Economic Implications of Moving Toward Global Convergence on Emission Intensities

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Abstract

One key contentious issue in climate change negotiations is the huge difference in carbon dioxide (CO₂) emissions per capita between more advanced industrialized countries and other nations. This paper analyzes the costs of reducing this gap. Simulations using a global computable general equilibrium model show that the average the carbon dioxide intensity of advanced industrialized countries would remain almost twice as high as the average for other countries in 2030, even if the former group adopted a heavy uniform carbon tax of \$250/tCO₂ that reduced their emissions by 57

percent from the baseline. Global emissions would fall only 18 percent, due to an increase in emissions in the other countries. This reduction may not be adequate to move toward 2050 emission levels that avoid dangerous climate change. The tax would reduce Annex I countries' gross domestic product by 2.4 percent, and global trade volume by 2 percent. The economic costs of the tax vary significantly across countries, with heavier burdens on fossil fuel intensive economies such as Russia, Australia, the United Kingdom and the United States.

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Economic Implications of Moving Toward Global Convergence on Emission Intensities

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1. Introduction

One of the contentious issues of the ongoing climate change negotiations is the huge difference in emission intensities (i.e., CO₂ emissions per capita) between developed and developing countries. Developing countries, which mostly fall in the Non-Annex I group, argue that since their per capita CO₂ emissions are very small compared to that of developed countries, it should be legitimate for them to increase their emissions to achieve anticipated economic growth. They further argue that one of the principles of a long-term climate change agreement should be equity in that emission intensities converge between the countries in the long-run. Several existing studies (e.g., Lecocq and Hourcade, 2012; Gaisford, 2010; Tol, 2005) highlight this issue of equity in climate change negotiations. On the other hand, developed countries assert that without meaningful participation of developing countries, especially the emerging developing economies – such as China, India, Brazil, and South Africa – achieving the objective the United Nations Framework Convention on Climate Change (UNFCCC)—stabilization of atmospheric concentrations of greenhouse gases (GHGs) at a level that would prevent dangerous anthropogenic interference with the climate system—would not be feasible (Rong, 2010; Timilsina, 2008). The merit of this argument rests on the fact that China has already surpassed the United States in CO₂ emissions (IEA, 2011a) and that non-OECD countries account for 90% of population growth, 70% of the increase in economic output and 90% of energy demand growth over the period from 2010 to 2035 (IEA, 2011b). These arguments can be attributed to the failure of recent climate change negotiations (Campbell and Klaes, 2011; Dimitrov, 2010).

A critical question is: Can the stabilization of GHG concentrations in the atmosphere to avoid climate change be achieved while converging the emission intensities between industrialized and developing countries? To avoid dangerous consequences in the earth's atmosphere, the earth mean average temperature should not be higher than 2 degrees Celsius from the pre-industrialization level (Stern, 2006). This entails concentrations of GHG emissions should be stabilized at 450 ppm CO₂-equivalent or below (400 ppm), which requires global emissions to peak before 2020, followed by substantial overall reductions of as much as 25% (45% for 400 ppm) compared to 1990 levels in 2050 (Timilsina 2008; den Elzen, and Meinshausen, 2006). Historical trends indicate that CO₂ emission intensity (or CO₂ emission per capita) has been decreasing for Annex I countries and increasing for Non-Annex I countries (see

Figure 1). In 1990, CO₂ emission intensity of Annex I countries was 11.83 tonnes CO₂ per capita, this has been decreased by 14 percent to 10.15 tonnes CO₂ per capita in 2009. During the same period (i.e., 1990-2009), Non-Annex countries emissions increased by 73 percent from 1.58 tonnes CO₂ per capita to 2.73 tonnes CO₂ per capita. The emission intensity gap between the Annex I countries and Non-Annex I countries has decreased by around 20 percent from 10.25 tonnes CO₂ per capita in 1990 to 7.42 tonnes CO₂ per capita in 2009.

