Carbon Tax vs. Cap-and-Trade: Implications on Developing Countries Emissions

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Abstract

Although world leaders did not come to any agreement in Copenhagen in setting CO_2 reduction targets for individual countries or for major emitters, the leaders did agree that inaction would lead to irreversible consequences and that there must be substantial cuts in carbon emissions. However, any mechanism for achieving such reductions should not hamper economic progress in the developing world. A key issue therefore is to find a way to engage developing countries under any emerging agreement that also ensures full participation of developed countries in climate change mitigation. This paper investigates the roles of carbon tax and cap-and trade policies to mitigate global CO_2 emissions, particularly focussing on reduction from developing countries. Long-run global energy scenarios are developed under tax and cap-and-trade policies. These policies are analysed using the 16 Region TIAM-UCL global model. This paper provides new insights into the role of developing countries under different mitigation mechanisms using a global model. In general, it is assumed that only developed countries buy emission credits from developing countries under cap-and-trade policies. Findings show that when the CO_2 mitigation target is widened, in order to meet the 450ppm atmospheric CO_2 only concentration target, it is globally cost optimal for some developing countries to buy credits in the long-term while some developed countries may sell credits depending on reduction targets.

Introduction

There are three ways for pricing carbon in order to reduce CO_2 emissions (Stern, 2008): first, carbon taxation (tax); second, carbon trading on the basis of trade in rights to emit which are allocated or auctioned (cap-and-trade); and third, implicit pricing via regulations and standards, which impose constraints on technologies that can be necessary where irremovable or unavoidable market imperfections exist. As this modelling exercise focuses on global CO_2 reduction, and regulation is in general implemented on a national level, this paper limits the discussion to the first two approaches: tax and cap-and-trade. The question of choosing between tax or cap-and-trade in order to address climate change (which system works better internationally) is an interesting one and has generated much discussion with impassioned advocates on both sides.

Stern (2008) states that taxes have the advantage of being implementable by individual governments without international agreement, but, environmental taxes have dead-weight losses (in actual reduction) in addition to their beneficial effects in addressing externalities. Establishing a price for GHGs through cap-and-trade has the advantage of providing greater certainty about quantities of emissions reduced than taxes (although this depends on allocation method). In theory, it allows for the creation of a market that provides the flexibility necessary to achieve the climate change mitigation target at the lowest cost.

The European Union Emissions Trading Scheme (EU-ETS) has shown that most large emitting sectors of the economy can be covered (currently around one half of European emissions) with relatively low administrative burdens by focusing on major emitting sources, such as power generation and industry. However, there have been some difficulties in achieving the projected reductions due to price being undermined by over-allocation and a major economic downturn.

Nordhaus (2009) says that "raising the price of carbon (by taxation) is a necessary condition for implementing carbon policies in a way that will reach the multitude of decision makers over space, time, nations, and sectors". Raising the market price of carbon provides strong incentives to reduce carbon emissions through four mechanisms:

- it provides signals to consumers about what goods and services produce high carbon emissions and should therefore be used more sparingly.
- it provides signals to producers about which inputs (such as electricity from coal) emit more carbon, and which inputs (such as electricity from wind) emit less or none. It thereby induces producers to move to low-carbon technologies.
- high carbon prices provide market signals and financial incentives to inventors and innovators to develop and introduce low-carbon products and processes, which can eventually replace the current generation of carbon-intensive technologies.
- most subtle of all, the use of carbon pricing economises on the information requirements that market participants need to undertake each of these three tasks.

Current international agreements differentiate between countries in their responsibilities to reduce emissions. Under the Kyoto Protocol, Annex I countries must limit their emissions, while non-Annex I countries have a variety of non-binding commitments as well as the ability to participate in the “clean development mechanism”. Nordhaus (2009) states that the Kyoto Protocol as currently designed is both inefficient and ineffective and should be supplemented or replaced (by tax approach), while Stern (2008) states that an aspect of quotas and trading (under the Kyoto Protocol) that is crucial is their potential role in international efficiency and collaboration.

Two questions can be identified from the literature that discusses tax and cap-and-trade policies: 1) which policy can be implemented effectively at the global level (and at low cost)?, and 2) which option can bring the developing countries into the system (increase their participation)? This paper analyses the possible emission reductions from and costs to developing countries under a quantity-based trade system and a price-based tax system.

It is commonly agreed that developed countries cannot reduce carbon emission enough to stabilise GHG concentrations to a level where the risk of global temperature exceeding 2C is minimised. Any solution needs the participation of developing countries, especially China and India. Their participation hopefully means greater availability of cost-effective mitigation as developing countries also have cheaper carbon abatement opportunities than developed countries as their energy infrastructure is being developed. However, participation of countries who are rapidly developing requires financial incentives so that any action does not compromise much needed economic growth.

