has a goal for decreasing the volume of vehicles on the roads by 65%.[16] 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[17].

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.

Table 4 summarizes the various city-level unilateral initiatives discussed here.

(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[18]. 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%.

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

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

[18] 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

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[19]. While such 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[20].

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[21]. 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[22].

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[19] 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

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

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

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

Business involvement in emissions mitigation also partly reflects the perceived profitability of going 'green'. For example, in Dubai, a company called Dynamic Architecture[23] 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[24].

Similar businesses are growing on a global scale and a large subsection of them, mostly from developed countries, attend the annual 'Clean Equity'[25] 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[26] 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)[27]; 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.

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

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

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

[26] 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/

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

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 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[28]. 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. Perhaps one of the most effective 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 contacted by a lead author of the Stern Review. His stated

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

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. Unilateral Measures and Global Learning

In this section, we examine the conditions under which global learning, building on the positive spillovers generated by unilateral actions, delivers ever deepening emission cuts over time and convergence to a low carbon world in finite time.

Rationale for unilateral measures:

A number of the examples discussed in the preceding section make the point that it could actually be in the self-interest[29] of relevant economic actors to undertake unilateral measures that also result lower emissions. Nevertheless, the diversity of unilateral initiatives reflects a underlying heterogeneity of interests, beliefs, motivation at the level of countries, regions and groups.

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[30]. A different possibility is that the agent who cuts emissions obtains a "warm glow" as discussed in the literature on philanthropy (see, for example, Andreoni, 2006) from the act of cutting emissions.

Straightforwardly, an economic agent will unilaterally cut emissions if the private benefit from "going green" is greater than the cost of cutting emissions. Importantly, the cost of cutting emissions could limit, at any one point of time, the size of the group of individuals, within a given population, who would be willing to unilaterally undertake costly emissions cuts. Although a national level commitment to emission cuts may not emerge as the outcome of majority voting, unilateral measures may then exist at various

[29] Examples of which include adaptation to the local impacts of climate change, ensuring energy security, halting the process of desertification, local development needs.

[30] A related 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 group can be rationalized if each individual in that group finds its optimal to cut emissions given that all individuals in that group conform to the rule of cutting emissions

subnational levels.

A formal model of unilateral measures, global learning and cumulative emission cuts

Formally, we consider a model with discrete time intervals which go from $t = 1, 2, ...$ There are $n = 1, ..., N$ countries. Each country consists of a number of individual entities of mass $m_n > 0$[31]and the total mass across countries is $M = \sum_i m_i$. At t, $e^t_{n,j} \in \{0, 1\}$ denotes the emissions of greenhouse gases by individual j belonging to country n so that at any $t, e^t_{n,j} = 0$ corresponds to adopting low carbon activities while $e^t_{n,j} = 1$ corresponds to persisting with a high carbon activities. Let $e^t_n = \int_j^{m_i} e^t_{n,j} dj$ denote the total emissions of country n in period t. Let $E^t = \sum_i e^t_n$ denote the total emissions at time t.

Let a fraction γ^t_n (respectively, $1 - \gamma^t_n$) of individuals j in country n have preferences an 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 assume that in each country n 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 n will commit to cut emissions to zero in period t (and in all subsequent periods) iff $\gamma^t_n \geq \frac{1}{2}$. Otherwise, the emissions level in country n at t is given by $e^t_n = (1 - \gamma^t_m)m_n$.

We will assume that $\gamma^0_n = \gamma_n < \frac{1}{2}$ so that no country is willing to commit to emission cuts as part of a multilateral agreement.

We model the preferences and behavior of individuals within a country as follows. Assume that individual j in country n obtains a private benefit $b_j \in [0, B]$, $B > 0$ with individuals within a country uniformly distributed on the interval $[0, B]$. Consistent with our earlier discussion, we interpret this private benefit to the individual from cutting emissions as derived from either group membership or a "warm glow" or just the direct benefit from successful local adaptation. Let $c_n \left(\sum_{n'} \rho_{n,n'} \gamma^{t-1}_{n'}\right)$ denote the cost of cutting emissions to individual located in country n given that a proportion $\gamma^{t-1}_{n'}$, $n' = 1, 2, ..., n$ of individuals in all countries have already cut emissions at $t - 1$ and $\rho_{n,n'}$, $0 \leq \rho_{n,n'} \leq 1$, captures the spillover from country n' to country n, with $\rho_{n,n} = 1$.