Figure 1: Historical emission intensity gap between the Annex I and Non-Annex countries (tons CO₂ per capita)

Source: IEA (2011a)

The objective of this analysis is to examine the costs to the global economy of moving forward in the direction to converse emission intensities between Annex I and Non-Annex I countries. A range of uniform carbon taxes are introduced in Annex I countries as a policy instrument while non-Annex I countries are exempted from the carbon taxes. The impacts of the policy instruments are simulated using a global, dynamic, multi-sector computable general equilibrium model. Our study finds that the CO₂ intensity gap between the Annex I and Non-Annex I countries would decrease by 65 percent in 2030 from the level in the baseline if a relatively high carbon tax of \$250/tCO₂ is imposed to Annex I countries. However, the CO₂ intensity of Annex I countries would still remain almost twice as high as that of Non-Annex I countries although CO₂ emissions in the former decreases by 57 percent from the baseline. This

level of carbon tax would reduce developed countries' GDP by 2.4 percent and global trade volume by 2 percent. The economic costs vary significantly across countries, with heavy burden on fossil fuel intensive economies, such as Russia, Australia, United Kingdom and the United states. On the other hand, global emissions in 2030 would be still more than 15 percent higher from the current level.

The paper is organized as follows. Section 2 briefly describes the model following by discussions on the impacts on CO₂ emissions and emission intensities of various countries and region due to the policy instrument implemented to reduce the intensity gaps in Section 3. Section 4 presents the impacts of the policy instrument on economic outputs and international trade. Finally, key conclusions are drawn in Section 5.

2. Methodology and Data

We used a multi-regional, multi-sector, recursive dynamic CGE model for the purpose of this study¹. The basic data needed for the calibration of the model is derived from the GTAP 7.0 database. The main reason for using the GTAP database is that no other comprehensive global database required by this study exists. Moreover, most CGE models simulating climate change policies use the GTAP database, and the use of this database in our study helps compare our results with those of others. The original GTAP database provides information for 113 countries and 57 commodities and production sectors. We further worked on the database to have only 28 sectors and 25 countries/regions as needed by our model.

Each of the 28 sectors is depicted by a set of nested constant elasticity of substitution (CES) production functions (see Figure 2). At the top tier of the production structure, firms in each country/region minimize their production costs by choosing an optimal combination of the aggregate non-energy intermediate input (ND) and the composite of value added and the aggregate energy input (VAE). On the left hand side of the second tier of the nested production structure, a non-energy commodity in a country/region is formed through a CES combination of that commodity produced in the country/region and that imported from various countries/regions.

¹ For a more elaborated discussion on the model please refer to Timilsina et al. (2010 and 2011).

Similarly, on the right-hand side of the same tier, the value added-energy composite is formed through a CES combination of the value added and the aggregate energy consumption. The process continues as illustrated in Figure 2.

The study gives special attention to the energy sector modeling for two reasons. First, since a carbon tax is introduced to fossil fuels, we need an explicit representation of the fossil fuel sector including various petroleum products. Second, the study aims to assess the competitiveness of biofuels with fossil fuels when carbon tax is introduced into the latter; therefore, we also need an explicit representation of biofuels. As shown in Figure 3, the total demand for energy is a CES composite of electricity and an aggregate of non-electric energy commodities. One component of the latter is the liquid fuel, which is a CES composite of the ethanol-gasoline and diesel-biodiesel bundles. The model is structured in such a way that it allows direct substitution between gasoline and ethanol, and between diesel and biodiesel.

Figure 2: Structure of the CGE Model: Production Sectors

Figure 3: Module for the Energy Sector

Land use changes are incorporated into the model via a constant elasticity of transformation (CET) representation of land supply for each country/region. Figure 4 presents structure of the land-use module incorporated in the CGE model. Total land areas are first divided into 18 agro-ecological zones (AEZ) in every country/region. Under each AEZ in a country or region, total available land area is allocated to forest land, pasture and crop land. On the second level, crops are further divided into the four different categories: rice, sugar-crops, grains and oilseeds, and fruits and vegetables. Finally, the grains and oilseeds category is partitioned into wheat, corn, other coarse grains, and oilseeds. Land use change is induced by changes in relative returns to land as each of the CET nests of our land module, agents maximize payoffs by optimally allocating the fixed land area for this nest to the various competing uses.