Model

The new 16 region TIAM-UCL global model (Anandarajah et al. 2010) has been developed under the UK Energy Research Centre (UKERC) Phase II project. It is based on the 15 region TIMES integrated assessment model (ETSAP-TIAM), which was developed and is maintained by the Energy Technology Systems Analysis Programme (ETSAP), but has the United Kingdom (UK) 'broken out' from the Western Europe Region.

ETSAP-TIAM is a global multiregional implementation of the TIMES (The Integrated Markal Efom System) model generator (Loulou and Labriet, 2007 and Loulou et al., 2009). It is a least cost, technology rich bottom–up model having an objective that minimises the total discounted system cost. The main building blocks of a TIMES model are the processes and commodities, which are connected by commodity flows in a network representation called a Reference Energy System (RES). The dynamic part of a model is determined by the time horizon and resolution, the evolutionary development of energy supply and technologies, the growth of the demand for energy services, and policies (e.g., mitigation targets, renewable portfolio standards), complimented by various alternate scenarios. The 15 region ESTAP-TIAM model has been applied in various studies to analyse climate change and energy policy such as Syri et al. (2008); Loulou et al. (2009); Ekholm et al. (2010), Lechon et al. (2005), Vaillancourt et al. (2008).

Under a carbon-constrained case, the TIAM-UCL model not only estimates the trajectory of carbon emissions to 2100, but the technology mix in different sectors of the energy system (industry, commerce, transport, household) required to achieve the CO_2 reductions, together with the marginal cost of abatement (CO_2 shadow prices). As a least-cost optimisation model, working in a perfectly efficient world, a tax set at the level of the revealed marginal cost of carbon abatement should produce the outcomes of the model runs under the equivalent reduction target-trade case.

Scenario Description

Five main scenarios are defined (Table 1): one is the Reference (REF) Scenario, to which no climate change policies are applied; two different scenarios under each cap-and-trade policy and tax policy are defined.

Table 1: Scenario definition

Scenario	Reduction target compared to 2005 emission level					
	Developed countries		China and India		Other regions	
	2050	2100	2050	2100	2050	2100
REF: Reference Case	-	-	-	-	-	-
CAP-80: Low Carbon Scenario under cap-and-trade policy targeting only developed countries	-80%	-90%	-	-	-	-
CAP-450: Low Carbon Scenario under cap-and-trade policy targeting all regions to achieve a target of CO_2 only concentration of 450 ppm	-80%	-80%	-30%	-30%	+30%*	+30%*
TAX-50: Low Carbon Scenario with low CO_2 tax policy	Same tax is applied to all regions. CO_2 tax of US$ 50/t is applied from 2020.					
TAX-200: Low Carbon Scenario with high CO_2 tax policy	Same tax is applied to all regions. CO_2 tax of US$ 50/t from 2020, US$100/t from 2030 and US$200/t from 2050 is applied.					

*can emit 30% more than the 2005 emission level.

Results

Reference Scenario

Global emissions increased by more than three times from 2005 to 2100 in the Reference (REF) Scenario in the absence of climate policies, with coal dominating power generation and industrial energy use especially in China and India. Developing country emissions increase more rapidly than developed countries due to the expected high economic growth as well as near term population growth. They are responsible for more than two thirds of global emissions by 2100 when there is no climate policy implemented (**Figure 1**) compared to a contribution of 43% in 2005. By 2100, China is the single largest emitter whose contribution increases from 18% in 2005 to 30% in 2100 while the US share decreases from 22% to 12% over the same timescale. In absolute terms, China's emissions in 2100 exceed global emissions in 2005. Given the increase in global emissions in the REF Scenario (**Figure 1**) it is clear that any action to limit atmospheric CO_2 concentration to 450 ppm (ETP Blue Map Scenario) requires the involvement of developing countries. Their future emissions alone are sufficient to increase the CO_2 concentration to well above 450 ppm.