We assume that $c_n(.)$ is strictly decreasing function so that a unilateral commitment

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

by a group of individuals within country n at each t to cut emissions in any time period stimulates innovative activity that lowers, over time, the relative cost[32] of adopting low carbon activities for other individuals both within country n and across all other countries $n' \neq n$.

We justify this key assumption in our model as follows. By undertaking unilateral measures economic actors demonstrate not only the feasibility of collective action and their awareness of the potential threats to other actors but also lower the cost of cutting emissions for all other actors as well. 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 the OECD, Europe and 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 technology standards in these key sectors will have a significant potential impact on overall emissions not only within these countries but also in other countries.

The spillover effects across countries, for any one country n, is captured by the term $\sum_{n'} \rho_{n,n'} \gamma_{n'}^{t-1}$. Specifically, both the sign i.e. whether or not $\rho_{n,n'} > 0$ and the magnitude of $\rho_{n,n'}$ for a pair of countries n, n' will be a consequence of the use of appropriate policy mechanisms that build on positive technological spillover across countries. Such a policy will be designed to 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. Subsidized targeted technology transfer may be essential to alter the participation constraints of nations over time. This will be the focus of the discussion on policy in the following section.

Let $g_n^t = \left\{ j : b_j - c_n \left(\sum_{n'} \rho_{n,n'} \gamma_{n'}^{t-1} \right) \geq 0 \right\}$ denote the group of individuals for whom it becomes a dominant action to cut emissions at time t within a nation n. Define the

[32] 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.

function

$$G_n\left(\sum_j \rho_{i,j}\gamma_j^{t-1}\right) = \mu\left(\left\{j : b_j - c_n\left(\sum_{n'} \rho_{n,n'}\gamma_{n'}^{t-1}\right) \geq 0\right\}\right)$$

where $\mu(.)$ is the Lebesgue measure. Thus, $G_n(.)$ denotes the proportion of individuals in country n for whom it becomes a dominant action to cut emissions at t.

We will assume that $G_n(x) = 1$ for all $x \geq 1$. This is equivalent to requiring that $c_n(x) = 0$ for all $x \geq 1$ a strong assumption that will simplify the statement of the main result. In effect we are assuming 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). After the statement and proof of the main result below, we will show how our result is robust to this assumption.

Finally, we assume that underlying preferences (which we do not explicitly specify) are such that it is globally efficient to set $e_n^t = 0$ for all n, t. 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 high emission activities.

The evolution of γ_n^t within each country n over time is described, for $t \geq 2$, by the system of difference equations :

$$\gamma_n^t = \min\left\{\gamma_n^{t-1} + \lambda_n\left(G_n\left(\sum_{n'} \rho_{n,n'}\gamma_{n'}^{t-1}\right) - \gamma_n^{t-1}\right), 1\right\}, \; n = 1, ..., N, \quad (1)$$

where λ_n, $0 < \lambda_n \leq 1$, is a measure of inertia in learning within country n: not all individuals within country n who benefit from switching actually do so- this could be due to variety of factors such as habit formation, lack of awareness and information etc. 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 n.

We assume that the map $G = \{G_n : n = 1, ..., N\}$, $G : [0, N]^N \to [0, N]^N$, is continuous and increasing on $[0, 1]^N$: learning within and across countries is complementary.

Will each country eventually be in a position to commit to cut emissions? We say that country n is connected to country n' if $\rho_{n,n'} > 0$. Define a directed graph over N where the vertices are individuals and an arc (n, n') exists iff n is connected to n'. 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 (n, n') there exists a path connecting n to n'. 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 $\rho_{n,n'} > 0$ for all $n \neq n'$ (the complete graph) so that no one country is pivotal in driving the global learning process. A different strongly connected scenario is one where $\rho_{n,1} > 0$, $\rho_{1,n} > 0$ but $\rho_{n,n'} = 0$ for $n \neq n'$ whenever $n' \neq 1$ (the star graph). In the latter case, country 1 (like the US) is pivotal in the global learning process as any connection between two other countries must go through country 1. Other possibilities include scenarios where a group of countries (e.g. US, countries within the EU, the BRICs) are pivotal in ensuring that the countries are globally strongly connected.

More generally, when countries are globally strongly connected, between any two countries n, n', there is a chain of countries $n_0 = n, ..., n_S = n'$ with $\rho_{n_s,n_{s-1}} > 0$, $s = 1, ..., S$.

