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Paris Climate Agreement and the Global Economy

Winners and Losers

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Abstract

The 2015 Paris Climate Agreement was the first instance of countries adhering to take a collective action against global warming. More than 190 countries came forward and submitted their contributions in the form of Intended Nationally Determined Contributions, reflective of their ability and capacity to reduce greenhouse gas emissions, as each country set its own targets and actions. For some countries, it meant a significant decline in their emissions by 2030, while others, like China, the United States, and India, decided on a more gradual phasing out extending beyond 2030. This paper estimates the economic impacts of implementation of the Paris Climate Agreement in terms of its implications for welfare, gross domestic product, investments, and trade for major countries and regions. It uses a computable general equilibrium framework to model global, regional, and country impacts. The analysis suggests that the economic impacts will be mostly felt in the European Union if the Paris Agreement is fully implemented. The European Union is likely to suffer a welfare loss of 1.0 to 1.5 percent by 2030. Among non-European countries, Australia, New Zealand, and Mexico will also be affected, with an expected welfare loss of about 1.5 percent. Some of the major emitters, such as China and India, will experience minimal impacts to their welfare, and the United States will experience a welfare loss of only about 0.7 by 2030. The sectoral analysis of production and trade suggests a significant loss to fossil fuel–based sectors, while clean energy sectors can experience significant gains.

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Paris Climate Agreement and the Global Economy: Winners and Losers

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1. Introduction

In the past, there has been a general reluctance on the part of countries to take voluntary and unilateral action on climate for the fear that if only some countries act, there was a risk that their efforts will be rendered futile as some emissions could simply move to countries with less strict climate-change regulations, thereby resulting in so-called carbon leakage. It was also believed that this could result in distortions to competitiveness, particularly for energy- and carbon-intensive industries, as producers in mitigating countries would face costs for reducing emissions and compete against firms not burdened or burdened less by such costs. In this context, the Paris Agreement is an improvement over its predecessor, "the Kyoto Protocol" which differentiated between the developed and developing countries. Under the Kyoto Protocol, the developed countries (also known as Annex 1 countries under the UNFCCC Convention) had commitments to reduce their GHG emissions by 5.2 percent from the 1990 level; the developing countries did not have any commitment. The Paris Agreement on the other hand is unprecedented since it nullifies that differentiation by eliciting commitment from all countries (see Annex 1).

Around 190 countries got-together in Paris and adopted an historic international climate agreement at the U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in December 2015. Through this agreement, the countries acknowledged the seriousness of the climate change issues and outlined the post-2020 climate actions they intended to take. The commitments came to be known as their Intended Nationally Determined Contributions (INDCs). These INDCs were communicated by UNFCCC Parties to its Secretariat much before the Paris Agreement. Countries negotiated on them and agreed on the Nationally Determined Contributions (NDCs) "on a voluntary basis."

INDCs were primarily designed for governments to communicate the steps they will undertake to address climate change in their own countries. INDCs were supposed to reflect in some sense each country's ambition for reducing emissions, taking into account its domestic circumstances and capabilities. Moreover, some countries also took the opportunity to highlight the ways they will adapt to climate change impacts, and the support they will need in terms of climate finance, or will provide to other countries to adopt low-carbon pathways, in order to build climate resilience (UNFCCC, 2016).

The climate actions communicated in these INDCs, thus, will largely determine if the world will be able to achieve the long-term goals of the Paris Agreement- to restrict the increase in global average temperature to well below 2°C, to pursue efforts to limit the increase to 1.5°C, and to achieve net zero emissions in the second half of this century. Under the provisions of the Paris Agreement, countries are expected to submit an updated NDC every five years, which will then represent a progression beyond the country's then current NDC to reflect its highest possible ambition.[2]

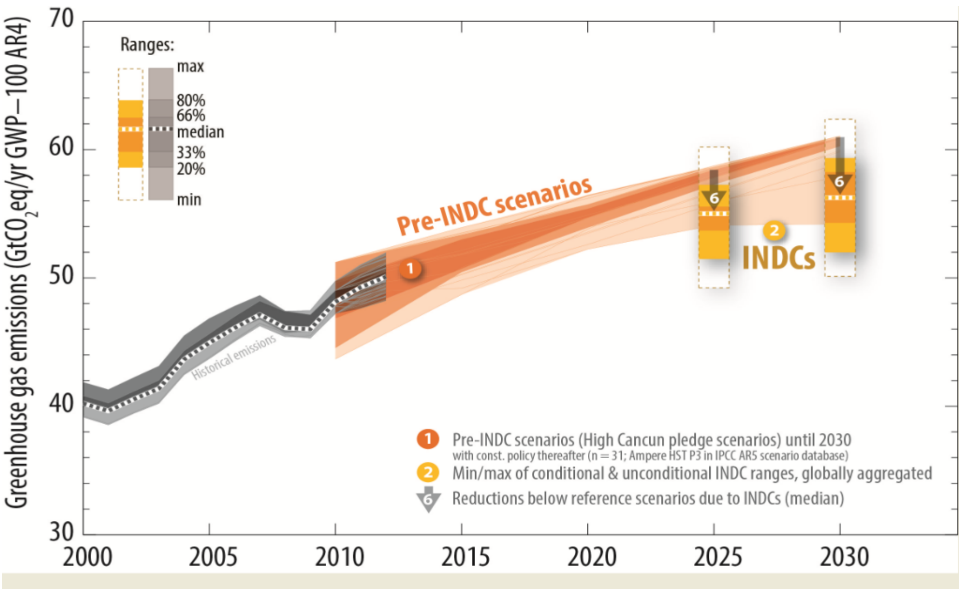
A well-designed NDC is a signal to the world that the country is doing its part to combat climate change and limit future climate risks. NDCs should also emphasize a country's efforts in

[2] The word "intended" was used initially because countries were communicating proposed climate actions ahead of the Paris Agreement being finalized. However, as countries formally join the Paris Agreement and look forward to implementation of these climate actions – the "intended" is dropped and an INDC is converted into a Nationally Determined Contribution (NDC).

integrating climate change into other national priorities, such as sustainable development and poverty reduction, and for fostering effective partnerships with the private sector to contribute to these efforts.