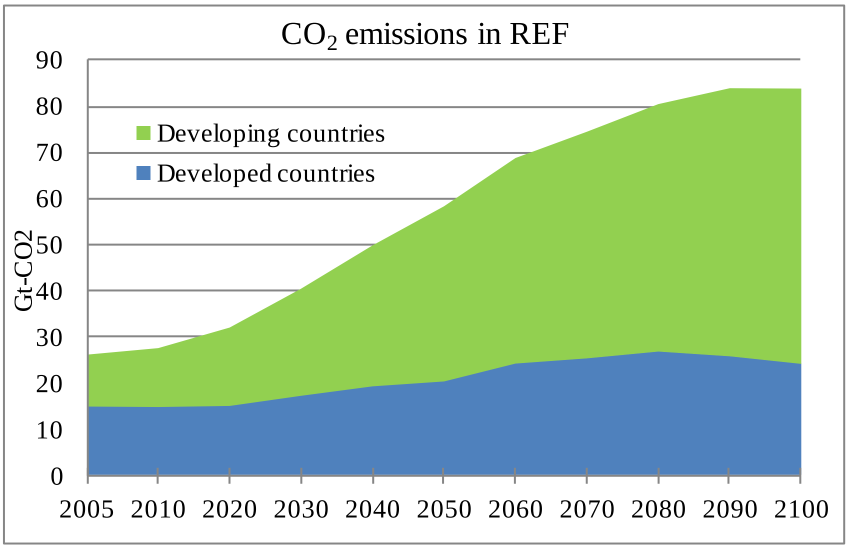

Figure 1: Global CO_2 emissions in REF SCENARIO during 2005-2100

Cap-and-trade policy

Figure 2 presents emission levels from developed and developing countries, and reductions under a cap-and-trade policy during 2005-2100 under the CAP-80 Scenario. Actual emissions from developed countries include own emissions and traded emissions . Such reductions in developing country emissions are credited to developed countries, as shown in **Figure 2**. Model results show that emission trading plays a key role in meeting the developed countries' CO_2 reduction target. All developing countries trade emissions in this scenario. Although developed countries' emissions were targeted, CO_2 emission reductions from developing countries exceed those of developed countries, particularly during the last quarter of the century, illustrating that abatement is more cost-effective[1]. Marginal CO_2 abatement cost in the CAP-80 Scenario range from US$12/t-$CO_2$ to US$30/t-$CO_2$ during 2020-2100 (**Figure 3**).

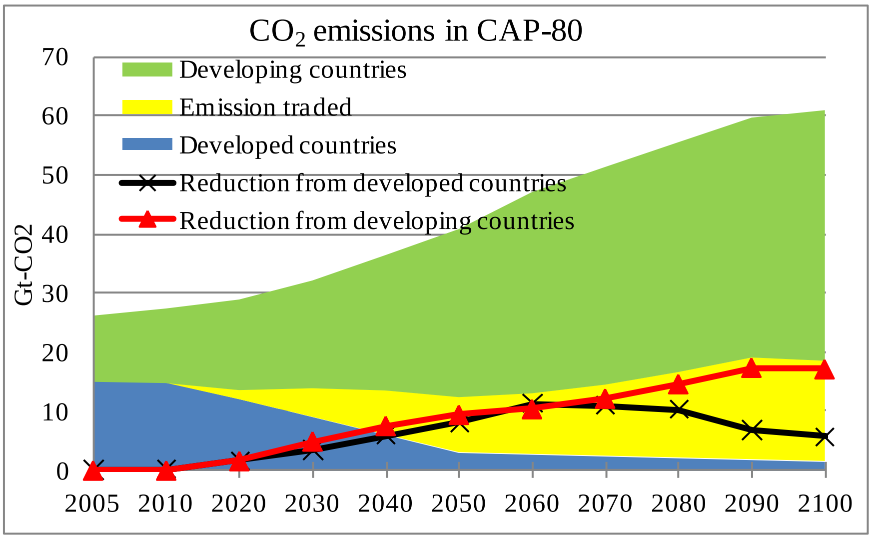

Figure 2: Global CO_2 emissions in CAP-80 Scenario during 2005-2100

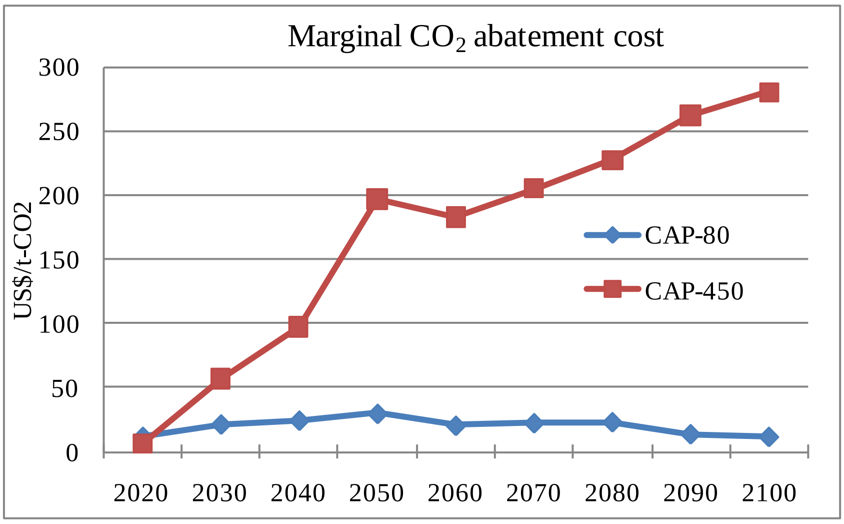

Figure 3: Marginal CO_2 abatement cost under cap-and-trade-policy during 2005-2100

[1] It is important to note that carbon trading is viewed as 'free' by the model and does not involve any transaction costs.

