**Paper 2:** [**Introducing Carbon Taxes in Pakistan: A CGE Framework**](https://copass.iioa.org/article-2584.html)

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**Abstract**

Pakistan is one of the most vulnerable nations from climate change, which is visible in its changing crop cycle, monsoon patterns, severe weather events, and frequent natural disasters such as earthquakes and floods. Pakistan suffered the economic losses of around USD 15 billion during floods of 2010, 2011 and 2012. The severe flood in 2010 was the worst in Pakistan’s history, around 20 million people suffered and more than 300,000 people were displaced. In June 2015, the country was hit by severe heat waves which resulted in a loss of more than 1,500 lives. Just two months later, the severe floods devastated homes and the agricultural fields. The Climate Risk Index for 2014 describes Pakistan as the 5th most affected country in 2014. To overcome these vulnerabilities, the Ministry of Climate Change has challenging objectives. Goal of Pakistan’s climate change policy is to ensure that climate change has a mainstreamed position in the not only economically, but also socially vulnerable sectors of the country based on a climate resilient development. However, in the fiscal budget for the financial year 2016, the Ministry of Finance has allocated only USD 0.01 billion (0.02% of the total budget) for environment protection. With this inadequate environment protection budget, it looks impractical to secure such big ambitions set by the Ministry of Climate Change. Hence, the objective of this study is to reexamine Pakistan’s environment protection policy through micro and macro lenses. For this purpose, this study uses a modified version of the GTAP-E model to assess the potential economic effects of introducing carbon tax in Pakistan. The empirical results of carbon taxing include macroeconomic effects and microeconomic ones.

**Keywords**: Energy, Environment, Carbon tax, GTAP-E model

**JEL Classification:** C68, D61, P35, Q43

**Introduction**

Pakistan has experienced an accumulative loss of around $15 billion due to the recent floods in last three years (2012-14) while 22.8% area and 49.6% population of the country is still at risk because of the climate change. The country has been facing severe environmental degradation which is approximately equal to 6% of GDP (PKR 365 billion annually). After 1950s, accelerated jumps in the temperature trend are much higher over Pakistan compared to the global change in temperature trend. From 1991 to 2005, the mean temperature has increased by 0.74 degree Celsius in Pakistan.[[2]](#footnote-2)  
  
Although Pakistan's contribution in the global Greenhouse Gas (GHG) emissions is around 0.8%, making Pakistan a low per capita emitter, but the country is one of the worst victims of climate change. Because of the greenhouse gas emissions, it is expected that the total size of the Himalayan glaciers might shrink from 500,000 square kilometer to 100,000 square kilometer.[[3]](#footnote-3) This elaborates Pakistan's vulnerability to the climate change. As Pakistan's economy is mainly based on agriculture sector which is sensitive to climate changes, it might result in food insecurity in the country.

All over the world, climate is changing in many parts of the world overtime. From 1995 to 2014, around 525,000 people died on this planet and there were losses of around $ 2.97 trillion. These losses were the direct result of around 15,000 severe weather events. There might be the similar disasters in future if suitable action are not taken towards global warming. Further, these events are affecting the developing countries the most. Hence; if timely mitigation efforts are not taken, the world would suffer even more from severe climate changes.[[4]](#footnote-4)

The Global Climate Risk Index (CRI) analyses the impact of severe weather events in terms of fatalities and resulting economic losses.[[5]](#footnote-5) The CRI examines absolute as well as the relative impacts to construct an average ranking in 4 categories of countries. A country with a higher CRI rank is considered more impacted from the climate changes. Basically the CRI analysis explains exposure and vulnerability of various countries to climate-related risks.[[6]](#footnote-6)

Based on a reliable dataset, CRI reflects the impact of current and previous climate variability and the extent of climate change on a country. The CRI 2016 identifies Honduras, Myanmar and Haiti, Philippines, Nicaragua, Bangladesh, Vietnam, Pakistan, Thailand and Guatemala are the ten most affected countries in the last 20 year period. The following Table 1 shows 10 the most affected countries in the last 20 years with their CRI ranking (CRI score).

**Table 1- Climate Risk Index (CRI) for last two decades: 10 most affected countries (annual averages)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CRI  1995–2014 | Country | CRI  score | Death toll | Deaths per  100 000 inhabitants | Total losses in million US$ PPP | Losses per unit GDP  in % | Number of events (total  1995–2014) |
| 1 | Honduras | 11.33 | 302.75 | 4.41 | 570.35 | 2.23 | 73 |
| 2 | Myanmar | 14.17 | 7 137.20 | 14.75 | 1 140.29 | 0.74 | 41 |
| 3 | Haiti | 17.83 | 252.65 | 2.76 | 223.29 | 1.55 | 63 |
| 4 | Philippines | 19.00 | 927.00 | 1.10 | 2 757.30 | 0.68 | 337 |
| 4 | Nicaragua | 19.00 | 162.30 | 2.97 | 227.18 | 1.23 | 51 |
| 6 | Bangladesh | 22.67 | 725.75 | 0.52 | 2 438.33 | 0.86 | 222 |
| 7 | Vietnam | 27.17 | 361.30 | 0.44 | 2 205.98 | 0.70 | 225 |
| 8 | Pakistan | 31.17 | 487.40 | 0.32 | 3 931.40 | 0.70 | 143 |
| 9 | Thailand | 32.33 | 164.20 | 0.25 | 7 480.76 | 1.05 | 217 |
| 10 | Guatemala | 32.50 | 83.35 | 0.66 | 407.76 | 0.50 | 88 |

Source: Global Climate RISK Index 2016

The year 2014 witnesses a number of climate change episodes resulting in not only in a great loss of human lives but also the severe economic losses. The five most affected countries in this report are Serbia, Afghanistan, Bosnia and Herzegovina, Philippines, Pakistan. These countries are followed by Bulgaria, Nepal, Burundi, Bolovia, and India. The following Table 2 shows 10 the most affected countries in the last 20 years with their CRI ranking for 2014 (CRI score).

**Table 2 - Climate Risk Index (CRI) for 2014: 10 most affected countries (annual averages)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Ranking  2014 | Country | CRI  score | Death toll | Deaths per  100 000 inhabitants | Absolute losses  (in million  US$ PPP) | Losses per unit GDP  in % | Human Development Index 2014 |
| 1 | Serbia | 8.17 | 59 | 0.8236 | 3 300.307 | 3.4435 | 77 |
| 2 | Afghanistan | 10.67 | 434 | 1.3875 | 337.085 | 0.5543 | 169 |
| 3 | Bosnia and  Herzegovina | 11.50 | 26 | 0.6717 | 3 584.776 | 9.3617 | 86 |
| 4 | Philippines | 12.50 | 328 | 0.3299 | 3 312.686 | 0.4777 | 117 |
| 5 | Pakistan | 12.67 | 1 227 | 0.6590 | 2 220.527 | 0.2511 | 146 |
| 6 | Bulgaria | 13.83 | 31 | 0.4304 | 2 383.604 | 1.8463 | 58 |
| 7 | Nepal | 15.83 | 533 | 1.8962 | 143.101 | 0.2131 | 145 |
| 8 | Burundi | 16.00 | 80 | 0.8695 | 73.382 | 0.8727 | 180 |
| 8 | Bolivia | 16.00 | 47 | 0.4162 | 449.454 | 0.6395 | 113 |
| 10 | India | 16.17 | 1 863 | 0.1460 | 36 950.507 | 0.4986 | 135 |

Source: Global Climate Risk Index 2016

In March 2014, low rainfalls resulted in food insecurity for the poor households in Pakistan. In the same year, heavy monsoon rains caused severe floods in September resulting in 367 deaths. It affected around 2.5 million people, and it destroyed around 130, 000 houses and around 1 million acres of the agriculture land. Pakistan is threatened by the extreme weather events each year, and the problem is worsened because of the insufficient climate change mitigating efforts.

**Objective of the Study**

In the Paris Summit 2015, many governments have signaled to end the era of fossil fuel consumption. It is first time that so many governments are committing for a universal agreement. In doing so, the collective efforts might reduce the dangerous effects of the changing climate. However, it is hard to devise a solid mechanism for concrete environmental protection.

Carbon pricing is linked directly to the carbon emissions. It indicates the marginal cost faced by a carbon emitter firm. Through the carbon tax, market signals would force carbon emitters to shift towards other kinds of clean fuels. In a way, the policy of carbon taxing is a step forward towards a green globe. Hence, the present study aims to find out the carbon tax for Pakistan and rest of the World given the Paris Summit 2015 CO2 reduction targets.