The Paris Agreement reflects an acceptance among countries that climate change is happening and it poses a significant threat to the global economy in the long-term. This has resulted in an understanding among countries that the long-term benefits of combating climate change will far outweigh the economic costs of taking action now. A report by UNFCCC (2016) has highlighted that INDC commitments cover 86 percent of global greenhouse gas emissions – almost four times the level of the first commitment period of the Kyoto Protocol and will bring global average emissions per capita down by as much as 8 percent by 2025 and 9 percent by 2030, compared to business as usual (Figure 1). It is also expected that more ambition will be built into the commitments as the countries revise their NDCs every five years.

Figure 1: INDCs will lead to reductions in GHG emissions by 2030



Source: UNFCCC (2016)

However, the recent withdrawal of the United States from the Paris Agreement has once again brought to light the concern among countries about the economic impacts of taking measures to combat climate change. Another lingering question is if other countries will follow suit and weaken the premises of the treaty. In this backdrop, the paper assesses the economic impacts of INDC commitments on the global economy and major countries in terms of their GDP growth, investments, and exports.

Section 2 provides a brief review of the recent literature, while section 3 highlights the data sources and methodology used in the paper. Section 4 describes simulation scenarios for the Computable General Equilibrium (CGE) analysis. Section 5 shows the findings with a focus of analyzing the impacts on GDP, welfare, investments and exports of major signatory countries.

Finally, the conclusions highlight the potential of investment in renewable energy which can make the economic costs of implementation of the Paris Treaty far more manageable.

2. Review of Recent Literature

There have been a few studies in the existing recent literature which have examined the economic impacts of the Paris Agreement. A recent study by Bohringer and Rutherford (2017) focuses on the carbon tariffs that the United States might face in the context of its withdrawal from the Paris Accord (the paper was written before the actual US withdrawal). The authors examine the economic impacts of a US withdrawal from the Paris Agreement for four policy-relevant scenarios against a reference scenario in which all signatory parties to the Paris Agreement including the United States comply with their INDC targets. Scenario 1 is where the United States defects from the Paris Agreement without any sanctions by trading partners. In scenario 2 the remaining regions to the Paris Agreement levy carbon tariffs on US imports at their respective domestic emission prices and in scenario 3, the United States retaliates with optimal tariffs. In scenario 4, the three strategic players, the United States, China, and Europe, end up in a tariff war. The empirical results suggest that carbon tariffs are not an effective instrument to prevent US withdrawal from the Paris Agreement, as carbon tariffs do not come as a credible threat to the United States when accounting for retaliatory tariffs and the possibility of a tariff war. Also, the United States performs slightly better under carbon tariffs compared to the Paris Agreement. Moreover, the prospect of a tariff war where China and Europe levy tariffs on US imports would not come as a credible threat to the United States, rather it would be China (the most trade-intensive region) that could incur a drastic economic loss from such a tariff war.

Hof et al (2017) estimate the annual abatement costs of achieving the NDC reduction targets, if countries would take additional targets beyond the Paris Agreement to keep global warming well below 2°C and pursue efforts towards 1.5°C by 2030. The authors find the abatement costs to be highly sensitive to socioeconomic assumptions. The global abatement costs of achieving the unconditional NDCs are projected between 58–135 billion USD in 2030 representing the differences between the three baselines, i.e. under SSP3 (with assumptions of slow economic growth, rapidly growing population, and high inequality) the global abatement costs are estimated at USD135 billion by 2030 which is more than twice the level as under the more sustainable socioeconomic assumptions of SSP1. These findings are consistent with Fujimori et al. (2016), who calculate the abatement costs for unconditional NDCs and a more ambitious greenhouse gas emission reduction scenario consistent with the 2°C goal using a general equilibrium model. The authors then assess the benefit of carbon emission trading on achieving the NDCs and show that welfare losses could be reduced by 75 percent when emissions trading was allowed.

Sokolov et al (2016) focus on the climate impact of the Paris Accord in the next few decades. Using the MIT Integrated Global System Model, the authors consider a ‘no climate policy’ scenario and three other scenarios that effectively extend the NDCs to 2100: 1) no additional climate policy after 2030, but the proposed cuts are extended to 2100; 2) reductions in emissions and emission intensities after 2030 at the same rate as in the 2020-2030 period; and 3) no country increases its GHG emissions after 2050. The empirical results indicate that the Paris

Agreement can reduce the global mean surface air temperature (SAT) in 2100 between 0.63 and 1.07°C relative to the no climate policy case. However, since the climate system takes many years to respond to emissions reductions, in 2050, the SAT is reduced only by about 0.12°C under all three scenarios. Moreover, the rise in SAT relative to preindustrial times (1861-1880) exceeds the 2°C goal in 2053, and in 2100, reaches between 2.7 and 3.6°C under all three scenarios.