The following proposition states the conditions under which global learning, building on unilateral actions within some country, delivers a switch to low emissions in finite time:

Global Learning Result: *Suppose learning within each country is described by the map (1), countries are globally strongly connected and $\gamma_n > 0$ for some country n. Then, there exists $\hat{t}_n$, decreasing in λ_n, $\rho_{n,n'}$, $n, n' = 1, ..., N$, such that country n will commit to cut emissions for all $t \geq \hat{t}_n$, with $e_n^t = (1 - \gamma_n^t)m_n$ for all $t < \hat{t}_n$. A stable global agreement to cut emissions will emerge at $\hat{t} = \max_i \hat{t}_n$.*

Proof. Suppose the set of countries is globally strongly connected with $\gamma_n > 0$ for some country n. Consider the map $G = \{G_n : n = 1, ..., N\}$ where $G : [0, n]^N \to [0, n]^N$. Note that by construction $G_n(x) = 1$ for all $x \geq 1$, $n = 1, ..., N$. Therefore, the vector $(1, ..., 1)$ is always a fixed-point of G.

Note that $G_n\left(\sum_{n'} \rho_{n,n'}\gamma_n\right) > \gamma_n$ whenever $0 < \gamma_{n'} < 1$ for some $n' \neq n$ with $\rho_{n,n'} > 0$. Whenever $\gamma_{n'}^t > 0$, for some country n' at some t, as there is a path connecting each country n to country n', $n' \neq n$, there exists $t' \geq t$ such that $G_n\left(\sum_{n''} \rho_{nn''}\gamma_{n''}^{t'-1}\right) > \gamma_n^{t'-1} \geq 0$: $t = t'$ if $\gamma_n^t > 0$ and $\rho_{nn'} > 0$, otherwise $t' > t$, $t' \leq t + s$ where s is the minimum number of vertices (the minimum taken across all the paths connecting n to n') between n and n'.

As $\gamma_n > 0$ for some country n, 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 n $\sup_t \gamma_n^t = 1$ and as $\{\gamma^t : t \geq 1\}$ is a component-wise increasing sequence, $lim_{t\to\infty}\gamma_n^t = 1$ for all $n = 1, ..., N$.

Let $\hat{t}_n = \inf\left\{t : \gamma_n^t \geq \frac{1}{2}\right\}$. Therefore, for all $t \geq \hat{t}_n$, $\gamma_n^{\hat{t}_n} \geq \frac{1}{2}$ and a stable global agreement to cut emissions will emerge at $\hat{t} = \max_n \hat{t}_n$. As the RHS of (1) is increasing in λ_n, $\rho_{n,n'}$, $n, n' \in N$, for each country n, $\hat{t}_n$ is decreasing in λ_n, $\rho_{n,n'}$ $n, n' \in N$. ■

The above result implies that as long as there are some (however weak) spillover effects in learning across countries n so that all countries are globally strongly connected, eventually a majority of voters in each country n will vote to commit to cut emissions.

Some remarks:

1. In the proof of the preceding proposition, we assumed 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). It is straightforward to note that nothing essential in the preceding proof requires the G to be increasing over the whole of $[0,1]$. What is essential for the argument is that any fixed-point of G is greater than (in the usual vector ordering) the vector $\left[\frac{1}{2},...,\frac{1}{2}\right]$ which requires that G is increasing on $\left[0,\frac{1}{2}\right]^N$ so that negative influences dominate positive influences when a sufficiently large fraction of individuals within each country have already switched to cutting emissions.

2. While 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 $\lambda_n = 1$ and $\sum_n \gamma_n \geq \frac{1}{2}$: if $\rho_{nn'} = 1$ for all countries n, n', then $\gamma_n^t \geq \frac{1}{2}$ for all n for each $t \geq 2$. This is clearly a best-case scenario, one where convergence is immediate: $\hat{t} = \hat{t}_n = 2$. More generally, as for each country n, $\hat{t}_n$ is decreasing in λ_n, $\rho_{n,n'}$, $n, n' = 1,...,N$, policy interventions that increase the values of these variables (i.e. reduce learning inertia within a country and strengthen spillover effects across countries) will increase the rate at which there is global convergence to a low emissions regime, and even if these cannot be influenced on a national level due to economic or political realities, it may still be possible to alter policy at a subnational level in some instances.