**Regional Analysis of CO2 Emissions in South Asia**

There are three basic sources of CO2 emissions in South Asia: natural gas, coal and petroleum products. The historical data shows that India is the biggest source of CO2 emissions in South Asia, while Pakistan and Bangladesh stand at second and third positions, respectively. In the year 2013, India added around 104 million metric tons of CO2 emissions in the environment while Pakistan and Bangladesh added around 65 million metric tons and 45 million metric tons of CO2 emissions respectively (see Figure 1).

**Figure 1: CO2 Emissions from Natural Gas Consumption**

**(Million Metric Tons)**

Source: US Energy Information Administration

On the other hand, analyzing the CO2 emissions form the coal consumption reveals that India again is the biggest producer of CO2 emissions in South Asia while rest of the countries contribute very negligible amounts of CO2 emissions. From 2008 to 2012; India added around 991.3 million metric tons in 2008, 1123.1 million metric tons in 2009, 1159.9 million metric tons in 2010, 1212.3 million metric tons in 2011 and 1280 million metric tons in 2012 (see Figure 2).

**Figure 2: CO2 Emissions from Coal Consumption**

**(Million Metric Tons)**

Source: US Energy Information Administration

Analyzing the CO2 emissions from the petroleum products show that India augments the highest amount of CO2 emissions in South Asia compared to the combined total of rest of other South Asian countries. On the other hand; Pakistan, Bangladesh and Sri Lanka also augment little CO2 emissions in the environment. For the year 2012; India, Pakistan, Bangladesh and Sri Lanka contributed around 443 million metric tons, 68 million metric tons, 18 million metric tons and 14 metric tons of CO2 emissions, respectively (see Figure 3).

**Figure 3: CO2 Emissions from Petroleum Consumption**

**(Million Metric Tons)**

Source: US Energy Information Administration

**Climate mitigation through the carbon tax**

Carbon tax is the most useful tool that helps governments to reduce the carbon emissions in the environment. In practice, it places a fee on the greenhouse gas pollution resulting from the burning of fossil fuels. Thus, a carbon tax places a monetary price on the use of carbon. It encourages households, businesses and the industry towards clean technologies, the use of energy-efficient products increases which spurs investment in green solutions.  
  
This system strengthens the economic signal that encourage the green choices. For instance, a stronger price on carbon emissions will encourage more investment in the clean energy sources (solar energy and wind power etc.). Making the polluting activities more expensive, a carbon tax makes the green technologies more reasonable through the rising price signals over time. Hence, a carbon tax puts the green solutions into practice. However, the number of countries that have introduced carbon tax is limited. The following table describes the countries that have imposed carbon tax, the year adopted, coverage of carbon tax, and its tax rate.

**Current Status of Carbon Taxes in Various Countries**

A carbon tax is an explicit form of carbon pricing where a tax is linked directly to the carbon emissions. It provides certainty about the marginal cost faced by the carbon emitter firms. However, this policy is unable to restrict the level of carbon emissions to a certain level. The carbon tax produces market signals that guide carbon emitters to shift towards other kinds of fuels with lesser carbon content. Hence, the policy of carbon taxing is a step forward towards a green economy. Carbon taxes vary from country to country, following Table 3 provides a list of countries where carbon taxes are applicable and their coverage area.

**Table 3: Countries with Carbon Tax**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Country/Jurisdiction** | | | **Type** | **Year**  **Adopted** | **Coverage** | **Tax Rate** | |
| 1 | | British Columbia | Sub- national | 2008 | Carbon tax applies to the purchase (use) of fuels within the province. It is revenue neutral such that all the funds generated by this tax are returned to the citizens by reducing other taxes. | CAD 30 per tCO2e (2012) | |
| 2 | | Chile | National | 2014 | Chile enacted legislation, and it is to start from thermal power plants in 2017, and from the power sector in 2018. | USD5 per  tCO2e (2018) | |
| 3 | | Costa Rica | National | 1997 | Costa Rica enacted carbon tax in 1997, set at 3.5% of market value of the fossil fuels. The tax generated revenues goes to the Payment for Environmental Services (PSA) program. | 3.5% tax on hydrocarbon  fossil fuels | |
| 4 | | Denmark | National | 1992 | Carbon tax covers the use of all fossil fuels (coal, natural gas, oil), but with partial exemptions and refund. Fuels used as input for electricity production are also not carbon taxed. | USD31 per tCO2e (2014) | |
| 5 | | Finland | National | 1990 | Finland combines its carbon tax with energy tax. Initially applied to the heat and electricity production, but later it was expanded to transportation and heating fuels. | EUR 35 per  tCO2e (2013) | |
| 6 | | France | National | 2014 | Carbon tax was introduced on gas, heavy fuel oil, and coal. It going to increase from €7/tCO2 in 2014 to EUR14.5/tCO2 in 2015 and EUR 22/tCO2 in 2016. From 2015 onwards, carbon tax will be expanded to heating oil and transport fuels. | EUR7 per tCO2e (2014) | |
| 7 | | Iceland | National | 2010 | All imported fossil fuels (aircraft and jet fuels, gas, diesel oils, and petrol) are liable for carbon tax. | USD10 per  tCO2e (2014) | |
| 8 | | Ireland | National | 2010 | The tax applies to auto-diesel, aviation gasoline, coal and peat, fuel oil, heavy oil, kerosene, liquid petroleum gas (LPG), natural gas, and petrol. | EUR 20 per tCO2e (2013) | |
| 9 | | Japan | National | 2012 | The carbon tax covers all fossil fuels such as coal, natural gas, and oil. | USD2 per  tCO2e (2014) | |
| 10 | | Mexico | | National | 2012 | The carbon tax rate is 3% of the sales price of the fossil fuels. However the natural gas is not subject to the carbon tax. | Mex$ 10 -50  per tCO2e (2014)  \* Depending on fuel type |
| 11 | | Norway | | National | 1991 | Norway covers 55% of its CO2 emissions through carbon tax. Emissions that are not covered include ETS (EU Emission Trading System) linked to the European ETS in 2008. | USD 4-69 per tCO2e (2014) |
| 12 | | South Africa | | National | 2016 | The carbon tax is to cover all the GHG emissions from fuel combustion and non-energy industrial process emissions. | R120/tCO2 (Proposed tax rate (2016) |
| 13 | | Sweden | | National | 1991 | Major carbon taxed sectors include: coal, gasoline, home heating oil, light and heavy fuel oil, liquefied petroleum gas (LPG), and natural gas. | USD168 per  tCO2e (2014) |
| 14 | | Switzerland | | National | 2008 | The carbon tax covers all the fossil fuels, except used for energy. However, there are ETS exemptions. | USD 68 per  tCO2e (2014) |
| 15 | | United Kingdom | | National | 2013 | Carbon tax on fossil fuels consumption to generate electricity. Carbon tax rate applied to gas, liquefied petroleum gas (LPG), and solid fuels used in electricity generation. | USD15.75  per tCO2e (2014) |
| 16 | | India | | National | 2010 | Petrol, Diesel, and coal. | USD 60/ton of CO2 for petrol, USD 42/ton for diesel, USD 1/ton for coal (2014). |
| 17 | | Zimbabwe | | National | -- | Petroleum and diesel products. | USD 0.03/liter of petroleum & diesel products or 5% of the cost, insurance and freight price whichever is greater. |

Sources: World Bank[[7]](#footnote-7), India Budget[[8]](#footnote-8), Zimbabwe Revenue Authority[[9]](#footnote-9).

**Carbon Taxes in Pakistan**

In the past, a few Pakistani politicians have provided their view point about carbon taxes but in a limited way. In November 2015, Mr. Sartaj Aziz (the former finance minister) proposed a carbon tax for all fuel prices at the rate of 1 cent per unit of fuel. This view was supported form the fact that the number of countries is increasing rapidly to curtail greenhouse gas emissions along with the generation of revenues for the mitigation measures obligatory for a concrete changing climate policy. However, there was no practical implementation of this suggestion.[[10]](#footnote-10)

However, the Supreme Court of Pakistan suspended parliament's decision about levying carbon tax on petroleum products via budgetary action in 2009. The proposed carbon tax for petrol, diesel and kerosene was PKR 10 (1 cent), PKR 8 (8 cents) and over PKR 6 (6 cents), respectively. Finally, the Supreme Court of Pakistan ordered the Oil and Gas Regulatory Authority (OGRA) to remove this carbon tax. The following Tables 4-5 provides the details of the proposed carbon taxes.