Another study by Vandyck et al (2016) assesses the energy and economic implications of the climate mitigation policies in the NDCs. The study presents 3 scenarios: first, the Reference scenario, which includes only the existing climate policies particularly for 2020, without adding new additional policies. The second scenario represents the climate change mitigation pledges made by individual countries in the run-up to the COP21 in Paris. The third scenario considers a pathway of global greenhouse gas emissions that is likely to be consistent with limiting global temperature increase to 2°C by the end of the century. The results of simulations indicate that the NDCs have little impact on global demand for oil and gas. Rather, considerable demand reductions of energy and solid fuels would lead to lower greenhouse gas emissions. However, they argue that a substantial gap will remain between the global GHG emissions in the NDCs and the 2°C scenario in 2030, one-third of which could be bridged by decarbonizing the power sector. Moreover, the NDCs imply modest reductions in GDP for most regions (less than 1 percent compared to the Reference in 2030), whereas some regions will experience an increase in GDP due to gains in competitiveness. Overall, the analysis shows that global economic growth rates would be only marginally below the levels of the Reference with emerging and lowest-income economies maintaining high rates of economic growth, while fossil-fuel exporting countries could face larger impact.

This paper builds on the given literature and looks specifically at how the Paris commitments will impact the signatory countries.

3. Model, methodology and data

Model

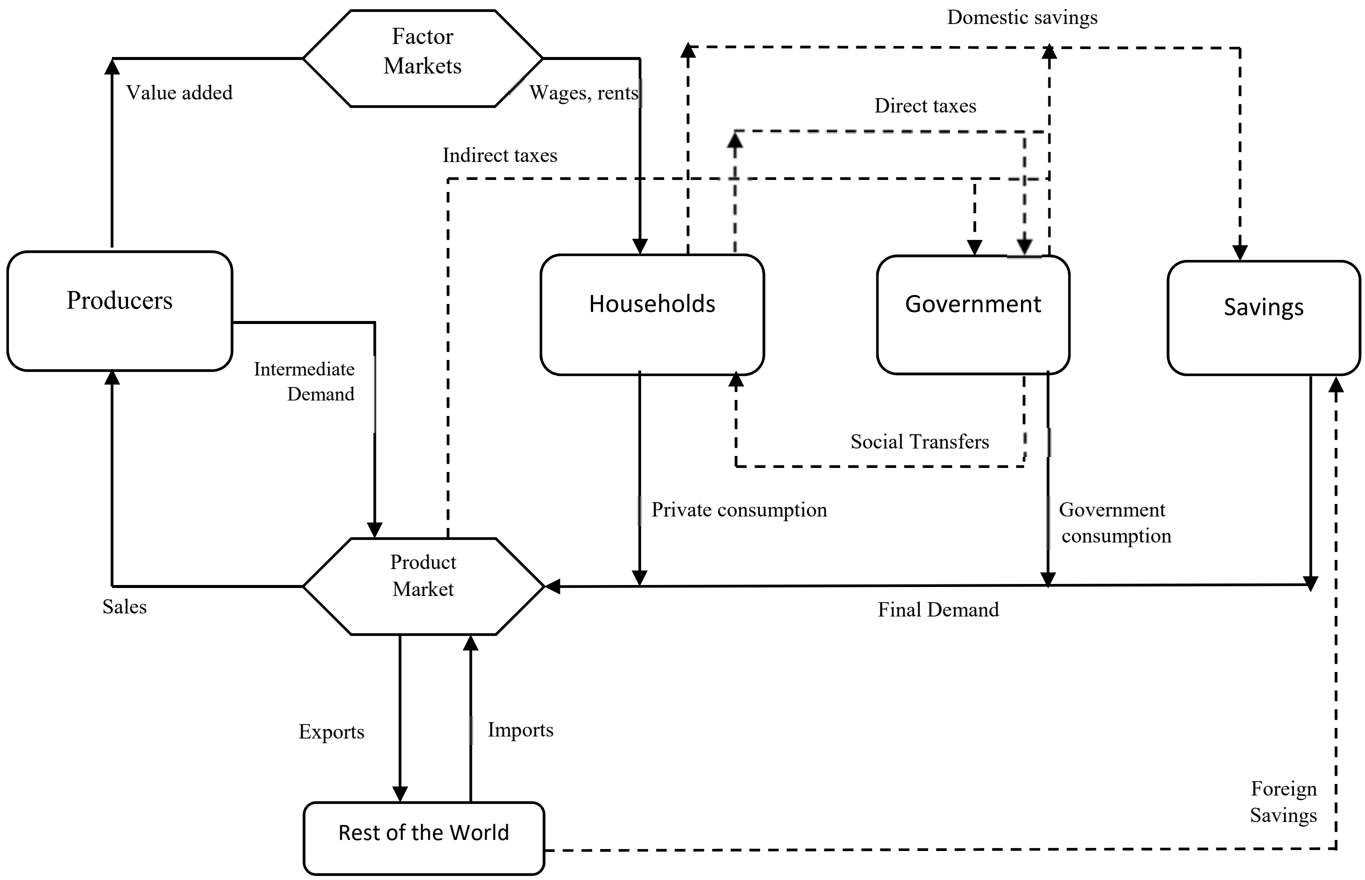
To analyze the economic impacts of the Paris Agreement on countries, the study uses a comparative static Computable General Equilibrium (CGE) model. CGE models are powerful tools for tracing how changes in one sector are propagated through the rest of the economy, affecting dependent sectors, patterns of trade, income and consumption and the fiscal and international financing needed for macroeconomic stability and growth goals (Figure 2).

CGE models are widely used to analyze the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets. They have also been deployed to analyze the effects of specific instruments or a combination of instruments. Examples of their application may be found in areas as diverse as fiscal reform and development planning (see, e.g., Perry et al 2001; Gunning and Keyzer 1995), international trade (Shields and Francois 1994; Martin and Winters 1996; Harrison et al 1997), and, increasingly, environmental regulation (Weyant 1999; Bovenberg and Goulder 1996; Goulder 2002).