3. Implicit in our formulation is the assumption that individuals within a country behave myopically. If, on the other hand, individuals in a country anticipate that unilateral actions lower the cost of switching to low emission activities for individuals in other countries, even if it isn't in the direct short-term interests of certain actors to cut emissions, by anticipating that such activities will generate a similar response from others, such actors may undertake unilateral measures[33] thus speeding up the process of convergence to a global low carbon regime. Economic actors in countries that (a) create the largest spillover effects, either directly or indirectly, on global learning, (b) are pivotal

[33] A simillar result has been obtained in a model of farsighted network formation in Dutta, Ghosal and Ray (2005). Chatterji and Ghosal (2009) also make a simillar assumption in the context of a discussion on climate change.

(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 spillover in learning across countries. For example, if $\lambda_n = 1$, $\rho_{nn'} = 1$ for all countries n, n', voters in country n could choose to cut emissions to zero (so that $\gamma_n^1 = 1$) anticipating that $\gamma_{n'}^t \geq \frac{1}{2}$ for all $n' \neq n$, $t \geq 2$.

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 $\rho_{nn'} = 0$ for all $n \neq n'$: in this there are no cross-country spillovers and each country is isolated. In this case, all learning takes place within a single country and the evolution of γ_n^t within each country n over time is described, for $t \geq 2$, by the equation:

$$\gamma_n^t = \min\left\{\gamma_n^{t-1} + \lambda_n\left(F_n\left(\gamma_n^{t-1}\right) - \gamma_n^{t-1}\right), 1\right\} \;\; n = 1, ..., N \qquad (2)$$

where $F_n(.) = G_n(.)$ 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 n 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 $\gamma_n^* = \min\{\gamma \in [0, 1] : F_n(\gamma) = \gamma\}$ is smallest fixed point of the map $F_n : [0, 1] \to [0, 1]$. γ_n^* is well-defined as 1 is always a fixed point of $F_n(.)$ and the set of fixed-points of $F_n(.)$ is closed subset of a compact set and hence, compact. Let $\{\gamma_n^t; t \geq 1\}$ denote the sequence generated by an iterated application of the RHS of (2) with $\gamma_n^0 = \gamma_n \geq 0$ and $\gamma_n^* \geq \gamma_n > 0$. Clearly, if $\gamma_n = 0$, country n never moves away from 0. If $\gamma_n > 0$, then by continuity of $F_n(.)$, $\sup_t \gamma_n^t = \gamma_n^*$ and as $\{\gamma_n^t; t \geq 1\}$ is an increasing sequence, $lim_{t\to\infty}\gamma_n^t = \gamma_n^*$. Therefore, as long as $\gamma_n^* < \frac{1}{2}$ learning within country n will never result in country n, as a whole, switching to low emissions.

More generally, it is straightforward to construct examples where $lim_{t\to\infty}\gamma_n^t < \frac{1}{2}$ for most countries when countries aren't globally connected. Suppose $0 < \gamma_1 < \frac{1}{2}$, $\gamma_n = \rho_{n1} = 0$, $n \neq 1$. Then, no country other than country 1 moves away from 0 as country 1 is isolated (i.e. not linked to any other country) and this is the only country where unilateral actions are being undertaken. Clearly, other less extreme examples, along the above lines, can be constructed.

In conclusion, our formal analysis has shown 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.*

In the following section, we will use these results to develop a policy proposal that explicitly accounts for the possibility that global learning, by building on unilateral measures, could, in principle, deliver a switch to a low carbon world.

4. Global learning, the role of technology and IP, and the road to a low carbon paradigm

In this section, we use the results of the model developed in the preceding section to discuss key features of a global policy regime that ensures cross-country convergence to a low emissions regime by effectively building on the positive externalities inherent in the unilateral initiatives.

In practice, national unilateral measures almost inevitably interact with multilateral negotiations. This is quite evident in the recent Copenhagen Accord document, which relies quite heavily on unilateralism to achieve any sort of emissions reduction. Many countries announced unilateral measures in the lead up to Copenhagen and, while such commitments could be interpreted as a way of simply staking out bargaining positions, the argument we put forward is that, by including them in the Accord, it increasingly causes the Accord to become a viable basis for an effective global climate change adaptation/mitigation framework. By committing to specific unilateral measures in the Accord, how can such nations positively alter the incentives of other nations to commit to new measures – in essence causing a snowballing race to zero carbon on a wide scale?