**Table 4: Proposed Structure for Petrol Price (PKR Currency Unit)**

|  |  |  |
| --- | --- | --- |
| Pricing Structure | Prevailing Petrol Price | [Supreme Court Puts Proposed Carbon Tax On Hold](http://www.dawn.com/news/848411/supreme-court-puts-carbon-tax-on-hold) (Prices in PKR) |
| Ex-refinery Price | 31.9 | 36.6 |
| Petroleum Development Levy (PDL) | 10.5 |  |
| Sales Tax | 7.8 | 8.6 |
| Oil Marketing Companies Margin (OMCM) | 1.4 | 1.6 |
| Dealer's Commission | 1.7 | 2.0 |
| Inland Freight Charges | 2.9 | 3.4 |
| **CARBON TAX** | **--** | **10.0** |
| Total Price | 56.2 | 62.1 |

Source: <http://www.dawn.com/news/848411/supreme-court-puts-carbon-tax-on-hold> (Accessed on: Feb 1, 2016)

**Table 5: Proposed Structure for Diesel Price (PKR Currency Unit)**

|  |  |  |
| --- | --- | --- |
|  | Prevailing Diesel Price | [Supreme Court Puts Proposed Carbon Tax On Hold](http://www.dawn.com/news/848411/supreme-court-puts-carbon-tax-on-hold) |
| Ex-refinery Price | 34.8 | 40.9 |
| Petroleum Development Levy (PDL) | 8.5 |  |
| Sales Tax | 7.7 | 8.6 |
| Oil Marketing Companies Margin (OMCM) | 1.4 | 1.4 |
| Dealer's Commission | 1.5 | 1.5 |
| Inland Freight Charges | 2.2 | 2.2 |
| **CARBON TAX** | **--** | **8.0** |
| Total Price | 56.1 | 62.7 |

Source: <http://www.dawn.com/news/848411/supreme-court-puts-carbon-tax-on-hold> (Accessed on: Feb 1, 2016)

**Literature Review**

If climate change follows the same path and there is no effort to fix this problem, it can cause severe socioeconomic losses in future. Therefore, the world should work together to reduce the fossil fuel consumption which is the main reason behind the climate change. Fossil fuel consumption can be reduced if countries shift their energy consumption away from fossil fuels while move towards the renewable energy sources. On the other hand, greenhouse gases can be reduced by reducing the energy demands and increasing energy efficiency.

Both of these mechanisms have different economic implications. The private sector would increase investment in renewable energy sector, if the governments put a tax on fossil fuels. Later, the revenue from this tax can be used to subsidize the renewable initiatives. On the other hand, there are a lot of options to reduce the energy demand, but the commonly used method is the carbon taxing. However, such a policy raises concerns in the developing countries. The carbon taxing increases the cost of doing business. Hence, the business activity would be disturbed. Summing up, most of the economists believe that a price (tax) on carbon is an important policy tool to fix the climate change problem. The following Table 6 highlights the finding of various studies, and provides the economic implications of the carbon taxing.

**Table 6: Carbon Taxing in Various Regions across the Globe**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S. No. | Name | Period | Country | Methodology | Findings |
| 1 | Vera & Sauma  (2015) | 2014 | Chile | OSE2000 Model Simulations | The carbon tax of $5/Ton CO2 reduces CO2 emissions by 1% but it increases system marginal cost by 3.4% during the period of 2014-24. |
| 2 | Murray & Rivers  (2015) | 2011 Primary Survey Data | British Columbia | Linear Probability Model | Carbon tax of C$30/t CO2 has reduced the CO2 emissions by 5%-15% since implemented. The carbon tax has a negligible impact on the economy. |
| 3 | Rivers & Schaufele  (2015) | 1990-2011 | North America | Log-linear Model | During the first four years, carbon tax reduced CO2 emissions from gasoline consumption by around 2.4 million tons. |
| 4 | Liu et al., (2015) | 2012-13 Survey Data of 201 companies | China | Latent Class Model | A carbon tax rate of 10–30 Yuan/t-CO2 would be an optimal carbon tax rate which is more realistic. |
| 5 | Beck et al., (2015) | 2012 | British Columbia | CGE | The carbon tax of $30/t on is highly progressive because of its negative impact on households with income below-median is smaller than the households with income above-median. |
| 6 | Martin et al., (2014) | 1993-2004 Micro-data | UK | Pooled OLS | The carbon tax reduces energy intensity around 18.1% and electricity consumption around 22.6%. There is no evidence of negative impact on employment level. |
| 7 | Dray et al., (2014) | 2006-2009 | The Whole World | Aviation Integrated Model | By 2050, carbon taxes can reduce CO2 emissions by up to 34% in aviation industry. |
| 8 | Cabalu et al., (2015) | 2010 | Philippines | CGE | A carbon tax of $US5/ton of CO2 emissions reduces 9.8% emissions, while the GDP falls by 0.5%. |
| 9 | Lim & Kim (2012) | 2008 | Korea | CGE | Across-the-board R&D subsidy can increase carbon intensity, but R&D subsidy with a focus on carbon tax may reduce carbon intensity while reducing the mitigation cost. |
| 10 | Jiang & Shao (2014) | *2012* | China | *Suits Index* | Imposing the carbon tax on fossil fuel consumption can increase income inequality. |
| 11 | Guo et al., (2014) | 2010 | China | CGE | The carbon taxes can reduce the carbon emission significantly. |
| 12 | Jenkins (2014) | *2013* | USA | Theoretical Political- economy Frameworks | The household are willingness to pay for the climate policy in the range of around $80–$200 annually. Hence, the carbon prices can face political constrains as low as of around $2–$8 per ton of CO2 emissions. |
| 13 | David & Montag (2014) | 2013 | EU | 2SLS | The social cost of CO2 emissions from petrol and diesel range from Euro 0.05 to Euro 0.75 and Euro 0.06 to Euro 0.86 respectively. |
| 14 | Lee et al., (2013) | 2010 | China, USA, Asia, South America | GTAP-E | China can suffer the greatest loss in real GDP among all the countries. For a $90/tCO2 global maritime carbon tax, real GDP loss to China can be around 0.02%. |
| 15 | Zhou (2013) | 2004 | Japan | CGE | The carbon tax can reduce the domestic emissions, but it can also trigger the carbon leakage resulting in higher global emissions. |
| 16 | Zhou (2011) | 2007 | China | CGE | A carbon tax of 30, 60, and 90 RMB/ton can reduce CO2 emissions by 4.5%, 8.5%, and 12.2% along with a drop in GDP growth rate by 0.1%, 0.3%, and 0.4% until 2020, respectively. |
| 17 | Zhao (2011) | 1993-2005 | 21 OECD countries | Gravity Model | Carbon tax can have a negative impact on the competitiveness of energy-intensive industries operating globally. |

**GTAP Energy Model**

The standard GTAP model has no inter-fuel or fuel-factor (primary factor) substitution. Considering energy in GTAP model requires to address two important issues. First once is the choice between a *top-down* or *bottom-up* method. Second, it needs to address the issue of complementarity or substitutability between capital and energy inputs over-time.

**Top-Down/ Bottom-Up Approach**

Energy can be incorporated into the GTAP model through two different ways. The bottom-up (also famous as engineering) approach which normally starts with a detailed structure of energy-producing technologies. Given a specified demand for energy services (such as air-conditioning, heating, lighting, steel making, travel, etc.), it investigates about the most efficient way to meet this demand through the energy technology and the use of inputs. The top-down (macro-economic or computable general equilibrium) approach, first describes the macro-economy in detail. From there, it derives demand for energy inputs in various sectors through aggregate production (cost) functions.

The bottom-up approach can specify detailed energy technologies, which is helpful to incorporate newly developed (future) technologies into the analysis. This way provides a more realistic approach than an econometric-specified production function in the top-down approach. However, the top-down approach claims the benefit of using the historical evidence while assumed a behavioral response in production function, while the bottom-up approach may lack such a behavioral content.

For a concrete analysis, a top-down model can be connected to a bottom-up model. Solving these two models simultaneously can combine advantages of both methods. However, such a linkage comes with many theoretical/computational difficulties. For this reason, sometimes a partial link can be pursued or a simulation can be run. Though these partial approaches come with a few certain advantages. However it results in a complexity model, which requires more data and parameters. Because of such difficulties, it is suggested to use a simple top-down model which can unite most of the important features of the top-down models.