The paper uses a GTAP which is a publicly available multi-sectoral multi-regional CGE model. The model follows the standard approach of most CGE models in the sense that it models competitive market behavior via producers, consumers, and government and their interaction with and within a set of countries. This has several standard features of a global CGE model such as Constant Elasticity of Substitution (CES) nests for production and trade and firms supply commodities for private and government consumption and to other firms in the form of intermediate use. Some of the special features of the GTAP model relate to the use of a flexible Constant Difference Elasticity (CDE) functional form for allocating consumption across commodities,[3] Cobb-Douglas utility function for the aggregate regional household, perfect competition, constant returns to scale, conversion of all global savings into all global investment and Armington assumptions to capture product heterogeneity between domestic and imports as well as among imports from different sources (see Figure 2). This model is well-documented at length in Hertel (1997).

[3] In each region of the GTAP model, a regional household allocates income to maximize per capita aggregate utility per a Cobb-Douglas utility function. The utility function is described as "aggregate" utility because it comprises both government and private sector behavior. The arguments in the utility function are per capita utility from private consumption, per capita utility from government consumption, and per capita real saving. Real saving is a single commodity, defined as saving deflated by a saving price. Utility from government consumption is a Cobb-Douglas aggregate of government consumption of individual commodities. Per capita utility from private consumption is aggregated from per capita private consumption of individual commodities using a constant difference elasticity (CDE) demand system (Hertel, 1997).

Figure 2: Description of the workings of a CGE Model



Source: Breisinger et al (2009)

The paper uses a newly developed special version of the GTAP model, named the GTAP-POWER model. This is documented in Peters (2016). In this model, there is a substitution between capital and energy products as a composite commodity; there is a multi-level nesting system among different energy products, including both renewable and non-renewable energy. This accounts for substitution among these sources in response to either carbon taxes for cutting emissions or to any other economic and technological policy changes in the economy. Further to these changes, another modification is made to this model, which enriches the labor supply specification; in the standard GTAP model, one assumes a horizontal or vertical labor supply curve, whereas in this model, the labor supply curve for different countries is defined using the estimated labor supply elasticities. This helps in capturing a more realistic labor supply situation. Further in reality, the actions on climate change may affect technological innovations as well as investment levels. Therefore, the assumption is that investment and savings both are endogenous in each region in the model. The model does capture the reduction in investment due to reduced output and savings. Substitutability across energy sources does vary across sectors and regions, as the parameters and shares of different variables that influence substitutability have huge variations across sectors and regions.

One of the main policy instruments to achieve the INDC targets is through pricing of carbon dioxide emissions. The level of the carbon value/price is calculated endogenously in the model to achieve the targeted reductions in emissions. A simple supply and demand economics is used here to illustrate some of the key concepts embedded in the models used to assess mitigation targets/costs. Figure 3 shows the supply and demand for energy/carbon. If a tax is imposed on carbon, this creates a gap between the supply and demand price and a reduction in carbon emissions. One can then plot the tax/carbon reduction relationship as a marginal cost curve for carbon emission reductions as shown in Figure 4. This tells us how much emission reduction a market-based incentive (carbon tax) achieves or it can be used to assess the implication of a targeted emission reduction on the implicit price of carbon (on the y-axis).

Figure 3: Carbon supply and demand

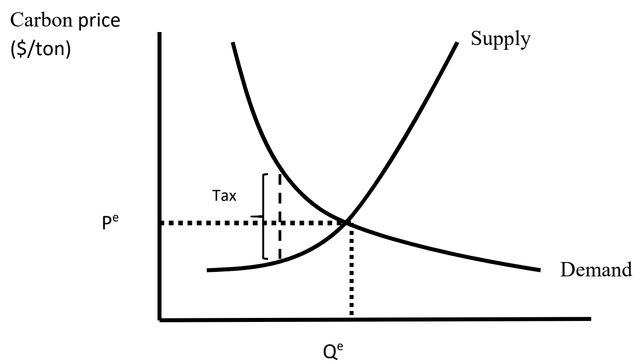
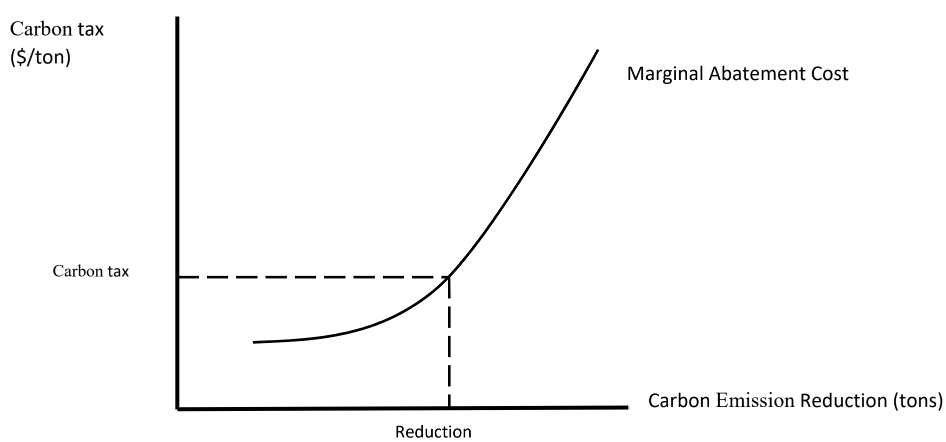


Figure 4: Emission Reduction and Marginal Abatement Cost



The introduction of an emission restriction, first and foremost, makes energy expensive. However, not all sources of energy are affected similarly as different types of energy have varying degrees of carbon content. The paper uses the power generation sector to illustrate how emission restriction policies propagate through the economy. This sector, like many others in the model, uses labor, capital, intermediate goods, and energy to produce power. By their very nature, energy inputs are interchangeable in production but differ in terms of their carbon intensity. Therefore, in the baseline scenario, production is a mix of fossil fuels and other power generation technologies and it happens to be the case that high-carbon intensive sources like coal are cheaper than low-carbon alternatives. When emission restriction policy is applied, the cost of all types of fuel used in power generation rises as there are no carbon free inputs. However, the rise in input price makes low carbon energy sources relatively cheaper than, say, coal or other high carbon fuels. This change in energy mix of inputs in favor of low carbon fuels derives the economy-wide decline in carbon emissions (Harris et al, 2017; Peters, 2016).