While modeling the household sector, we assumed that a representative household maximizes its utility, using a non-homothetic Constant Difference of Elasticities (CDE) function, subject to the budget constraint. The households' disposable income consists of the factor incomes (net of taxes) minus the direct tax. A household savings rate determines the fraction of disposable income that is saved, and thus available for investments. Hence, total national income accrues to government expenditures, household expenditures, and investments.

Figure 4: Structure of the Land-Use Module

The government derives revenue from a number of indirect taxes, tariffs and a direct tax on households. Government expenditures are an exogenously determined share of nominal GDP. Government revenue equals the sum of government expenditures and government savings so that, in the model, the public sector always has a balanced budget. The direct tax on households is adjusted each period to ensure a balanced public budget. International trade is modeled by a system of Armington demands that give rise to flows of goods and services between the regions. On the national/regional level, import demand is driven by CES functions of domestic and imported components of demand for Armington commodities. Export supply is depicted by a two tier constant elasticity of transformation (CET) function, where, on the first tier, the total output of a sector is designated either to total exports or to domestic supply, and, at the second tier, total exports are partitioned according to their destinations.

The capital stock is composed of old and new capital, where new corresponds to the capital investments at the beginning of the period and old corresponds to the capital installed in previous periods. The ratio of new to old capital is also a measure of the flexibility of the economy, as new capital is assumed to be perfectly mobile across sectors. Furthermore, each

period, a fraction of the old capital depreciates. Population and productivity growth are exogenous drivers of the model's dynamics. The former is taken from the projections of the United Nations Population Division, where labor force growth corresponds to growth of the population aged 15-64 years. Productivity growth is modeled as exogenous and factor neutral for agricultural sectors and labor augmenting for industrial and service sectors. Productivity of energy follows an autonomous energy efficiency improvement (AEEI) path so that there is no endogenous technological change in the model. To ensure equilibrium in the model, three sets of market clearing conditions are met. First, total production of each commodity equals the sum of domestic consumption and export so that the goods and services markets clear. Second, total investment equals total saving, where savings are composed of private (household) savings, public (government) savings and exogenously fixed foreign savings. Third, factor markets clear, which implies full employment.

The model is calibrated with GTAP version 7.0 data. However, not all data needed for the model are available in the GTAP database. For example, biofuels are not a proper sector in the original GTAP 7.0; therefore, we modified the database in a way that allowed us to introduce biofuels sectors in our CGE model. For this purpose, we collected detailed information on production, consumption and trade, a total of seven new biofuel sectors, which have been created by splitting existing GTAP sectors. The land data are also based on the GTAP 7.0 database.

3. Impacts on Intensities and Absolute Emissions

The study simulates various level of carbon tax ranging from US\$10 to US\$250 per ton of carbon dioxide. Per ton of carbon, the range corresponds to US\$37 to US\$917, the upper range is indeed a very high level of carbon tax. This section presents key results from simulations of the model.

3.1 Impacts on emission intensities

Figure 5 illustrates that emission intensities of Annex I and Non-Annex I countries are moving closer as rate of carbon tax increases. Under the business as usual scenario the average emission intensity of the Annex countries would be 13.2 tCO₂ per capita in 2030. This is 3.62 times as high as the average emission intensity of Non-Annex I countries in the same year. A uniform carbon tax of US\$10/tCO₂, US\$50/tCO₂ and US\$ 100/tCO₂ in the Annex I countries

would reduce their emission intensities by 8%, 24% and 33%, respectively from the BAU case. If the carbon tax is raised to a very high rate of US\$ 250/tCO₂, the average emission intensity of Annex I country would drop by 46%. On the other hand, the 250/tCO₂ carbon tax in Annex I countries would cause emission intensity of Non-Annex countries to increase slightly, by 2.8%. Although Annex I countries' emission intensity would still be 1.9 times as high as that of Non-Annex I countries at 250/tCO₂ carbon tax case, the gap in emission intensity between Annex I and Non-Annex I countries would drop by almost 65%.