Developing countries' contribution to emission in 2100 in the CAP-80 Scenario is about 70%, about the same as observed in the REF Scenario. The contribution increases to 79% under the CAP-450 Scenario (**Figure 2** and **Figure 4**), where both developed and developing countries are targeted. Regional emissions during 2005-2100 under the CAP-450 Scenario are presented in **Figure 5**. This figure represents the actual emissions in different regions and not the targeted emission level that also takes account of traded emission credits (either buying or by selling emission credit). In the CAP-450 Scenario, at least 40% of the global emissions during the second half of the century are actually emitted in China, which meet its reduction target by buying credit from other regions.

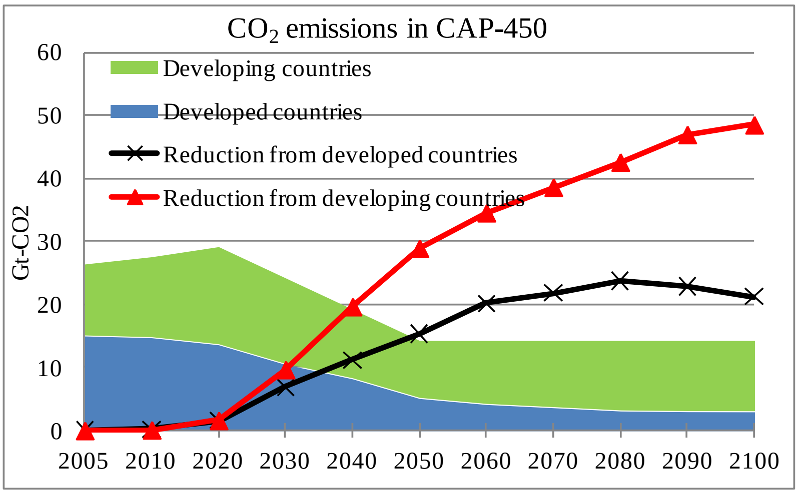

Figure 4: Global CO_2 emissions under the CAP-450 during 2005-2100

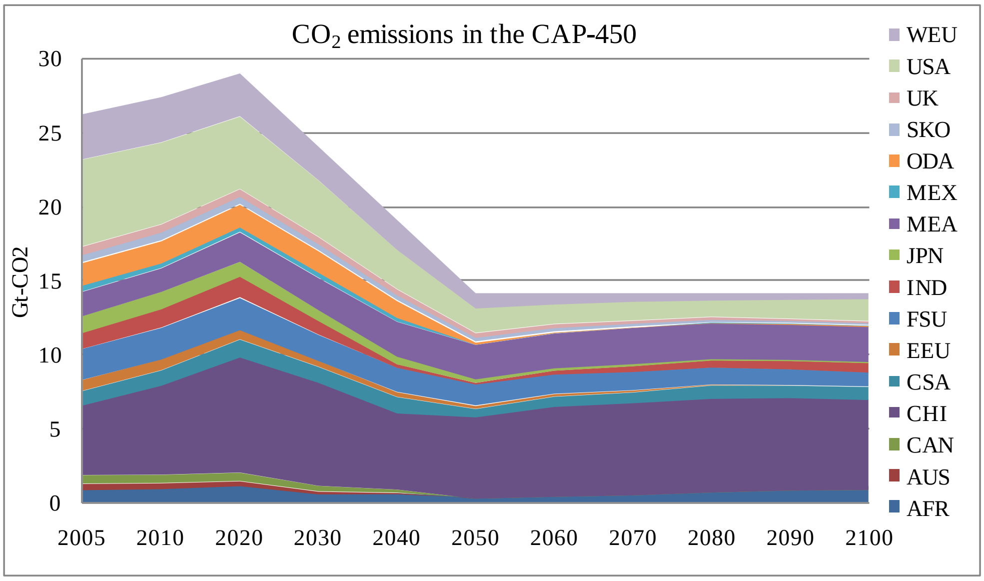

Figure 5: Actual CO_2 emissions from different region under the CAP-450 during 2005-2100