In the model, electricity is an intermediate good whose production cost also depends on the cost of all other inputs including energy. The extent of the price increase will ultimately depend on the elasticity of demand for electricity. In the immediate run, firms will have little time to substitute away from electricity in the face of the price rise, hence demand will likely be inelastic for all intended purposes. Hence, the production of electricity will be increased slightly but the now higher cost of production will be passed through to prices i.e. other sectors buying and final consumers of electricity will face higher prices. Other things remaining constant, expensive electricity leaves less income in the hands of consumers leading to a fall in overall economy-wide demand. On the supply side, increase in the price of electricity demands more resources i.e. with little opportunity to shift away from electricity in the short run, firms now spend more to get the same level of output. This leaves less resources for producing other goods. Hence, one would expect aggregate supply to decline following the rise in electricity price. Reduced output and demand mean lower employment of factors of production like capital, labor, and other intermediate inputs. The decline in total output will not be the same across sectors as the degree to which sectors use electricity differs markedly. Those that use less electricity will see modest change while those that rely on electricity will see noticeable decline in output. The example used so far about the impact of the emission restriction on the power generating sector can be applied to any sector of the economy that is carbon intensive. The qualitative nature of the story will remain the same while the magnitudes will differ across sectors. The basic process of transmission will start with an initial increase in production cost which will be partly passed through to prices and the rest of the economy leading finally to decrease in aggregate demand and supply (Harris et al, 2017; Peters, 2016).

Data

The data source for this paper is the GTAP-POWER data set documented by Peters (2016). The data used in GTAP-POWER come from numerous IEA publications. For example, data on electricity production (in GWh) by fuel source for each region, levelized (i.e., annualized cost per GWh) capital, operating and maintenance (O&M), fuel, and effective tax costs of electricity for select generating technologies and regions are all collected from IEA and then processed and combined with the standard GTAP database. The standard GTAP Data Base is documented in Narayanan et al (2015). Version 9 of the Global Trade Analysis Project (GTAP) model, with

2011 as the base year, is used to analyze the economic implications of the Paris Climate agreement.[4]

4. Scenarios

Two scenarios modeled here are:

Scenario 1-Implementation of INDCs by all member countries that signed the Paris Accord.

Scenario 2 - Scenario A along with exogenous reduction in the prices of renewables by 25 percent.

Starting from 2011, a baseline model is run until 2030 for GDP, labor force, and population, which would expand the whole global economy, including aspects such as production, trade, and investment. The baseline is based on IIASA's Sustainable Socioeconomic Pathways (SSP). The emission reduction commitment is treated in the model as an endogenous tax on carbon on sectors that use carbon-intensive inputs. It is important to keep in mind that the experiments reported are conducted under the counterfactual or “what if” analysis. The INDCs are unlikely to be implemented at the same time in all the regions reported and even more uncertain is the exact time frame these policies will likely get implemented and therefore a simpler approach is taken for imposing INDC shocks on the global economy for the base year 2011.

The analysis assumes no change in the trade account: thus, the variable representing the current account balance (DBALCAR**)** is set to be exogenous and equal to zero in all countries/regions except one. The slack variable, cgdslack, is made endogenous. These variables are usually exogenous in the standard GTAP closure. The implication here is that investment is calculated as a residue in order to guarantee no change of the trade account. The quantitative restrictions applied to carbon emissions are introduced by making the real carbon tax RCTAX (i.e. the nominal carbon tax deflated by the GDP deflator) endogenous and the emission growth rates gco2t exogenous and equal to the Paris commitments. It is also possible to impose an exogenous real or nominal carbon tax (RCTAX or NCTAX, respectively) and leave the emission growth rates to be determined endogenously.

5. Main findings

All the results are cumulative as happening in the final year of analysis, i.e. 2030 and not annualized or year-by-year. The results from Scenario 1 are discussed below and highlighted in Figures 5 through 8, which show both welfare and macroeconomic impacts of the Paris commitments across countries. Four other hypothetical alternative sub-scenarios were also examined, besides the original INDC commitment scenario. They include: (i) INDC_50MR scenario that looks at the impact of increasing the INDC commitments by 50 percent more than what countries initially intended to achieve. This is an extreme case, however, having such a scenario helps in giving benchmark values to alternative policy measures (ii) INDC20 looks at the impact of achieving just 20 percent of the INDC targets. (iii) INDC50 shows percent

[4] https://www.gtap.agecon.purdue.edu/ GTAP (1997), T. Hertel Ed., Global Trade Analysis Modeling and Applications, NY, USA.

achievements of the original INDC commitments. (iv) INDC80 assumes 80 percent achievements of the original INDC commitments.