One interesting observation is that at carbon tax rate greater than 50/tCO₂, not only Annex I countries would suffer with economic losses but also non-Annex country starts exhibiting economic losses despite the fact these countries are exempted from any carbon tax. This is due to international trade effect. Although a carbon tax in Annex I countries might cause moving some emission intensive industrial production to Non-Annex countries, this substitution effect would not be able to cause a complete offset of losses in economic outputs that occurred in Annex I countries.

Table 1 presents percentage change in emission intensities in various countries and region. Countries such as Russia, Australia, United Kingdom and United States would exhibit relatively higher drop of their emission intensities, whereas France will see the lowest drop. This is because the energy system, particularly electricity generation is based on fossil fuels, such as coal in the former countries, whereas more than 80 percent of electricity is generated from nuclear power plants in France. All developing countries would experience increase in emission intensity as these countries are exempted from carbon tax. This clearly indicates the leakage in emission reduction as the carbon tax in Annex I countries would cause migration of carbon intensive industrial production to Non-Annex I countries.

An important issue is that the emission intensities of developed and developing countries move towards convergence only when the former undertake a large cut in their emissions, whereas the latter are allowed to increase their emissions. In other words, the movement towards the convergence occurs if a high carbon tax is imposed to developed countries, and developing countries are exempted from any carbon tax. However, meeting the ultimate objective of the UNFCCC - stabilizing atmospheric concentration of GHG emissions at the level that avoids climate change - would not be possible through reductions of GHG emissions from developed

countries only. Developing countries also need to significantly reduce their emissions to achieve the ultimate goal of the UNFCCC. But, if developing countries start reducing their emissions, emission intensities of developed and developing countries start diverging instead of converging. Some developing countries, such as India and China, have announced their plans to reduce their emission intensities², particularly CO₂ emissions per capita GDP. To achieve their plans, these countries are expected to make huge investment in clean energy technologies on both energy supply and demand sides. Furthermore, their emission intensities are expected to decrease in spite of significant increase in their income (i.e., GDP per capita) unless the income effect (i.e., the rate of increase in GDP per capita) is greater than intensity effect (i.e., the rate of decrease in emission per capita GDP). The decrease in emission intensities in developing countries would lead to further divergence of emission intensities between developed and developing countries.

² China announced that it will reduce its carbon emission per capita GDP by . Similarly, Indian government has a plan to reduce carbon emission per capita GDP by.

Figure 5. Movement of Emission Intensities Gap between Annex I and Non-Annex Countries along with Annex I Countries' Carbon Tax Rates

Table 1: Change in emissions intensity (CO₂ emissions per capita) at various levels of carbon tax in Annex I countries from the BAU case in 2030