**Relation between Energy and Capital: Complementary or Substitutionary**

As it is obvious that a top-down approach can represent energy-substitution in the model in a better way. The next step is to choose a structure which could represent a possible substitution between alternative energy fuels (such as inter-fuel substitution) and also between energy aggregate and the remaining primary factors, which possibly may include capital and labor (also known as fuel-factor substitution). However, in literature, energy-capital complementarity or substitutability specification is a major challenge. In the following paragraphs, the present section would focus on this issue from a theoretical perspective.

Energy-capital complementarity/substitutability issue may become crucial if one needs to adjust aggregate output resulting from an energy price change (Vinals, 1984). The key parameter determining the change in output produced after an energy price shock is based on complementarity/substitutability relationship between energy and capital (measured by the EK parameter). Other than the theoretical debate about the EK parameter, empirical research estimating this parameter has many challenges. Both the sign and magnitude of the EK parameter may vary over a long range among various studies.

This problem arises because energy and capital have a long-term substitutionary adjustment process. Therefore, an empirical research should find a solution of how short-term energy consumption can be adjusted dynamically to an optimal point in the long-run. Such an adjustment is based on the level of investment. As a result, capital should also adjust to the expected change in energy prices in the long-run.

Hogan (1989) shows that a proper description of a dynamic capital-energy consumption structure can provide more accurate estimates of inter-fuel substitution elasticities and energy-factor substitution elasticities. The main idea is that a model should be flexible in energy usage in the long-run, however it should also allow short-run rigidity due to capital constraint.

There are two factors resulting in inflexible capital adjustment; technological factors and adjustment costs. This inflexibility can be described by technology (process) model. On the other hand, capital can also be added directly in the economic model for the long-run adjustment process (Burniaux, et al., 1992). However, it is always hard to have empirical estimates for EK parameter in these models, because of the uncertainty of energy-capital substitutability or complementarity issue.

**The Structure of Production Process with Energy Substitution**

During the production process, energy should be taken out of intermediate inputs group to incorporate into value-added group nest (Figures 4-5). The energy is incorporated into the value-added nest in two steps. First, energy commodities are separated into electricity and non-electricity group, allowing some degree of substitution within the non-electricity group and also between electricity and non-electricity groups (Babiker, et al., 1997).

Primary energy (including coal, gas, and crude oil) can be used not only as energy input for different industrial and household activities, but also as a feedstock. In the latter case, chemical content of an energy input (for example natural gas) can become a part of output commodity (for example fertilizer).

In the next step, energy group is combined with capital producing an energy-capital composite. This composite is then combined with various other primary factors in the value-added-energy nest through a CES (Constant Elasticity Substitution) structure (see Figure 6). However, the elasticity of substitution between capital and energy composite is assumed positive. Given that the value of elasticity in capital energy nest is lower than Value-Addition-Energy nest, overall substitution elasticity (at the outer nest) between capital and energy might be negative (Borge & Goulder, 1984). More precisely, Keller (1980) specifies the connection between the inner nest and outer nest elasticity of substitution. It is as follows:

σ KE −outer = [σ KE −inner − σ VAE ] / S KE + σ VAE / SVAE

Where SKE is cost share of KE-composite in outer nest (value-added), KE-inner and KE-outer specify inner and outer substitution-elasticities between capital and energy respectively.

Figure 4: Standard GTAP Production Structure

Output

σ = 0

Value-added All other inputs

σVA

(including energy inputs)

σD

Land Labor

Capital

Domestic

Foreign

σM

Region 1 …

Region r

Figure 5: GTAP–E Production Structure

Output

σ = 0

Value-added-Energy

(Including energy inputs)

σVAE

All other inputs (Excluding energy inputs but including energy feedstock)

σD

Natural

Resource

Lan Labor

σ

LAB

Capital-Energy

Composite

Domestic

Foreign

σM

Skille Uskilled

Region 1

… Region r

Figure 6 GTAP–E Capital-Energy Composite Structure

Capital-Energy Composite

σKE

Capital Energy Composite

σENER = 1.0

Non- Electric

σNELY =0.5

Electric

σD

σ

Coal σD

Non-Coal

σNCOL =

Domesti

σNCOL=1.0

Foreign

Domestic

Foreign

σM

Gas

…

Oil

…

Petroleum products

σD

Region 1

… Region r

Region 1 Region

Domestic

Foreign

σM

Region 1 …

Region

Finally, the Armington elasticities show the substitution between domestic goods and imported good (σD), and also among imported goods from various regions (σM).

**Consumption Structure**

The consumption structure of the standard GTAP model assumes private consumption separately from the government consumption (households consuming publicly provided goods) and the private savings. The government spending is Cobb- Douglas in nature with respect to other commodities. In the GTAP-energy model, energy and non-energy commodities are separated with a nested-CES function (see Figure 7).[[11]](#footnote-11) Normally GEN ≠ GENNE ≠ 1, so that the GTAP energy model can facilitate varying substitution elasticities between energy and non-energy. The current GTAP energy model has adopted the following values: GEN equals 1 while and GENNE equals 0.5. This arrangement is similar to the household demand provided by Rutherford et al., (1997), and Bohringer & Pahlke (1997).

Figure 7: GTAP-E Government Purchases

Demand for composite

σGENNE = 0.5

Energy composite Non-energy composite

σGEN = 1

σGNE = 1

Coal

σD

....

....

....

.... ....

Domestic Foreign

σM

Region r

....

Region r

Private household consumption is structured following the constant-difference elasticity (CDE) functional form. Within a CDE structure, if energy commodities have the same income and same substitution parameters, in this case the CDE structure can aggregate these commodities into a single composite form with same parameters like the individual parameters. In the current GTAP model, four out of five energy commodities (such as coal, gas, oil, and electricity) have similar parameters, different from the petroleum and coal products.

In this situation, energy commodities can be aggregated into a composite, where the CDE parameter values are the same as the individual energy commodities. For a flexible substitution between individual energy commodities, now energy composite is specified as a CES sub-structure. Following Rutherford et al. (1997), it has a substitution elasticity of 1, similar to the value of GEN (see Figure 8).

Figure 8: GTAP-E Household Private Purchases

Household demand for

Private Goods

CDE

Energy composite

σPEN (CES)= 1

Non-energy commodities

σD

Coal

σD

.... ....

Domestic Foreign

σM

Domestic Foreign

σM

Region r

....

Region r

Region r

....

Region

**Description of the Data Base**

The GTAP (Global Trade Analysis Project) data base is a fully documented and publicly available global data base. It contains a global data base of environment, economy, transport, bilateral trade information, and protection linkages. The present study uses the latest version of the GTAP V9 data base released in 2016.[[12]](#footnote-12) It contains the data base of 140 regions and 57 commodities for each region.

The newly added regions in the latest version of the GTAP data base include: Benin, Burkina Faso, Guinea, Togo, Rwanda, Brunei Darussalam, Jordan, Dominican Republic, Jamaica, Puerto Rico, and Trinidad and Tobago. In addition, the updated/improved regions include: Brazil, Colombia, Paraguay, Belarus, Pakistan, Turkey, China, Japan, Korea, Singapore, Taiwan, Australia, New Zealand, Norway, Malawi, Mozambique, Nigeria, Senegal, Tanzania, and Zambia. A detailed description of the data base it available in the Annex.

**Results of the GTAP-E V9 Simulations**

The results in this section are based on two scenarios. In scenario 1 (benchmark case), there is no trade among the countries. Hence, all the countries are bound to meet their Paris Summit 2015 targets without relying on the flexibility mechanisms. On the other hand, the scenario 2 allows the use of flexibility mechanisms such as ET (Emission Trading) and JI (Joint Implementation). These flexibility mechanisms help countries to reduce the marginal abatement costs through international trade. The carbon emission restrictions for both of the scenarios are the same.

Table 7 discusses the emission reduction in the scenario 1 (no trade) and the scenario 2 (global trade) along with the marginal abatement costs. In the no trade scenario, the marginal abatement costs are higher for EU27, China and Korea and the costs are $ 222.84, $ 144.84 and $ 134.74 per ton of CO2 emission, respectively. It is interesting to note that even though a few countries (regions) have zero emission reduction targets, still these countries has some positive real carbon tax rates such as Pakistan, Nepal, EEFSU and the Rest of the World. It indicates that these countries have a higher tendency for positive carbon emissions. To halt any addition in carbon emissions, these countries require to impose some real carbon tax.