Emission trading is unilateral under CAP-80 Scenario when only the developed countries are targeted. When all the regions' emissions are constrained under CAP-450 Scenario with full emission trading option, developing countries also adopt emission reduction targets resulting in bilateral trade (**Figure 6**). Buyers in early periods become sellers in the later periods. Developing countries (China and Middle-East) become buyers while developed countries (Australia, Canada, Japan and Western Europe) become sellers. Even though developing countries targets are relatively lower in percentage terms than those for developed countries, they struggle, i.e., the cost is higher, to meet their targets. It is because of a high assumed economic growth for developing countries, their energy consumption increases at a much faster rate. For example, developing countries' share in final energy consumptions increases from 44% in 2005 to 74% in 2100 in the REF Scenario. In absolute terms, reduction targets for developing countries are therefore much higher than for developed countries.

Among developing regions, China, who becomes a buyer from 2030, is the largest buyer of emission credits followed by Middle-East. Emission trading (buying credits from other regions) account for 15% and 12% of China's CO_2 reduction in 2050 and 2100 respectively. Australia and Canada becomes sellers from 2020 and 2030 respectively while Japan and Western Europe become sellers from 2060 and 2070 respectively. When all individual regions are targeted under CAP-450 Scenario, emission trading volumes are relatively low as compared to that observed under CAP-80 Scenario, where only developed countries are targeted (**Figure 6** and **Figure 2**). When developing countries' emissions are also targeted, inevitably it reduces the availability of traded credits because previously credits that were sold are not marketed as they are needed for domestic mitigation accounting.

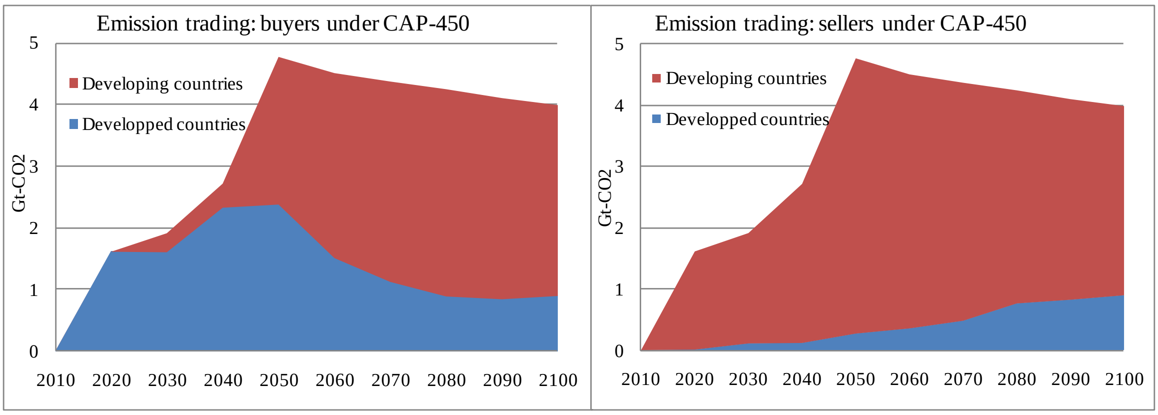

Figure 6: CO_2 emission credit buyers and sellers under the CAP-450 Scenario

Tax policy

Tax policy scenario results show the potential for large amounts of CO_2 reduction (**Figure 7**). Applying a CO_2 tax of US$50/t (TAX-50) across all regions bring downs the 2020 emission to below 2005 level and post 2050 emission is reduced by about 50% as compared to the REF Scenario. The TAX-200 Scenario shows a huge reduction in global CO_2 emissions from both developed and developing countries (**Figure 7**). Emission reduction from developing countries steadily increases while reduction from developed countries during 2080-2100 under both tax policy scenarios. This is due steady growth rate of developing countries emissions in the REF Scenario throughout the period, as shown in **Figure 1**. Though in absolute quantity emission reduction from developing countries is relatively high, percentage reduction as compared to REF Scenario is relatively more for developed countries under the TAX-50 Scenario.