	CO2 emission per capita				CO2 emission per GDP			
	Carbon tax rate (US\$/tCO ₂)							
	10	50	100	250	10	50	100	250
Australia and New Zealand	-14.9%	-36.0%	-46.2%	-58.7%	-14.8%	-35.6%	-45.5%	-57.6%
Canada	-9.4%	-26.7%	-36.6%	-50.8%	-9.3%	-26.2%	-35.7%	-49.2%
Germany	-6.4%	-21.1%	-30.5%	-43.8%	-6.4%	-21.0%	-30.2%	-43.2%
Spain	-4.2%	-15.2%	-23.6%	-37.5%	-4.2%	-15.0%	-23.2%	-36.7%
France	-2.9%	-10.8%	-17.3%	-29.4%	-2.9%	-10.7%	-17.1%	-29.0%
UK	-12.2%	-35.0%	-46.2%	-58.4%	-12.2%	-34.9%	-45.9%	-58.0%
Italy	-4.2%	-15.0%	-23.1%	-36.6%	-4.1%	-14.7%	-22.7%	-35.6%
Japan	-8.0%	-18.2%	-25.4%	-37.1%	-8.0%	-18.1%	-25.1%	-36.4%
EFTA Countries & Rest of European Union	-8.3%	-25.6%	-35.9%	-50.5%	-8.2%	-25.2%	-35.3%	-49.4%
Russia	-16.7%	-42.8%	-55.7%	-72.2%	-16.2%	-40.3%	-51.7%	-65.9%
United States	-10.8%	-31.6%	-43.1%	-57.8%	-10.7%	-31.3%	-42.5%	-56.9%
Non Annex I Europe & Central Asia	0.5%	1.9%	3.2%	4.7%	0.4%	1.8%	2.9%	4.3%
Argentina	0.1%	0.3%	0.6%	1.2%	0.1%	0.4%	0.7%	1.4%
Brazil	0.4%	1.6%	2.7%	4.9%	0.4%	1.6%	2.7%	5.0%
Rest of Latin America & Caribbean	0.3%	1.2%	2.1%	4.1%	0.3%	1.3%	2.3%	4.6%
China	0.2%	0.8%	1.3%	2.5%	0.2%	0.6%	1.0%	1.9%
Indonesia	0.3%	1.2%	2.0%	3.7%	0.3%	1.2%	2.0%	3.5%
Rest of East Asia & Pacific	0.5%	1.8%	2.9%	5.0%	0.4%	1.6%	2.6%	4.4%
Malaysia	0.2%	0.8%	1.3%	2.4%	0.2%	0.9%	1.5%	2.9%
Thailand	0.3%	1.2%	2.1%	3.7%	0.3%	1.0%	1.8%	3.3%
India	0.2%	0.8%	1.2%	1.9%	0.2%	0.5%	0.8%	1.1%
Rest of South Asia	0.2%	0.8%	1.4%	2.7%	0.2%	0.7%	1.2%	2.3%
Middle East & North Africa	0.0%	0.2%	0.4%	1.0%	0.2%	1.1%	2.0%	4.0%
South Africa	0.7%	2.2%	2.9%	3.8%	0.8%	2.2%	2.9%	3.7%
Rest of Sub-Saharan Africa	0.2%	0.9%	1.7%	3.4%	0.3%	1.4%	2.6%	5.1%

EFTA stands for European Free Trade Association and includes

3.2 Impacts on CO₂ Emissions

Figure 6 illustrates reduction in total CO₂ emissions due to the emission intensity converging efforts. A US\$10/tCO₂ carbon tax to Annex I countries would reduce their aggregate emissions by 11 percent in 2030. Since, the leakage effect (i.e., increase in emission in Non-Annex I countries due to carbon tax in Annex I countries) of this relatively small level of carbon tax would be negligible, it would reduce the global CO₂ emissions by 4 percent from the baseline. If the carbon tax level is raised to US\$250/tCO₂, the aggregate emission reduction in Annex I countries would be 57 percent in 2030. This high level carbon tax in Annex I countries would produce a significant leakage in Non-Annex I countries, thereby increasing the aggregate Non-Annex I CO₂ emissions by 3 percent in 2030. At the global, level the emission reduction would be around 18 percent from the baseline.

Figure 6: Impacts on Total CO₂ Emissions (Percentage change from the BAU case in 2030)

Table 2 presents reductions of CO₂ emissions by countries or region. As discussed above, countries with pre-dominant use of fossil fuel in their power generation would experience the relatively higher reductions in their total CO₂ emissions. A US\$50/tCO₂ carbon tax in Annex I

countries lead to reduction of their CO₂ emissions by 11 to 43 presents in 2030. On the other hand the US\$50/tCO₂ carbon tax in Annex I countries causes up to 2.2 percent increase of CO₂ emissions in non-Annex I countries.

Table 2: Percentage change in total CO₂ emissions at various levels of carbon tax in Annex I countries in 2030 from their BAU cases