On the other hand, the global trade reduces the marginal abatement costs among the trading countries. Although the ET and JI programs motivate many countries to reduce their carbon emissions while they encourage other countries to increase their carbon consumption. For example, the flexible trade mechanism reduces the carbon emissions in Pakistan, Bangladesh, Nepal, Sri Lanka, India, United States, EEFSU, and EEx while it increases the carbon emissions in Rest of the World. It is because of low marginal abatement costs in Pakistan, Bangladesh, Nepal, Sri Lanka, India, United States, EEFSU, EEx and higher marginal abatement costs in Rest of the World. Hence, the countries with lower marginal abatement costs sells carbon permits to the other countries with higher marginal abatement costs and earns money.

Many countries receive a lot of advantage from the global trade as it reduces their marginal abatement costs. These costs are reduced from $134.7 to $59.2 per ton of CO2 emissions for Korea, $144.8 to $59.7 per ton of CO2 emissions for China, $ 127.8 to $ 59.2 per ton of CO2 emissions for Japan, $ 222.8 to $ 59.3 to per ton of CO2 emissions for EU27 and $ 121.7 to $ 59.7 per ton of CO2 emissions for RoA1.

**Table 7: Emission Reduction and Real Carbon Rates**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Scenario 1 (No Trade) | | Scenario 2 (World Trade) | |
| Countries | Emission Reduction    (in %) | Real Carbon Tax Rate  ($ per ton of  CO2 emissions) | Emission Reduction  (in %) | Real Carbon Tax Rate  ($ per ton of  CO2 emissions) |
| PAK | 0.00 | 3.10 | -20.37 | 58.40 |
| BGD | -5.00 | 20.32 | -14.02 | 58.94 |
| NPL | 0.00 | 10.18 | -17.71 | 58.31 |
| SRI | -7.00 | 55.30 | -8.49 | 58.49 |
| IND | -35.00 | 14.22 | -52.96 | 58.79 |
| KOR | -37.00 | 134.73 | -22.09 | 59.27 |
| CHN | -65.00 | 144.84 | -49.84 | 59.76 |
| JPN | -26.00 | 127.86 | -14.15 | 59.26 |
| USA | -28.00 | 53.78 | -30.23 | 59.22 |
| EU27 | -40.00 | 222.84 | -15.82 | 59.32 |
| EEFSU | 0.00 | 5.55 | -29.62 | 59.40 |
| RoA1 | -36.00 | 121.75 | -23.09 | 59.72 |
| EEx | -10.00 | 14.47 | -28.25 | 59.68 |
| ROW | 0.00 | 5.20 | -22.17 | 59.32 |

Table 8 states the macroeconomic costs resulting from the implementation of carbon constraints. These costs have been provided in terms of equivalent variation (a welfare indicator) and the terms of trade. In the absence of flexibility mechanisms (no trade scenario), all the countries (regions) face less welfare level compared to the flexibility mechanism (world trade scenario). The improved terms of trade is a good indicator of change in overall welfare. Higher terms of trade indicate more welfare and vice versa.

Despite the fact that the EEFSU countries has no binding carbon constraint, but it has a negative welfare loss arising from the absence of flexible mechanism. Perhaps the main reasons behind this fact is the drop in energy exports resulting into deteriorating terms of trade. However, the flexible trade mechanism has improved the terms of trade by 2.44%. Emission trading through the flexible mechanisms save globally around $ 400 billion. Through this trading, major benefit goes to EU27, EEFSU, China, EEx as these countries save around $ 157 billion, $ 68 billion, $ 40.4 billion, and $ 42.4 billion respectively.

**Table 8: Equivalent Variation and Terms of Trade**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Equivalent Variation ($ Million) | | Terms of Trade (in %) | |
| Countries | Scenario 1  (No Trade) | Scenario 2  (World Trade) | Scenario 1  (No Trade) | Scenario 2  (World Trade) |
| PAK | 522.05 | 2076.47 | 0.82 | 2.07 |
| BGD | -296.39 | -255.35 | -0.12 | 0.36 |
| NPL | 41.52 | 134.99 | 0.69 | 2.52 |
| SRI | 356.94 | 358.58 | 1.73 | 1.70 |
| IND | 381.99 | 15901.09 | 0.44 | 2.15 |
| KOR | -1525.57 | -1384.40 | 2.09 | 1.33 |
| CHN | -205345 | -164948.00 | 1.16 | 0.27 |
| JPN | -20063.1 | -5077.79 | 2.08 | 1.53 |
| USA | -36200 | -28946.10 | 0.7 | 1.01 |
| EU27 | -225000 | -67996.70 | 1.47 | 0.55 |
| EEFSU | -65308.8 | 2738.99 | -4.81 | -2.37 |
| RoA1 | -41931 | -30973.30 | -0.87 | -0.72 |
| EEx | -101077 | -58654.70 | -3.98 | -3.00 |
| ROW | -32348.5 | 9271.96 | -1.09 | 0.03 |

The improved terms of trade is an indicator of appreciating currency while the welfare is associated with consumption level. A higher consumption level means rising welfare level. However, if the consumption level is increasing through imports it would destabilize the economy in the long-run. Therefore, it is important to analyze the real GDP. It is a macroeconomic indicator which shows the overall macroeconomic stability of a country.

Table 9 states the change in real GDP of each country (region) with and without the world trade. The results state that the real GDP growth rate is negative in both scenarios (no trade and world trade). However, the world trade scenario indicates less output losses compared to the no trade scenario. In addition, China, EU27, Korea are the biggest beneficiaries from the global trade which reduces their real GDP losses by 1.65%, 1.52% and 0.73%, respectively.

**Table 9: Change in Real GDP (in %)**

|  |  |  |
| --- | --- | --- |
| Countries | Scenario 1  (No Trade) | Scenario 2  (World Trade) |
| PAK | -0.01 | -0.24 |
| BGD | -0.20 | -0.54 |
| NPL | 0.00 | -0.16 |
| SRI | -0.03 | -0.03 |
| IND | -0.11 | -0.69 |
| KOR | -1.09 | -0.36 |
| CHN | -3.00 | -1.35 |
| JPN | -0.65 | -0.20 |
| USA | -0.34 | -0.38 |
| EU27 | -1.81 | -0.29 |
| EEFSU | -1.06 | -0.81 |
| RoA1 | -0.70 | -0.29 |
| EEx | -0.18 | -0.38 |
| ROW | -0.03 | -0.33 |

The change in GDP is linked with the domestic output production and net exports. Hence, it would be important to discuss both factors one by one. The Table 10 provides a detailed description of the change in domestic production due to the imposition of carbon restrictions in the absence of flexibility mechanism. Results show that coal, oil and oil products sectors are the most affected sectors. However, in a few countries (regions), the electricity sector is also negatively affected. This fact might be explained by the energy mix used in the electricity sector in these regions. A carbon based energy mix would definitely affect the production of electricity.

An interesting finding is the rising industrial production of the EEFSU in electricity, energy intensive industry, and the transport sectors. There are two factors which are the reasons for this increase in industrial production. First is the reduced volume of carbon related exports. This reduces the local price of such energy products, the local cost of production decreases resulting in higher domestic production. Second, the absence of carbon constraints makes the production of these products cheaper resulting in higher industrial production. However, such an impact is somehow weak for the EEx.