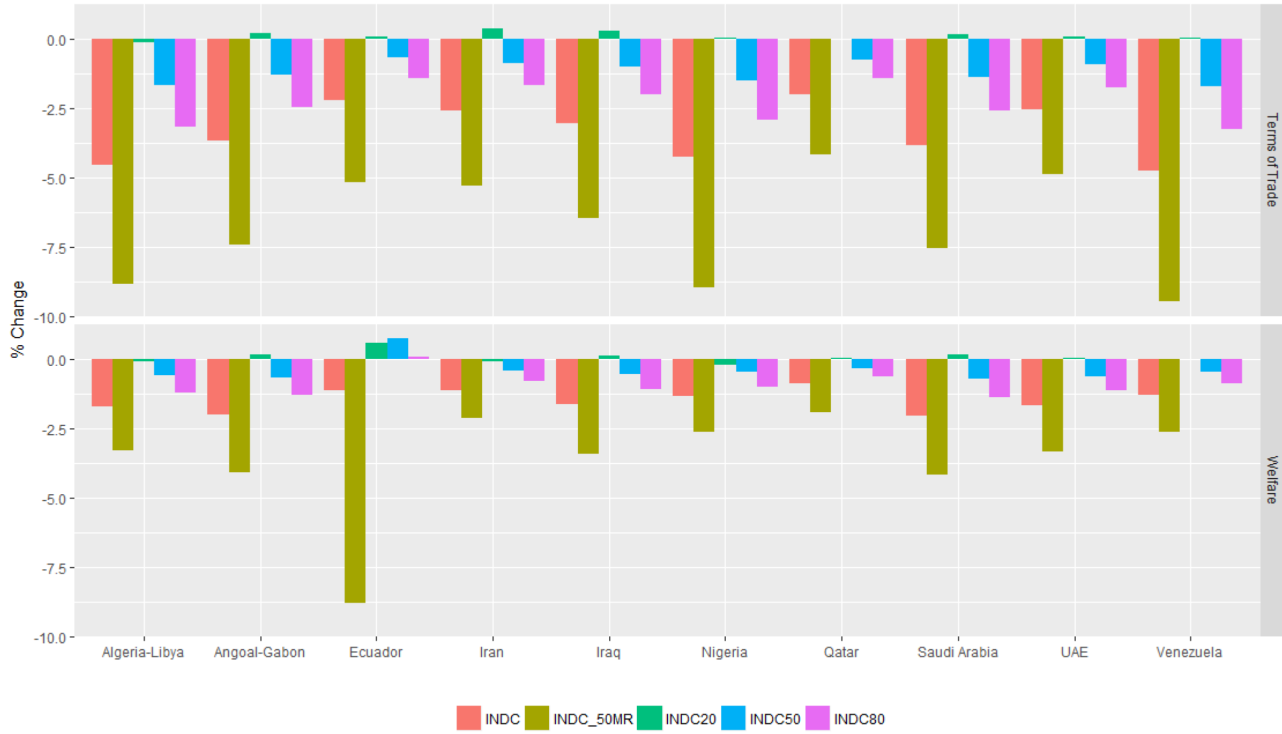
As shown in figure 5, for a few OPEC countries, the results indicate that overall these countries are likely to experience negative economic consequences following the global implementation of INDCs in all the five scenarios. The costs, as measured in terms of utility of the representative regional household, range from about 1 percent in Qatar to 2.1 percent in Saudi Arabia in the base INDC implementation scenario. The welfare loss in Saudi Arabia happens even though it has no carbon reduction commitments to comply with under the Paris deal. Overall, the higher cost in the OPEC region is partly explained by deterioration in terms-of-trade since the majority of the countries in the region are net energy exporters. Thus, even non-committed countries can experience welfare decline following the implementation of the INDCs. However, the welfare implications of the implementation of INDCs seem to be positively correlated with the size of ambition to reduce emissions. For instance, a 50 percent increase in commitments to reduce CO_2 emissions across the globe can contribute to a welfare loss of about 9 percent in Ecuador and 4 percent in Saudi Arabia. The welfare impacts of achieving only about 20 percent of the INDC targets are mixed. Welfare costs seem to be marginally negative and even positive in some countries.

Likewise, for some of the top net emission importers, the welfare costs of the INDC commitments are negative across the board (measured by $MtCO_2$ per year), as shown in Figure 6. The more ambitious are the commitments, the higher is the cost on society. However, the welfare loss is smaller in magnitude compared to the impact on OPEC member countries. Unlike OPEC countries, the terms of trade effect for these countries are in fact positive as they benefit from declining energy prices following the implementation of the carbon emission reduction policy. Moreover, some of these major countries have binding commitments to reduce emissions, by at least 40 percent from 1990 emissions levels.

Figure 7 shows the impact of INDC commitments across selected countries of the G20. The G20 group represents a mixed representation in terms of INDC commitments, some member countries have binding and ambitious INDC commitments (e.g. Australia and Canada), some have modest targets (the Republic of Korea, Japan and Argentina), while some countries (e.g. India, the Russian Federation, and South Africa) have no commitments to reduce emissions at all in the near-future. Overall, the Paris commitments would result in decline of welfare across these countries.