Country/Regions	Carbon tax rate (US\$/tCO ₂)			
	10	50	100	250
Australia and New Zealand	-14.9%	-36.0%	-46.2%	-58.7%
Canada	-9.4%	-26.7%	-36.6%	-50.8%
Germany	-6.4%	-21.1%	-30.5%	-43.8%
Spain	-4.2%	-15.2%	-23.6%	-37.5%
France	-2.9%	-10.8%	-17.3%	-29.4%
UK	-12.2%	-35.0%	-46.2%	-58.4%
Italy	-4.2%	-15.0%	-23.1%	-36.6%
Japan	-8.0%	-18.2%	-25.4%	-37.1%
EFTA Countries & Rest of European Union	-8.3%	-25.6%	-35.9%	-50.5%
Russia	-16.7%	-42.8%	-55.7%	-72.2%
United States	-10.8%	-31.6%	-43.1%	-57.8%
Non Annex I Europe & Central Asia	0.5%	1.9%	3.2%	4.7%
Argentina	0.1%	0.3%	0.6%	1.2%
Brazil	0.4%	1.6%	2.7%	4.9%
Rest of Latin America & Caribbean	0.3%	1.2%	2.1%	4.1%
China	0.2%	0.8%	1.3%	2.5%
Indonesia	0.3%	1.2%	2.0%	3.7%
Rest of East Asia & Pacific	0.5%	1.8%	2.9%	5.0%
Malaysia	0.2%	0.8%	1.3%	2.4%
Thailand	0.3%	1.2%	2.1%	3.7%
India	0.2%	0.8%	1.2%	1.9%
Rest of South Asia	0.2%	0.8%	1.4%	2.7%
Middle East & North Africa	0.0%	0.2%	0.4%	1.0%
South Africa	0.7%	2.2%	2.9%	3.8%
Rest of Sub-Saharan Africa	0.2%	0.9%	1.7%	3.4%

Note that at the 50% probability of maintaining the global mean temperature rise below 2°C relative to pre-industrial levels, atmospheric GHG concentrations must stabilize below 450ppm CO₂ equivalence (IPCC, 2007). To achieve this target, global GHG emissions should peak by 2020 at the latest and then be more than halved by 2050 relative to 1990 (Stern 2006). Our analysis shows that the global CO₂ emissions in 2030 would be only 18% lower compared to

that in the baseline, whereas more reduction would be needed to remain in the trajectory to maintain 2050 emission level at the half of 1990 level.

4. Impacts on Economic Outputs and International Trade

4.1 Impacts on GDP

Figure 7 presents economic impacts of moving towards emission intensity convergence. A US\$50/tCO₂ carbon tax to Annex I countries that reduces CO₂ emission intensity gap between Annex I countries and Non-Annex I countries by 33 percent from the BAU case, would cause 0.5 percent and 0.3 percent GDP losses at the Annex I and global levels, respectively in 2030. If the carbon tax level is raised to US\$250/tCO₂, it would reduce the CO₂ emission intensity gap by 65 percent at GDP costs of 2.4 and 1.4 percents at the Annex I and global levels, respectively in 2030.

Figure 7: Impacts on GDP (Percentage change from the BAU case in 2030)

The impacts on GDP would vary significantly across the Annex I countries (see Table 3). For example, the 33 reduction of CO₂ emission intensity gap between Annex I countries and Non-Annex I countries (i.e., US\$50/tCO₂ carbon tax case) would cause GDP losses from 0.1

percent (France) to 4.1 percent (Russia) in 2030. If the carbon tax level is raised to US\$250/tCO₂, the economic costs in some countries, such as Russia, would be very high.

Table 3: Percentage change in GDP at various levels of carbon tax in Annex I countries in 2030 from their BAU cases

Country/Regions	Carbon tax rate (US\$/tCO ₂)			
	10	50	100	250
Australia and New Zealand	-0.2%	-0.7%	-1.2%	-2.6%
Canada	-0.1%	-0.7%	-1.3%	-3.1%
Germany	0.0%	-0.2%	-0.4%	-1.1%
Spain	0.0%	-0.3%	-0.6%	-1.4%
France	0.0%	-0.1%	-0.2%	-0.6%
UK	0.0%	-0.2%	-0.4%	-1.0%
Italy	-0.1%	-0.3%	-0.6%	-1.4%
Japan	0.0%	-0.2%	-0.5%	-1.1%
EFTA Countries & Rest of European Union	-0.1%	-0.4%	-0.9%	-2.1%
Russia	-0.7%	-4.1%	-8.2%	-18.5%
United States	-0.1%	-0.5%	-1.0%	-2.1%
Non Annex I Europe & Central Asia	0.0%	0.2%	0.3%	0.4%
Argentina	0.0%	-0.1%	-0.1%	-0.2%
Brazil	0.0%	0.0%	0.0%	-0.1%
Rest of Latin America & Caribbean	0.0%	-0.1%	-0.2%	-0.5%
China	0.0%	0.2%	0.3%	0.6%
Indonesia	0.0%	0.0%	0.1%	0.2%
Rest of East Asia & Pacific	0.0%	0.2%	0.3%	0.5%
Malaysia	0.0%	-0.1%	-0.2%	-0.5%
Thailand	0.0%	0.2%	0.3%	0.4%
India	0.1%	0.3%	0.4%	0.8%
Rest of South Asia	0.0%	0.1%	0.2%	0.4%
Middle East & North Africa	-0.2%	-0.9%	-1.6%	-2.9%
South Africa	0.0%	0.0%	0.0%	0.0%
Rest of Sub-Saharan Africa	-0.1%	-0.5%	-0.8%	-1.6%