**Table 10: Decomposed Industrial Output of Scenario 1**

**(without World Trade, in %)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sectors/Countries (Regions) | PAK | BGD | NPL | SRI | IND | KOR | CHN |
| Agr | -0.23 | -0.32 | -0.06 | -0.48 | -0.04 | -2.53 | -1.69 |
| Coal | -3.60 | -33.25 | -27.46 | -33.62 | -68.44 | -49.81 | -68.45 |
| Oil | -13.01 | -20.57 | -6.18 | -13.38 | -6.56 | -13.20 | -17.09 |
| Gas | -2.58 | -5.98 | -10.48 | -22.42 | -16.79 | -64.47 | -100.00 |
| Oil\_pcts | 3.22 | -0.10 | -9.08 | -2.40 | 1.13 | -10.92 | -22.77 |
| Electricity | 0.72 | -3.06 | 1.65 | -3.46 | -5.0 | -29.94 | -46.42 |
| En\_Int\_ind | 0.86 | -2.76 | -1.47 | -1.62 | 0.43 | -8.57 | -14.04 |
| Oth\_Ind | -0.02 | -0.57 | -1.06 | -2.04 | -0.39 | -4.95 | -4.24 |
| Transport | 0.73 | 0.05 | 2.09 | -1.0 | 1.50 | -5.91 | -7.00 |
| Oth\_Ser | -0.19 | -0.23 | -0.11 | 0.40 | 0.10 | 0.05 | -1.63 |
| Sectors/ Countries (Regions) | JPN | USA | EU27 | EEFSU | RoA1 | EEx | ROW |
| Agr | -1.46 | -1.33 | -2.88 | 0.65 | -1.12 | 0.50 | -0.12 |
| Coal | -32.73 | -36.58 | -60.46 | -12.87 | -24.67 | -9.99 | -14.17 |
| Oil | -12.64 | -9.11 | -12.57 | -7.02 | -9.95 | -6.18 | -9.29 |
| Gas | -3.30 | -47.53 | -47.17 | -2.12 | -30.91 | -11.10 | -10.90 |
| Oil\_pcts | -9.95 | -8.21 | -17.49 | 0.65 | -20.49 | -0.85 | 4.51 |
| Electricity | -14.24 | -14.45 | -20.10 | 3.99 | -12.47 | -1.34 | 3.23 |
| En\_Int\_ind | -5.83 | -0.56 | -7.70 | 11.27 | -2.85 | 5.71 | 4.33 |
| Oth\_Ind | -3.07 | -1.05 | -2.61 | 2.41 | 0.65 | 2.73 | 0.18 |
| Transport | -2.93 | -4.48 | -13.78 | 2.04 | -6.83 | 2.48 | 4.01 |
| Oth\_Ser | -0.10 | 0.00 | -0.20 | -1.29 | -0.01 | -0.51 | -0.62 |

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| --- |
| It is important to sort out the impact of world trade after imposing the carbon constraints. The world trade enforces the flexibility mechanism and the countries with higher marginal abatement costs can buy carbon permits from other countries with lower marginal abatement costs. Hence, they can consume more carbon fuels resulting in higher industrial production. This fact is much obvious from the Table 11 which provides the decomposed industrial output in the presence of world trade.  The results show that losses in industrial production are reduced when a country buys the right to increase carbon from some other country. For instance, carbon reduction target for Korea is 37% but through the flexible mechanism its carbon reduction target reduces up to 22.09% (please see Table 1 for details). Hence, the industrial production of Korea in all the sectors improves in the presence of world trade compared to no trade scenario. This fact is also true for China, Japan, EU27, RoA1 as all of these countries increase their carbon emissions through flexible mechanism. Hence, it reduces their domestic industrial production losses. |

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| --- |
| **Table 11: Decomposed Industrial Output of Scenario 2**  **(with World Trade, in %)** |
| |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Sectors/Countries (Regions) | PAK | BGD | NPL | SRI | IND | KOR | CHN | | Agr | -1.16 | -0.64 | -0.27 | -0.38 | -0.40 | -1.18 | -0.57 | | Coal | -41.16 | -57.70 | -55.49 | -35.80 | -80.17 | -41.13 | -54.79 | | Oil | -25.19 | -23.85 | -10.65 | -13.38 | -9.09 | -9.09 | -9.98 | | Gas | -28.83 | -15.30 | -35.66 | -22.85 | -50.74 | -47.09 | -99.96 | | Oil\_pcts | -7.33 | -7.60 | -16.71 | -3.46 | -5.06 | -2.06 | -9.96 | | Electricity | -2.31 | -8.82 | 6.31 | -3.72 | -14.22 | -17.14 | -31.77 | | En\_Int\_ind | -13.16 | -11.51 | -9.74 | -1.88 | -8.74 | -2.08 | -6.59 | | Oth\_Ind | -0.39 | -1.55 | -3.72 | -1.75 | -2.26 | -2.58 | -1.46 | | Transport | -2.95 | -0.98 | -1.83 | -2.85 | -1.58 | -2.37 | -2.84 | | Oth\_Ser | -0.19 | -0.11 | 0.32 | 0.47 | 0.88 | -0.05 | -1.22 | |
| |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Sectors/ Countries (Regions) | JPN | USA | EU27 | EEFSU | RoA1 | EEx | ROW | | Agr | -0.67 | -1.20 | -0.84 | -0.68 | -0.26 | 0.24 | -0.36 | | Coal | -18.61 | -36.26 | -37.15 | -30.76 | -17.83 | -5.95 | -29.67 | | Oil | -9.85 | -8.96 | -7.23 | -5.89 | -7.51 | -4.9 | -8.02 | | Gas | -2.65 | -50.19 | -22.45 | -21.36 | -20.89 | -19.46 | -17.31 | | Oil\_pcts | -2.21 | -9.33 | -1.53 | -7.81 | -9.78 | -9.65 | -4.79 | | Electricity | -7.38 | -15.69 | -6.25 | -17.05 | -5.74 | -10.98 | -9.75 | | En\_Int\_ind | -1.48 | -1.42 | 0.16 | -12.79 | 0.52 | -1.08 | -2.07 | | Oth\_Ind | -1.63 | -1.23 | -0.97 | -1.48 | 0.69 | 1.42 | -0.72 | | Transport | -1.05 | -6.05 | -2.11 | -4.64 | -3.16 | -4.53 | -3.02 | | Oth\_Ser | -0.03 | 0.09 | -0.16 | 0.43 | -0.09 | 0.30 | 0.11 | |
|  |
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| --- |
| As the flexibility mechanisms provide a country to buy carbon permits from the other country, it changes the global exports structure too. In would be important to analyze the global exports structure after imposing the carbon emission restriction. The Table 12 provides the state of exports in the presence of flexibility mechanism. The results state that, on average, the exports of the products with higher carbon content such as coal, oil and oil products has reduced significantly while the exports of other products have increased such as electricity, energy intensive industry, and transport sectors. And the same is true for the imports. As the carbon constraints make the consumption of coal, oil and oil products expensive, it reduces their imports in the global trade. Resultantly, imports for electricity, energy intensive industry, other industry, transport and other services increase (please see Table 13).  **Table 12: Exports in Scenario 2 (with World Trade, in %)** |
| |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Sectors/Countries (Regions) | PAK | BGD | NPL | SRI | IND | KOR | CHN | | Agr | -4.48 | 0.48 | -3.98 | -1.11 | -1.88 | -0.64 | 4.84 | | Coal | -27.70 | 9.78 | 27.68 | -6.33 | 166.99 | 8.93 | -0.79 | | Oil | -47.37 | -34.83 | -40.22 | -26.34 | -18.36 | -20.25 | -10.77 | | Gas | -26.21 | 187.14 | -98.14 | -77.66 | 15.94 | -97.30 | -99.91 | | Oil\_pcts | -7.93 | -7.94 | -26.23 | -3.73 | -8.77 | -6.56 | -10.46 | | Electricity | 36.09 | 8.04 | 104.44 | 27.41 | 6.42 | -7.53 | -70.57 | | En\_Int\_ind | -19.27 | -19.29 | -15.06 | -1.44 | -11.56 | 1.82 | -5.85 | | Oth\_Ind | -4.13 | -0.34 | -9.70 | -3.56 | -6.06 | -1.54 | 2.90 | | Transport | 2.36 | 5.68 | -1.48 | -2.18 | 1.94 | 2.28 | 4.61 | | Oth\_Ser | -2.03 | 0.88 | -5.23 | -3.78 | -0.09 | 0.20 | 4.63 | | Sectors/ Countries (Regions) | JPN | USA | EU27 | EEFSU | RoA1 | EEx | ROW | | Agr | -0.22 | -0.71 | 0.81 | 1.39 | 0.57 | 1.66 | 0.57 | | Coal | -19.76 | -5.07 | -16.49 | -14.88 | -13.5 | 0.61 | 11.93 | | Oil | -24.88 | -12.73 | -15.03 | -8.51 | -10.62 | -8.08 | -13.21 | | Gas | -52.23 | 13.26 | -23.87 | 35.44 | -12.90 | 22.03 | 9.01 | | Oil\_pcts | -7.80 | -9.69 | -10.36 | -9.79 | -11.03 | -9.40 | -7.49 | | Electricity | 78.14 | -29.9 | 16.04 | -25.94 | 33.62 | -10.37 | 4.99 | | En\_Int\_ind | 2.22 | 2.38 | 3.74 | -12.08 | 4.30 | 2.96 | 0.97 | | Oth\_Ind | -1.54 | -0.82 | 0.72 | 1.00 | 3.63 | 5.76 | 0.70 | | Transport | 2.87 | -1.95 | 2.44 | 2.97 | 2.03 | -0.28 | 1.52 | | Oth\_Ser | -0.97 | 0.32 | 0.48 | 7.17 | 2.44 | 4.97 | 1.12 | |
|  |