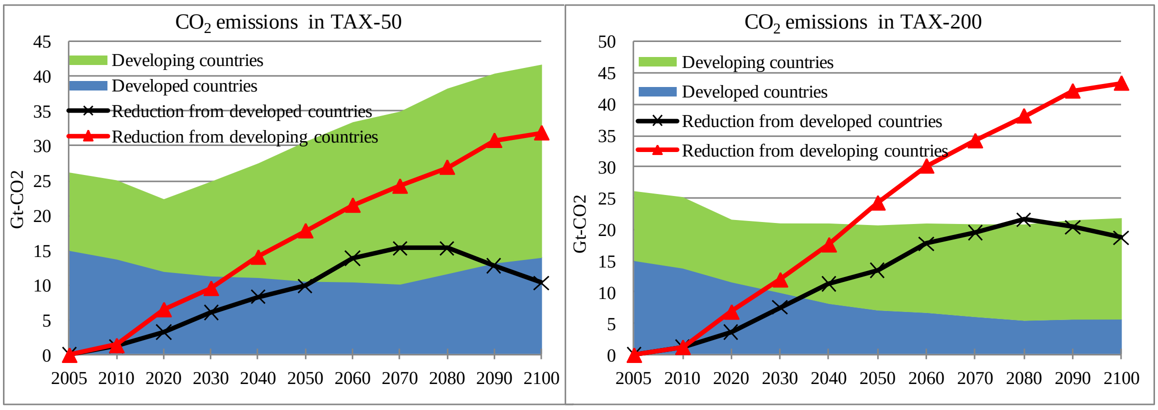

Figure 7: Global CO_2 emissions in TAX-50 during 2005-2100

Developing countries contribution to global CO_2 emissions in 2100 is reduced to 67% under the TAX-50 Scenario from 71% in the REF Scenarios while the TAX-200 Scenario increases it to 75%. **Figure 8** presents regional CO_2 emissions in the TAX-200 Scenario. Among the regions, China is the single largest contributor in this scenario also but its share is 33% which is relatively low as compared to the CAP-450 Scenario.

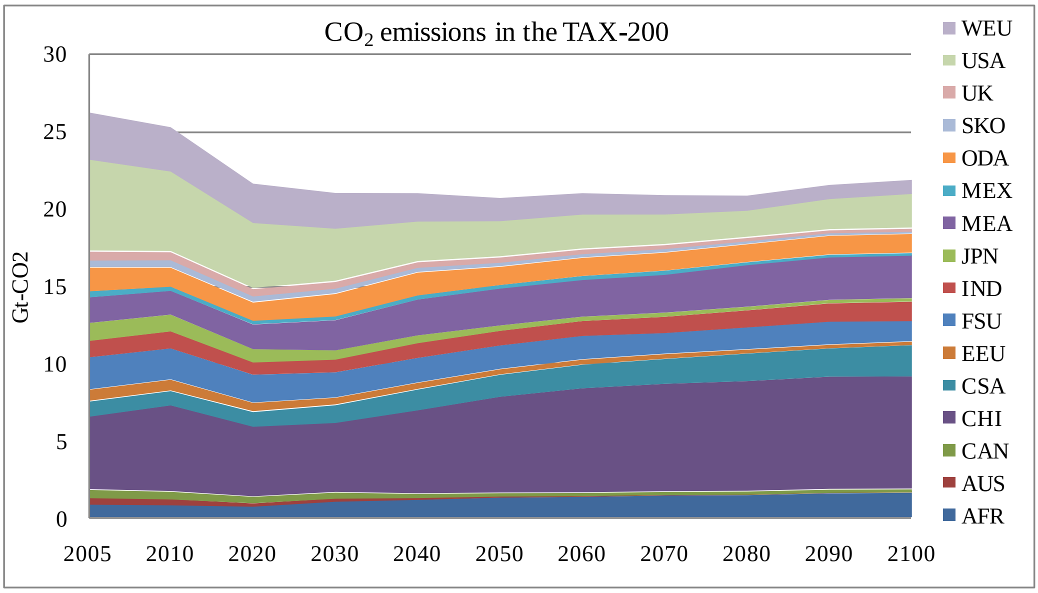

Figure 8: Regional CO_2 emissions in TAX-200 during 2005-2100

<u>Implications on costs</u>

Total global discounted energy system costs under different scenarios are presented in **Figure 9** along with the percentage change compared to the cost in the REF Scenario. These include investment costs, operation and maintenance cost, fuel cost, salvage value, decommissioning cost, demand reduction cost and CO_2 tax. The global discounted energy system cost under cap-and-trade policy scenarios and tax policy scenarios are incomparable as the later include tax collected in the total energy system cost. Change in Regional energy system cost (right in **Figure 9**) shows that these two policies cost more to developing countries than the developed countries, i.e., the energy system in developing countries are more CO_2 intensive than the developed countries in the REF Scenario.