4.2 Impacts on international trade

The carbon tax introduced in Annex I countries to move forward in the direction of converging emission intensity would have large impacts on international trade (see Figure 8). Global trade would shrink by 0.5 percent in 2030 if the emission intensity gap between the Annex I and non-Annex I countries is reduced by 33 percent through a US\$50/tCO₂ carbon tax

introduced in Annex I countries. The contraction in global trade would reach 2 percent when the emission intensity gap is reduced by 65 percent (i.e., introduction of a US\$250/tCO₂ carbon tax in the Annex I countries). Since domestic production would be more expensive due to carbon tax, Annex I countries exports would get impacted the most: 1.5 and 5 percents drops under US\$50/tCO₂ and US\$250/tCO₂ carbon tax cases, respectively in 2030. Non-Annex I countries would benefit as their exports increase and imports drop.

Like in the impacts on GDP, Annex I countries with carbon intensive economy (e.g., Russia, United States, Japan and Australia) would exhibit the highest impacts on their international trade (see Table 4). For example, a US\$50/tCO₂ carbon tax would cause reduction of exports by 1.5 percent in Australia and Japan, 2.5 percent in the United States and 6.6 percent in Russia. Most Non-Annex I countries would gain through increase in their exports.

Figure 8: Impacts on international trade(Percentage change from the BAU case in 2030)

Table 4: Percentage change in international trade at various levels of carbon tax in Annex I countries from the BAU case in 2030

	Exports				Imports			
	Carbon tax rate (US\$/tCO ₂)							
	10	50	100	250	10	50	100	250
Australia and New Zealand	-0.4%	-1.5%	-2.6%	-5.1%	-0.1%	-0.5%	-0.9%	-1.7%
Canada	-0.2%	-1.1%	-2.0%	-4.1%	-0.2%	-1.1%	-2.0%	-4.4%
Germany	-0.2%	-0.7%	-1.2%	-2.5%	-0.1%	-0.2%	-0.5%	-1.1%
Spain	-0.3%	-1.4%	-2.4%	-4.8%	0.0%	-0.2%	-0.5%	-1.3%
France	-0.1%	-0.7%	-1.3%	-2.6%	0.0%	-0.1%	-0.3%	-0.7%
UK	-0.1%	-0.5%	-0.9%	-2.0%	-0.1%	-0.3%	-0.6%	-1.3%
Italy	-0.2%	-1.1%	-1.9%	-4.0%	-0.1%	-0.4%	-0.7%	-1.8%
Japan	-0.4%	-1.5%	-2.7%	-5.3%	0.0%	-0.2%	-0.4%	-1.1%
EFTA Countries & Rest of European Union	-0.2%	-1.0%	-1.9%	-4.1%	-0.1%	-0.6%	-1.1%	-2.6%
Russia	-1.7%	-6.6%	-10.4%	-17.1%	-0.5%	-2.1%	-3.5%	-7.1%
United States	-0.6%	-2.5%	-4.3%	-8.0%	0.0%	-0.1%	-0.2%	-0.6%
Non Annex I Europe & Central Asia	0.0%	0.0%	0.0%	-0.5%	-0.1%	-0.3%	-0.5%	-1.3%
Argentina	0.2%	0.9%	1.6%	2.8%	-0.2%	-0.8%	-1.3%	-2.5%
Brazil	0.1%	0.3%	0.4%	0.6%	-0.2%	-0.7%	-1.3%	-2.7%
Rest of Latin America & Caribbean	0.2%	1.0%	1.6%	2.9%	-0.2%	-1.0%	-1.8%	-3.3%
China	0.0%	0.1%	0.2%	0.2%	0.0%	0.0%	-0.1%	-0.4%
Indonesia	0.1%	0.6%	0.9%	1.6%	0.0%	0.1%	0.1%	0.0%
Rest of East Asia & Pacific	0.0%	0.1%	0.2%	0.0%	0.0%	0.1%	0.1%	0.0%
Malaysia	0.1%	0.2%	0.3%	0.4%	0.0%	-0.2%	-0.4%	-0.9%
Thailand	0.0%	0.1%	0.2%	0.1%	0.1%	0.1%	0.2%	-0.1%
India	0.0%	0.0%	-0.1%	-0.4%	0.0%	0.1%	0.1%	-0.2%
Rest of South Asia	0.1%	0.3%	0.4%	0.7%	0.1%	0.2%	0.2%	0.2%
Middle East & North Africa	0.5%	2.3%	4.0%	7.7%	-0.7%	-3.0%	-5.1%	-9.2%
South Africa	0.0%	-0.2%	-0.4%	-0.8%	-0.1%	-0.3%	-0.4%	-0.8%
Rest of Sub-Saharan Africa	0.2%	0.9%	1.5%	2.6%	-0.3%	-1.1%	-2.0%	-3.8%