**Table 13: Imports in Scenario 2 (with World Trade, in %)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sectors/ Countries  (Regions) | PAK | BGD | NPL | SRI | IND | KOR | CHN |
| Agr | 4.92 | 0.69 | 4.89 | 2.24 | 3.40 | 0.56 | -2.23 |
| Coal | -47.22 | -50.41 | -63.72 | -33.02 | 5.27 | -27.08 | 34.81 |
| Oil | -3.54 | -10.41 | -11.56 | -6.52 | -8.20 | -6.11 | -13.92 |
| Gas | 43.08 | -35.97 | 28.16 | -0.58 | 28.16 | -19.74 | 17.69 |
| Oil\_pcts | -6.05 | -5.16 | -7.19 | -8.91 | -9.48 | -6.33 | -9.57 |
| Electricity | -0.35 | 11.82 | -11.59 | 8.72 | 10.8 | 12.53 | 96.18 |
| En\_Int\_ind | 9.34 | 5.85 | 3.43 | 1.90 | 3.79 | 0.63 | 1.32 |
| Oth\_Ind | 4.76 | 1.19 | 6.53 | 3.19 | 4.84 | 1.55 | -1.37 |
| Transport | 3.24 | 0.43 | 6.51 | 7.42 | 3.55 | 2.07 | -2.84 |
| Oth\_Ser | 3.65 | -1.26 | 6.10 | 6.03 | 2.96 | 1.96 | -2.19 |
| Sectors/ Countries  (Regions) | JPN | USA | EU27 | EEFSU | RoA1 | EEx | ROW |
| Agr | 1.18 | 1.69 | 1.64 | 0.12 | 1.53 | 0.89 | 1.23 |
| Coal | -19.47 | -12.13 | -19.30 | 8.30 | -2.97 | -6.78 | -9.24 |
| Oil | -6.79 | -12.86 | -4.96 | -11.29 | -13.62 | -14.39 | -8.43 |
| Gas | -19.27 | 78.2 | -16.3 | 78.07 | 42.11 | 200.2 | 13.88 |
| Oil\_pcts | -8.29 | -9.18 | -11.12 | -9.39 | -6.46 | -5.51 | -9.31 |
| Electricity | -12.16 | 31.91 | 1.75 | 25.52 | 4.15 | 15.44 | 12.9 |
| En\_Int\_ind | 1.23 | 1.17 | 1.72 | 1.59 | 1.69 | 0.66 | 1.19 |
| Oth\_Ind | 2.63 | 2.42 | 1.71 | 0.21 | 0.41 | -0.75 | 1.20 |
| Transport | 1.24 | 3.45 | 1.74 | -0.45 | 0.86 | 2.26 | 2.29 |
| Oth\_Ser | 2.73 | 2.04 | 1.96 | -2.40 | 0.47 | -1.17 | 1.23 |

**Conclusion**

Through the flexibility mechanisms, countries can reduce their marginal abatement costs. In the no trade scenario, the marginal abatement costs are quite high for EU27, China and Korea and the costs are $ 222.84, $ 144.84 and $ 134.74 per ton of CO2 emission, respectively. Many countries receive a lot of advantage from the global trade as it reduces their marginal abatement costs. These costs are reduced from $ 134.7 to $ 59.2 per ton of CO2 emissions for Korea, $ 144.8 to $ 59.7 per ton of CO2 emissions for China, $ 127.8 to $ 59.2 per ton of CO2 emissions for Japan, $ 222.8 to $ 59.3 to per ton of CO2 emissions for EU27 and $ 121.7 to $ 59.7 per ton of CO2 emissions for RoA1. Emission trading through the flexible mechanisms save globally around $ 400 billion. Through this trading, EU27, EEFSU, China, EEx save around $ 157 billion, $ 68 billion, $ 40.4 billion, and $ 42.4 billion, respectively.

China, EU27, Korea are the biggest beneficiaries from the global trade which reduces their real GDP losses by 1.65%, 1.52% and 0.73%, respectively. The GDP losses are mainly because of the decrease in industrial production in coal, oil and oil products sectors. However, in a few countries (regions), the electricity sector is also negatively affected. This fact might be explained by the energy mix used in the electricity sector in these regions. For instance, a carbon intensive energy mix would definitely affect the production of electricity sector in this scenario.

The losses in industrial production, however, are reduced when a country buys the right to increase carbon from some other country through carbon permits (flexibility mechanisms). Hence, the industrial production of such countries improves in the presence of world trade compared to no trade scenario. This fact is also true for Korea, China, Japan, EU27, RoA1 as all of these countries increase their carbon emissions through flexible mechanism. In addition, exports (and imports) of the products with higher carbon content such as coal, oil and oil products reduce significantly while the exports (and import) of other products increase such as electricity, energy intensive industry, transport and service sectors.

It is interesting to note that even though a few countries (regions) have zero emission reduction targets, still these countries have some positive real carbon tax rates such as Pakistan, Nepal, EEFSU and the Rest of the World. It indicates that these countries have a higher tendency for positive carbon emissions. To halt any addition in carbon emissions, these countries are required to impose some minimum real carbon tax. Although the ET and JI programs motivate many countries to reduce their carbon emissions while they encourage the other countries to increase their carbon consumption. Such as the flexible trade mechanism reduces the carbon emissions in Pakistan, Bangladesh, Nepal, Sri Lanka, India, United States, EEFSU, and EEx while it increases the carbon emissions in Rest of the World.