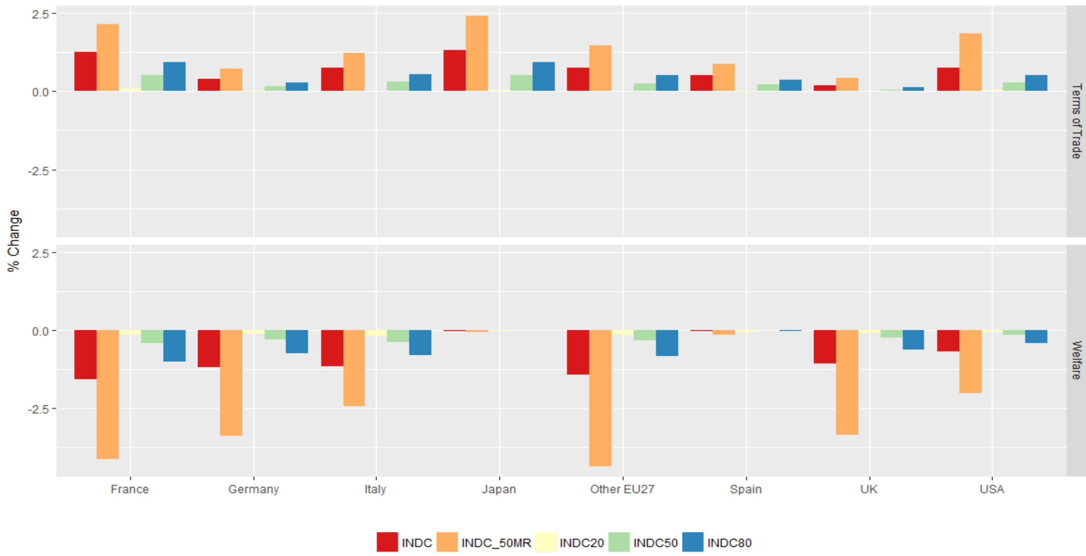
Figure 8 shows the marginal cost of achieving the Paris Agreement based on the alternative INDCs scenarios. The European countries face a high cost for meeting their aggressive Paris Agreement target which ranges from a low of \$54 per ton of CO_2 in Spain to \$372 per ton of CO_2 in France if they manage to reduce emissions by about 40 percent as planned. The cost is reduced if the target was set at only reaching 20 percent of the INDCs. In this case the marginal cost ranges from a high of \$35 per ton of CO_2 in France to \$7 per ton of CO_2 in Spain. A more stringent target, say achieving 50 percent more than what is stated in the INDCs leads to a much higher price of carbon in Europe. The price hike ranges from \$914 per ton of CO_2 in France to \$101 in Spain.

Figure 5: The cost alternative scenarios of achieving the INDCs, OPEC region



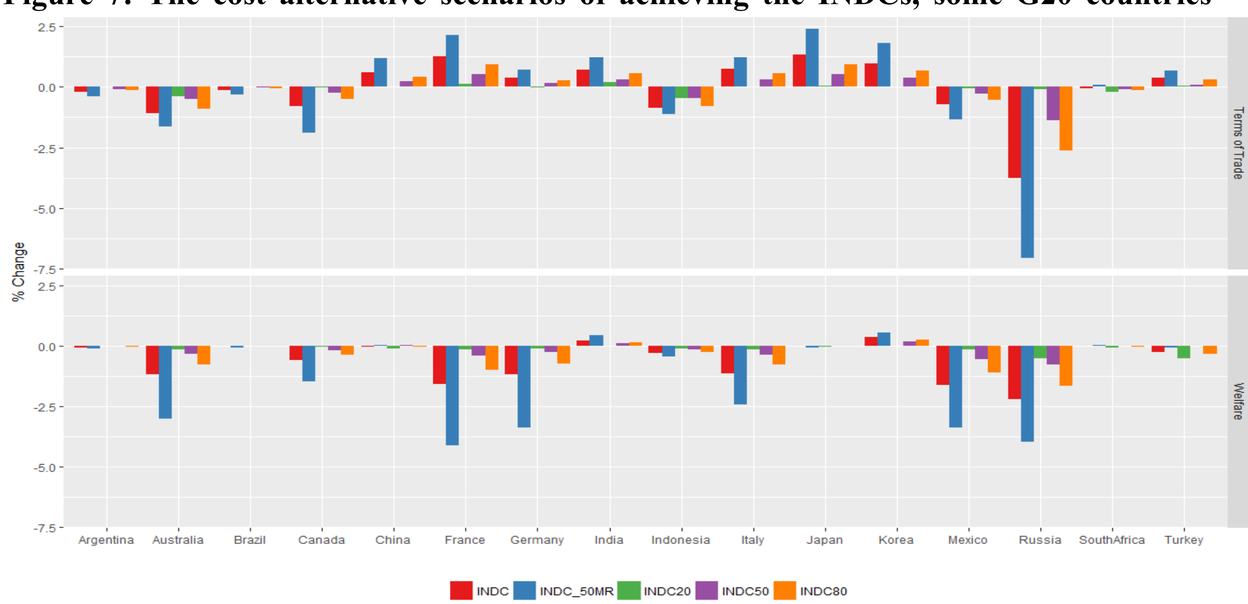
Source: Authors' computations. Note on the legend. The bars indicate the five different scenarios. INDC=the INDC commitments; INDC_50MR=Countries achieving 50 percent more than the original INDC commitments; INDC20=Countries achieving 20 percent of their original INDC commitments; INDC80=Countries achieving 80 percent of their original INDC commitments

Figure 6: The cost alternative scenarios of achieving the INDCs, Major net importers of emission[5]



Source: Authors' computations. Note on the legend. The bars indicate the five different scenarios. INDC=the INDC commitments; INDC_50MR=Countries achieving 50 percent more than the original INDC commitments; INDC20=Countries achieving 20 percent of their original INDC commitments; INDC80=Countries achieving 80 percent of their original INDC commitments