5. Concluding remarks

Currently Annex I countries' per capita CO₂ emission (or emission intensity) is about 4 times as high as that of Non-Annex I countries. Developing countries are strongly arguing that an agreement on ongoing climate change negotiation should help reduce this disparity thereby moving forward in the direction of converging on emission intensities between the industrialized and developing economies. In the absence of climate change mitigation policies in the industrialized countries, the emission intensity gap between the Annex I and Non-Annex I countries would still remain almost at the same level as of today. Using a global CGE model, we simulated a range of potential carbon taxes (\$10/tCO₂ to \$250/tCO₂) uniformly introduced in Annex I countries as a policy instrument to reduce the intensity gaps. The highest carbon tax considered in this study (\$250/tCO₂) would reduce Annex I countries' average emission intensity by 46 percent from the baseline case in 2030. Since the Non-Annex I countries are exempted from the carbon tax, their average emission intensity would increase by 3 percent from the baseline in 2030. The net result is a 65 percent drop in the gap of emission intensities between the Annex I and Non-Annex I countries. This would lead to around 60 percent of reduction of Annex I countries' total CO₂ emissions reduction from the baseline in 2030. However, this reduction would be mostly offset by increase in CO₂ emissions in Non-Annex I countries thereby leaving a merely 18 percent reduction at the global level. This reduction may be smaller than needed to remain in the emission trajectory to meet the 2050 level, which should be a half of 1990 level, for stabilization of atmospheric concentration of GHG emissions at the level to avoid dangerous climate change.

The carbon tax, on the other hand, would reduce Annex I countries GDP by 2.5% from the baseline in 2030. The economic impacts vary substantially across countries depending upon their fossil fuel intensities of economic outputs. Countries such as Russia, Australia, United Kingdom and the United states, are found to suffer with the higher economic loss compared to other countries. On the other hand, countries like France where nuclear power produces more than 80 percent of electricity would face the lowest economic loss. The policy instrument to reduce the intensity gaps between the Annex I and Non-Annex I countries would cause the global trade volume to shrink. The \$250/tCO₂ carbon tax would reduce global trade by 2 percent

from the baseline in 2030. Since domestic production would be more expensive due to carbon tax, Annex I countries' exports would drop by 5 percents in 2030.

Since the emerging developing countries, such as India and China, are planning to reduce their CO₂ emissions per capita GDP, they are expected to scale up deployment of clean energy technologies and substitute towards cleaner fuels. This could lead to a decrease in emission intensity unless the income effect (i.e., the rate of increase in GDP per capita) is greater than intensity effect (i.e., the rate of decrease in emission per capita GDP). In such case, the gap in emission intensities between the developed and developing countries may not converge unless developed countries reduce their emissions at levels much higher than estimated in this study.

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