To begin with, there is the issue of who the participants in global negotiations should be. Given that subnational groups are more likely to have the autonomy to commit resources in initiating unilateral measures, an open question, therefore, is whether subnational groups, such as provinces, states, or territories, who can exercise such autonomy in otherwise non-participating nations could be allowed to include their commitments directly in a global agreement post-Copenhagen.

Central to the model and the Accords is the idea of a global learning process, in which technology and innovation figure prominently. An alteration to the way technology transfer works on a global scale has already been proposed under paragraph 11 of the Copenhagen Accords. This proposal, which was presented by the G77 and China in Copenhagen, sets out a fast-track process for the diffusion of relevant technologies to either high emissions areas or those places were adaptation is already becoming a critical concern. As set out currently, this to be governed by an Executive Body on Technology which will operate under the authority of the COP and operate using a new fund called the Multilateral Climate Technology Fund, largely financed by Annex II countries but supplemented by Annex I contributions, with the incentive being that contributions to the Fund would count towards a country's Bali Roadmap responsibilities[34]. The proposal also sets out to accelerate the rate at which research and development on such technologies is conducted and to finance it through venture capital and aid in rapid commercialization and diffusion whereupon, presumably, a portion of the funds devoted to the innovation would be recovered back into the multilateral pool. There is an inherent selection bias in this, since the Executive Body is selecting the innovations to go forward to commercialization, but this might be possibly minimized by the makeup of this group and the oversight of COP.

In what follows, we examine key elements of this proposal in greater detail.

While the basic framework of this proposal is already present, there is little discussion so far of verifiability aside from the fact that the Executive Body would examine each case. A key issue that may arise is one that previously arose with the Clean Development Mechanism (CDM) under the Kyoto Protocol, that is the issue of how to ensure "additionality". In practice, this has been hard to verify. For example, firms would 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)). And so, missing in this proposal thus far is the issue of what sort of conditions should be attached to these payments to ensure "additionality". In the case of carbon mitigation technologies these conditions could be in the same terms as are commonly being made by nation states. That is, in terms of time bound carbon emission or carbon intensity targets, and this could be particularly useful in key sectors such as energy, infrastructure, transport and heavy industry.

Also, a conspicuously missing element of the proposal is how, exactly, it would interact with the currently existing intellectual property rights regime. What could be involved is a new global IP regime characterized by governments in countries developing publicly funded new technology that involves users in other countries at the development stage, paying a part (or whole) of the royalties paid by users in other countries for privately funded technology, joint ventures between relevant actors (either in the private and/or public sector) across national boundaries and lowering the cost of local use (and adap-

[34] A key advantage of this is that the amount of funding provided is not dependent on the price of carbon, allowing the flow of funds to be much more stable than otherwise.

tation) of proprietary technologies by designing an appropriate international licensing system.

In order to qualify for funding in the proposed global IP regime countries would have to adopt specific commitments i.e. specific time-bound quantity targets like initially lowering carbon intensity followed by emission cuts, the adoption of low carbon technology (carbon capture and storage, solar and wind energy etc.) in important sectors such as energy, infrastructure, transport and industry. The funding of individual projects within a qualifying country could decentralized so that royalties paid by users for privately funded technology originating elsewhere are refunded and the cost of local use (and adaptation) of such proprietary technologies subsidized. A portion of the funding could 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 would be essential to the successful operation of such a global innovation and technology transfer fund.

The details of this relation will be critical in determining the effectiveness of this proposal as, at present, innovations of the type needed particularly in the key sectors mentioned above typically have to go through years, and sometimes decades, of testing and red tape before they can become commercially available. If this generally remains the case under the proposed Technology Mechanism, then its effectiveness towards mitigating carbon and other emissions in a timely manner will be questionable, and to a lesser extent, this is also true of technologies related more towards adaptation. This process of testing and red tape, along with issues of adaptive capacity in countries that technologies diffuse to, is one of the main issues that raised the need for a fast-track diffusion process in the first place.

While not included in the proposal as it stands, the strength of the links (positive spillovers) between countries in this process would be very important in almost every aspect. For example, the US and the EU would be 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 would be important because of the size of their populations and potential for emissions mitigation. For example, existing "clean coal" power plants and carbon capture technologies can be developed and further refined in the US and EU with a subsequent transfer to China under the mechanism proposed where it would have a significant impact on cutting emissions. Other links may reflect structural similarities, land use patterns, existing patterns of carbon consumption, etc. Such a structure, if included in the current proposal, would aid in the efficient distribution of funds by allowing them to be distributed according to characteristics such as the degree of spillover by type of technology and by targeting countries that have the greatest potential to generate spillover effects[35]. Such a policy regime would involve platforms where information relating to unilateral initiatives can be exchanged and is likely to involve subsidized monitoring.