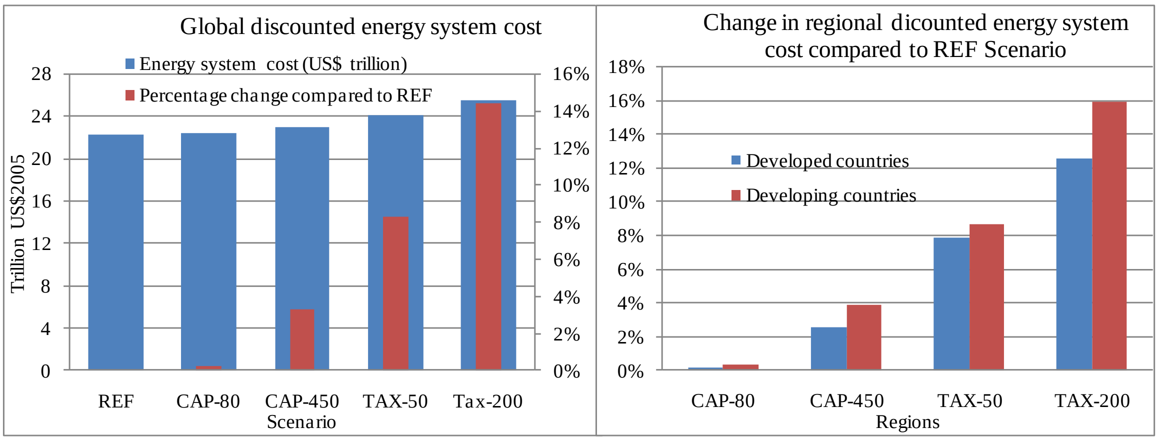

Figure 9: Discounted energy cost and percentage change as compared to REF Scenario

Discussion

Emission reduction from developing countries are observed under both policies. Developing countries contribution to remaining emissions increases under both policies when the policy is tough. Percentage emission reduction from developed and developing countries emissions under tax and cap-and-trade policy scenarios are presented in (**Figure 10**). Tax policy reduces more emission from developing countries than the cap-and-trade policy when the tax applied is greater than the marginal CO_2 abatement costs generated by under cap-and-trade policy.

Under cap-and-trade policy, sellers benefit from emissions trading,. presenting an incentive for developing countries to abate CO_2 emissions. A general argument is that should developed countries for the developing countries for emission mitigation as it cost them annually US$ 1-3 billion during 2030-2100 in the CAP-80 Scenario. It is important that leadership must come from major developed countries, which are collectively responsible for approximately three quarters (based on cumulative emissions data available in CAIT (2010)) of the increase in atmospheric greenhouse gas concentration above pre industrial level. Further, it is also cheaper to buy credit to meet part of their targets than domestic reduction.

In addition, those countries have generally higher per capita emissions, and have the technological capacity to lead the necessary investment. Therefore decision makers in developed countries have obligation to show leadership in addressing the challenge of climate change. Since developing countries will be mostly responsible for future emissions after a certain period some developing countries (like China) should join efforts to reduce emissions. This scenario of China having a target is reflected in the cap-and-trade policy scenario (CAP-450) results.

Developed countries can assist developing countries in terms of financing as well as technology transfer under a cap-and-trade policy. However, a large scheme that results in significant trades / financial flows will require a robust system that will ensure, for example, robust monitoring of mitigation.

Under a carbon tax policy, developing countries require investments in low carbon technologies to reduce cost. As Nordhaus (2009) stated a carbon tax policy provides signals to producers about which inputs imply more carbon emissions, and which inputs imply less or none. Clearly tax policy induces producers to move to low-carbon technologies. A key question is who will provide financial support for investors as there is no market-based financial flow under the tax policy. In addition, will the developing countries have access to clean technologies and have capacity to maintain this access under the tax policy, with lesser obligations for developed countries to provide technology and knowledge transfer.

A large amount of tax will be collected under tax policy. The tax collected can be used for low carbon investment. An internationally agreed mechanism could be developed to make sure that at least part of the collected tax should be invested in low carbon technologies and to monitor the actual reduction in emissions in both developed and developing countries. As consumers are paying the tax under tax policy, it will cost more for developing countries than that under cap-and-trade policy, which in addition have financial flow from developed countries.