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**Annex**

**GTAP Data Base Version 9**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| S. No. | Set of Regions | Regional Aggregation Mapping | Dissagregated Regions | Set of Traded Commodities | Sectoral Aggregation Mapping | Dissagregated Traded Commodities |
| 1 | PAK | RoA1 | aus | Agr | Agr | pdr |
| 2 | BGD | RoA1 | nzl | Coal | Agr | wht |
| 3 | NPL | ROW | xoc | Oil | Agr | gro |
| 4 | SRI | CHN | chn | Gas | Agr | v\_f |
| 5 | IND | CHN | hkg | Oil\_pcts | Agr | osd |
| 6 | KOR | JPN | jpn | Electricity | Agr | c\_b |
| 7 | CHN | KOR | kor | En\_Int\_ind | Agr | pfb |
| 8 | JPN | ROW | mng | Oth\_Ind | Agr | ocr |
| 9 | USA | ROW | twn | Transport | Agr | ctl |
| 10 | EU27 | ROW | xea | Oth\_Ser | Agr | oap |
| 11 | EEFSU | ROW | brn |  | Agr | rmk |
| 12 | RoA1 | ROW | khm |  | Agr | wol |
| 13 | EEx | EEx | idn |  | Agr | frs |
| 14 | ROW | ROW | lao |  | Agr | fsh |
| 15 |  | EEx | mys |  | Coal | coa |
| 16 |  | ROW | phl |  | Oil | oil |
| 17 |  | ROW | sgp |  | Gas | gas |
| 18 |  | ROW | tha |  | En\_Int\_ind | omn |
| 19 |  | EEx | vnm |  | Oth\_Ind | cmt |
| 20 |  | ROW | xse |  | Oth\_Ind | omt |
| 21 |  | BGD | bgd |  | Oth\_Ind | vol |
| 22 |  | IND | ind |  | Oth\_Ind | mil |
| 23 |  | NPL | npl |  | Oth\_Ind | pcr |
| 24 |  | PAK | pak |  | Oth\_Ind | sgr |
| 25 |  | SRI | lka |  | Oth\_Ind | ofd |
| 26 |  | ROW | xsa |  | Oth\_Ind | b\_t |
| 27 |  | RoA1 | can |  | Oth\_Ind | tex |
| 28 |  | USA | usa |  | Oth\_Ind | wap |
| 29 |  | EEx | mex |  | Oth\_Ind | lea |
| 30 |  | ROW | Xna |  | Oth\_Ind | lum |
| 31 |  | EEx | Arg |  | Oth\_Ind | ppp |
| 32 |  | EEx | Bol |  | Oil\_pcts | p\_c |
| 33 |  | ROW | Bra |  | En\_Int\_ind | crp |
| 34 |  | ROW | Chl |  | En\_Int\_ind | nmm |
| 35 |  | EEx | Col |  | En\_Int\_ind | i\_s |
| 36 |  | EEx | Ecu |  | En\_Int\_ind | nfm |
| 37 |  | ROW | Pry |  | Oth\_Ind | fmp |
| 38 |  | ROW | Per |  | Oth\_Ind | mvh |
| 39 |  | ROW | Ury |  | Oth\_Ind | otn |
| 40 |  | EEx | Ven |  | Oth\_Ind | ele |
| 41 |  | ROW | xsm |  | Oth\_Ind | ome |
| 42 |  | ROW | Cri |  | Oth\_Ind | omf |
| 43 |  | ROW | Gtm |  | Electricity | ely |
| 44 |  | ROW | hnd |  | Gas | gdt |
| 45 |  | ROW | Nic |  | Oth\_Ser | wtr |
| 46 |  | ROW | pan |  | Oth\_Ser | cns |
| 47 |  | ROW | Slv |  | Oth\_Ser | trd |
| 48 |  | ROW | Xca |  | Transport | otp |
| 49 |  | ROW | dom |  | Transport | wtp |
| 50 |  | ROW | Jam |  | Transport | atp |
| 51 |  | ROW | Pri |  | Oth\_Ser | cmn |
| 52 |  | ROW | Tto |  | Oth\_Ser | ofi |
| 53 |  | ROW | Xcb |  | Oth\_Ser | isr |
| 54 |  | EU27 | Aut |  | Oth\_Ser | obs |
| 55 |  | EU27 | Bel |  | Oth\_Ser | ros |
| 56 |  | EU27 | cyp |  | Oth\_Ser | osg |
| 57 |  | EU27 | cze |  | Oth\_Ser | dwe |
| 58 |  | EU27 | dnk |  |  |  |
| 59 |  | EU27 | est |  |  |  |
| 60 |  | EU27 | fin |  |  |  |
| 61 |  | EU27 | fra |  |  |  |
| 62 |  | EU27 | deu |  |  |  |
| 63 |  | EU27 | grc |  |  |  |
| 64 |  | EU27 | hun |  |  |  |
| 65 |  | EU27 | irl |  |  |  |
| 66 |  | EU27 | ita |  |  |  |
| 67 |  | EU27 | lva |  |  |  |
| 68 |  | EU27 | ltu |  |  |  |
| 69 |  | EU27 | lux |  |  |  |
| 70 |  | EU27 | mlt |  |  |  |
| 71 |  | EU27 | nld |  |  |  |
| 72 |  | EU27 | pol |  |  |  |
| 73 |  | EU27 | prt |  |  |  |
| 74 |  | EU27 | svk |  |  |  |
| 75 |  | EU27 | svn |  |  |  |
| 76 |  | EU27 | esp |  |  |  |
| 77 |  | EU27 | swe |  |  |  |
| 78 |  | EU27 | Gbr |  |  |  |
| 79 |  | RoA1 | Che |  |  |  |
| 80 |  | RoA1 | Nor |  |  |  |
| 81 |  | RoA1 | Xef |  |  |  |
| 82 |  | EEFSU | Alb |  |  |  |
| 83 |  | EU27 | Bgr |  |  |  |
| 84 |  | EEFSU | Blr |  |  |  |
| 85 |  | ROW | Hrv |  |  |  |
| 86 |  | EU27 | Rou |  |  |  |
| 87 |  | EEFSU | Rus |  |  |  |
| 88 |  | EEFSU | Ukr |  |  |  |
| 89 |  | EEFSU | Xee |  |  |  |
| 90 |  | EEFSU | Xer |  |  |  |
| 91 |  | EEFSU | Kaz |  |  |  |
| 92 |  | EEFSU | Kgz |  |  |  |
| 93 |  | EEFSU | Xsu |  |  |  |
| 94 |  | EEFSU | Arm |  |  |  |
| 95 |  | EEFSU | Aze |  |  |  |
| 96 |  | EEFSU | Geo |  |  |  |
| 97 |  | ROW | Bhr |  |  |  |
| 98 |  | EEx | Irn |  |  |  |
| 99 |  | ROW | Isr |  |  |  |
| 100 |  | EEx | Jor |  |  |  |
| 101 |  | EEx | Kwt |  |  |  |
| 102 |  | EEx | omn |  |  |  |
| 103 |  | EEx | Qat |  |  |  |
| 104 |  | EEx | Sau |  |  |  |
| 105 |  | ROW | Tur |  |  |  |
| 106 |  | EEx | Are |  |  |  |
| 107 |  | ROW | xws |  |  |  |
| 108 |  | EEx | Egy |  |  |  |
| 109 |  | ROW | mar |  |  |  |
| 110 |  | ROW | Tun |  |  |  |
| 111 |  | ROW | xnf |  |  |  |
| 112 |  | ROW | ben |  |  |  |
| 113 |  | ROW | Bfa |  |  |  |
| 114 |  | ROW | cmr |  |  |  |
| 115 |  | ROW | Civ |  |  |  |
| 116 |  | ROW | gha |  |  |  |
| 117 |  | ROW | Gin |  |  |  |
| 118 |  | EEx | nga |  |  |  |
| 119 |  | ROW | sen |  |  |  |
| 120 |  | ROW | Tgo |  |  |  |
| 121 |  | ROW | xwf |  |  |  |
| 122 |  | EEx | Xcf |  |  |  |
| 123 |  | ROW | Xac |  |  |  |
| 124 |  | ROW | Eth |  |  |  |
| 125 |  | ROW | Ken |  |  |  |
| 126 |  | ROW | mdg |  |  |  |
| 127 |  | ROW | mwi |  |  |  |
| 128 |  | ROW | mus |  |  |  |
| 129 |  | ROW | moz |  |  |  |
| 130 |  | ROW | rwa |  |  |  |
| 131 |  | ROW | tza |  |  |  |
| 132 |  | ROW | uga |  |  |  |
| 133 |  | ROW | zmb |  |  |  |
| 134 |  | ROW | zwe |  |  |  |
| 135 |  | ROW | xec |  |  |  |
| 136 |  | ROW | bwa |  |  |  |
| 137 |  | ROW | nam |  |  |  |
| 138 |  | ROW | zaf |  |  |  |
| 139 |  | ROW | xsc |  |  |  |
| 140 |  | ROW | xtw |  |  |  |

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2. <http://www.brecorder.com/top-stories/0/1152639/> [↑](#footnote-ref-2)
3. <http://tinyurl.com/h9ehlrc> [↑](#footnote-ref-3)
4. See The Global Commission on the Economy and Climate, 2014: The New Climate Economy Report: http://newclimateeconomy.report/TheNewClimateEconomyReport.pdf [↑](#footnote-ref-4)
5. Anemüller, S., Monreal S. and Bals, C. (2006): Global Climate Risk Index 2006. Germanwatch, Bonn;

   available at http: //germanwatch.org/en/3644 [↑](#footnote-ref-5)
6. Analyses of Columbia University: http://ciesin.columbia.edu/data/climate/, Maplecroft’s Climate Change Vulnerability Index: http://maplecroft.com/themes/cc/ [↑](#footnote-ref-6)
7. <http://tinyurl.com/msf9xaz> (Accessed on: January 28, 2016) [↑](#footnote-ref-7)
8. <http://indiabudget.nic.in/es2014-15/echapvol1-09.pdf> [↑](#footnote-ref-8)
9. <http://www.zimra.co.zw/index.php?option=com_content&view=article&id=32&Itemid=99> [↑](#footnote-ref-9)
10. <http://www.dawn.com/news/1217281> (Accessed on: Feb 2, 2016) [↑](#footnote-ref-10)
11. If the elasticity of substitution for government’ energy consumption (GEN) in the inner energy nest and elasticity of substitution for government’s energy and non-energy consumption (GENNE) in the outer nest both are equal to 1, and elasticity of substitution in the non-energy nest (GNE) is assumed equal to 1, then GTAP energy model is equivalent to the standard GTAP model. [↑](#footnote-ref-11)
12. <https://www.gtap.agecon.purdue.edu/databases/v9/> [↑](#footnote-ref-12)