Identifying, quantifying and calculating such spillovers will be key to the success of the proposed mechanism and could feasibly fit into the mandate of the Strategic Planning Committee within the proposed Executive Body on Technology. This will be essential, as encouraging the type of technologies needed in generating positive spillovers on these across countries are both likely to be costly and trade-offs may become necessary.

In general, measures that reduce emissions inertia within a country and measures that strengthen the positive spillover effects across countries are both likely to be costly. With resource constraints, there is likely to be a trade-off between the two such as subsidizing measures that improve the energy efficiency of domestic households or subsidizing 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 within a country.

A further minor complication, as stated previously, is the fact that the COP has not officially adopted this proposal. The phraseology within it assumes that the Mechanism will answer to the authority of the COP, and as stated in the introduction, the way things played out in Copenhagen suggests that it may be possible to move this process forward more effectively and efficiently through a body other than the COP and the UNFCCC such as the G20 or even just the US and the BASICs. Depending on the way things play out the structure of the proposal may have to be changed to reflect this.

But despite these complications the proposal has the potential, if the spillovers we mention can be created in sufficient strength, to speed the convergence to a global low carbon regime significantly, particularly if the largest global actors in the climate change issue indicate a willingness to become involved.

The process described here may take time to play out so that the emission cuts required to stabilize global temperatures may not be delivered quickly. We envisage a process of technology diffusion that involves chains of innovations 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

[35]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.

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 innovation and subsequent transfer of new technologies is essential, emissions reduction may 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 could be persuaded to insulate their houses or install solar panels by a combination of subsidies (or low cost loans), and by the extension of carbon markets to individual households and small firms/businesses. As already argued, subsidized 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 globally) would require a new global IP regime.

If cross-country spillovers occur on the level this proposal would need in order to be considered a success, and almost inevitable question arises of what this would do to trade flows. If this Mechanism is to be a central feature of global climate change adaptation and mitigation efforts the implication is for a further rise in globalization and, to a limited extent, some integration between the trade and climate change spheres. This would have a number of benefits, not the least of which is giving the private sector incentive to be active on the climate change issue through the proliferation of innovations necessary for a global low carbon paradigm.

It also suggests an eventual enforcement mechanism in the form of trade sanctions or increased protectionism (or even the threat of such) against free riders or those who refuse to participate. 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 talks on carbon based border adjustments to address issues of leakage.

Finally, note that to achieve the goal of ensuring that the pace of innovation in low carbon technologies is rapid, such a policy would have to be supplemented by other measures. 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 the first place.

5. Concluding remarks

In this paper we discuss both the size and extent of the unilateral commitments to reduce carbon emissions which are being taken in countries around the world and their potential for inclusion in the emerging Copenhagen Accord process. The advantage to this over previous attempts at a multilateral climate change agreement is, of course, that if multilateral commitments are to be largely met through unilateral processes (particularly ones already underway or planned), then commitments taken on by negotiators involve little additional cost. But more broadly the question is whether unilateral measures can act as an effective engine for reduction in carbon emissions and achieve the goal of limiting temperature rise to 2°C. Ultimately, this will depend on unilateral measures' relative effectiveness, their number, and their ability to create the synergies necessary to reduce the cost for other economies globally to follow suit and switch to low carbon via process of global learning. For such a process to be successful, the post- Copenhagen process going forward should attempt to build on both national and subnational efforts to promote the development and spread of effective unilateral action and encourage implementation of policy that strengthens the spillovers of such actions across nations, which is key to the social learning process we have previously described in the model. Absolutely key for this process will be changes to the effective international intellectual property rights regime of the sort described in paragraph 11 of the Accord. A less restrictive regime is critical for allowing spillovers across nations to take place on a timescale, according to the current science, that would be meaningful for dealing with climate change. Thus contrary to the popular view of the Copenhagen Accord being empty and a papered over agreement, in the context of the model described here, the Accord has the potential to become a solid foundation for an effective post-Kyoto global climate change regime. Whether that potential will be realized remains to be seen.

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Table 1: Country-wide 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: Interstate 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: Individual State 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: City-Level 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