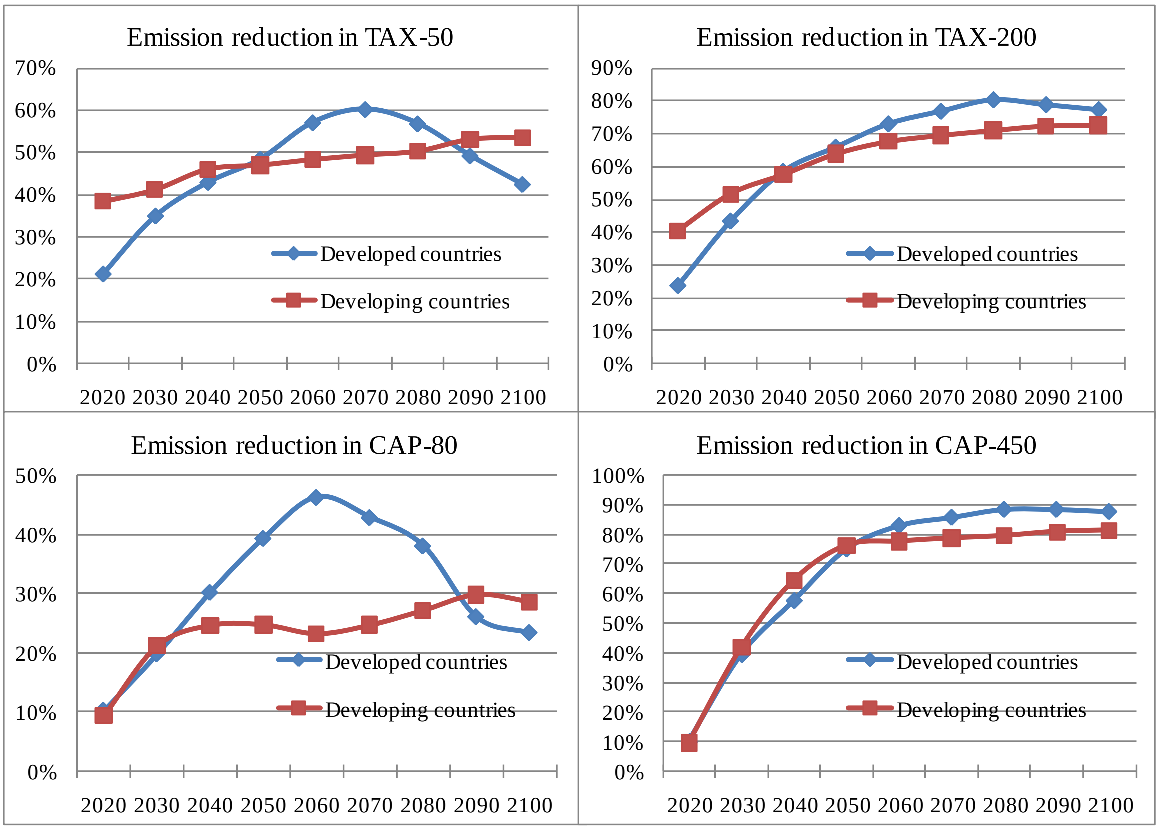

Figure 10: Emission reduction under different scenarios compared to CO_2 emissions in the REF

Conclusions

This paper quantified level of emission reductions, emission trading and costs under a quantity-based trade system and a price-based tax system. Analysis show that both carbon tax and cap-and-trade policies result in emission reduction in developing countries. Under a cap-and-trade policy, when only developed countries are constrained to 80% in 2050 and 90% in 2100, a considerable amount of developing countries' emissions are reduced as it is cheaper to abate emissions in developing compared to developed countries. Annual emission trading costs are about US$ 1-3 billion during 2030-2100 for developed countries under cap-and-trade policy scenarios. Marginal

CO_2 abatement cost decreases from US$ 30/t CO_2 in 2050 to 12/t CO_2 in 2100 under the CAP-80 Scenario while it increase respectively from US$ 30/ t-CO_2 to US$ 281/ t-CO_2 under CAP-450 Scenario.

Important finding is that when the mitigation target is high, meeting a 450ppm CO_2 only concentration target, in which developing countries are also included, some developing countries become buyers and some developed countries become sellers. China becomes the buyer from 2030 and emission trading (buying credits from other regions) account for 15% and 12% of China's CO_2 reduction in 2050 and 2100 respectively.

In developing countries, energy system and infrastructure is being developed/built, if we target those countries later, it will cost more as they will be locked into inefficient/high carbon energy system. Applying a high carbon tax (under tax policy) in developing countries in the near term may not be appropriate as their immediate goal is economic development, which may be affected by high energy prices.

But, they will be better off when providing financial and technology support to invest in clean energy infrastructure under a cap-and-trade policy when their economy is being developed. It is appropriate that developed countries, who have greatly contributed to the climate change problem by emitting greenhouse gases since the industrialisation, help developing countries to invest in cleaner technologies while developing countries build their energy system. When thinking of implementing the policies effectively to bring in developing countries in the process, cap-and-and policy is preferred as it provide financial support and technology transfer. But in the long term carbon tax policy would work in developing countries if the early investments were in clean energy infrastructure and technologies under cap-and-trade policy.

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