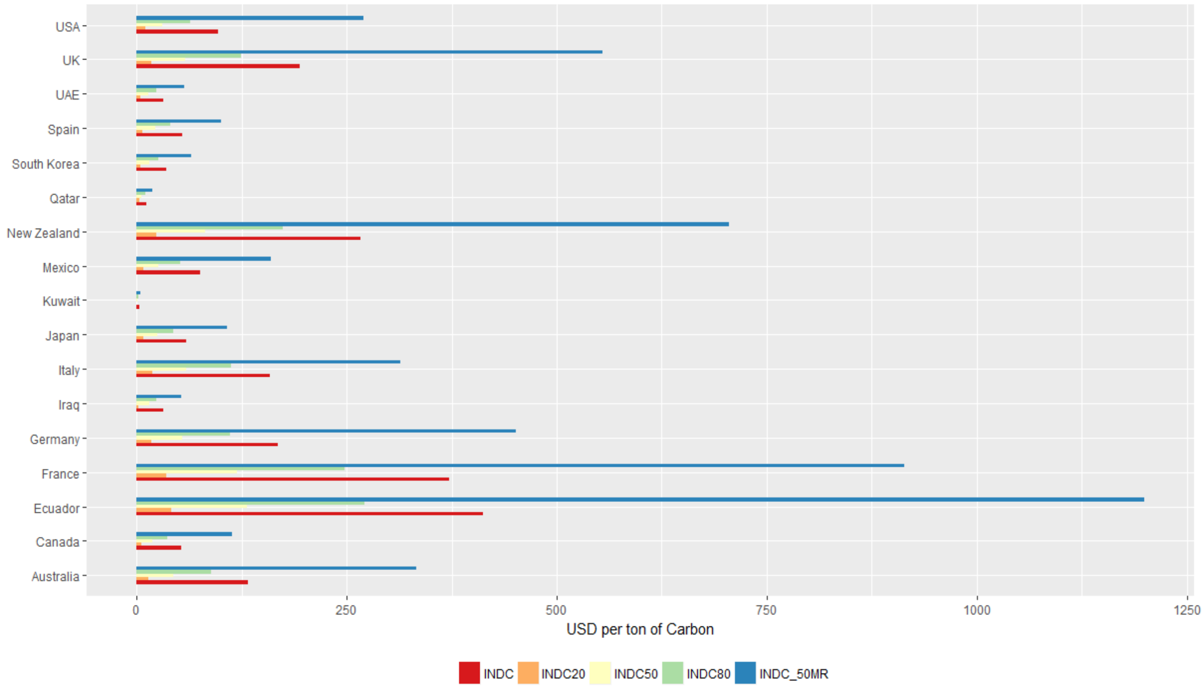
Figure 7: The cost alternative scenarios of achieving the INDCs, some G20 countries



Source: Authors' computations. Note on the legend. The bars indicate the five different scenarios. INDC=the INDC commitments; INDC_50MR=Countries achieving 50 percent more than the original INDC commitments; INDC20=Countries achieving 20 percent of their original INDC commitments; INDC80=Countries achieving 80 percent of their original INDC commitments

[5] As measured in $MtCO_2$ per year, Figure 5 in Davis and Caldeira (2010).

Figure 8: Marginal Costs of Achieving the INDC targets



Source: Authors' computations. Note on the legend. The bars indicate the five different scenarios. INDC=the INDC commitments; INDC_50MR=Countries achieving 50 percent more than the original INDC commitments; INDC20=Countries achieving 20 percent of their original INDC commitments; INDC80=Countries achieving 80 percent of their original INDC commitments. Norway was removed from this figure as the marginal cost of abatement was an outlier (the USD per ton CO2 ranged from 1,230 to 5,645) for the different scenarios, significantly affecting the scaling of the figure.

Table 1 highlights some of the major macro-economic results for the global economy (by major regions and countries) following implementation of the Paris Agreement. The results suggest that countries in Europe including the European Union are likely to be the most impacted if the Paris Agreement is fully implemented. They can witness a GDP loss of 1.0 to 1.5 percent by 2030 (Norway being the extreme with a loss of 4.6 percent). The GDP of France can decline by about 1.6 percent, while Germany, Italy and the United Kingdom can experience about 1.0 percent decline in their respective GDPs. Among non-European countries, Australia, New Zealand and Mexico will be impacted the most, with an expected GDP loss of about 1.0 percent. Interestingly since commitments of some of the major emitters such as China and India will not take into effect by 2030, they will experience minimal impact in their GDPs. GDP in the United States can decline by about 0.6 percent by 2030. The majority of the countries in Asia, Latin America and MENA will witness a marginal decline in their GDPs. Among African countries, Sub-Saharan Africa will experience a decline in GDP of about 1.0 percent. Overall, the analysis does not indicate that adhering to the Paris commitments will entail any major global economic downturn.

Table 1: Implications of Paris Treaty for GDP, Investment and Trade

Regions/Countries	percent Change in GDP	percent Change in Investment	percent Change in Imports	percent Change in Exports
Australia	-0.84	-0.47	-3.08	-1.93
New Zealand	-1.06	0.65	-3.14	-4.3
East Asia				
China(Mainland)	-0.06	-0.01	1.19	0.55
Japan	-0.26	-0.28	-1.67	-2.99
Korea, Rep.	0.04	0.99	-1.04	-1.89
Indonesia	-0.02	-0.23	-0.28	0.58
South Asia				
India	-0.01	0.16	0.28	-0.91
Rest of South Asia	-0.01	-0.09	0.45	-0.14
North America				
Canada	-0.27	0	-0.6	0.18
United States	-0.62	0.8	-1.19	-2.81
Mexico	-1.18	-0.27	-0.65	-0.07
Latin America and Caribbean				
Brazil	0	-0.01	-0.22	-0.1
Ecuador	0.32	5.97	1.1	2.7
Venezuela, RB	-0.1	-0.68	-5.13	0
Argentina	-0.01	-0.04	0.02	0.19
Other Latin American	0.01	-0.11	-0.26	0.31
Central America and Caribbean	0.01	-0.11	0.14	-0.06
Europe and Central Asia				
France	-1.63	0.38	-4.3	-6.04
Germany	-1.06	0.97	-3	-3.11
Italy	-1.13	0.08	-3.46	-4.54
Spain	-0.23	-0.29	-1.6	-2.38
United Kingdom	-1.06	-0.52	-2.63	-3.35
Other European Union 27	-1.61	0.05	-3.9	-4.53
Rest of Europe	-1.27	0.68	-3.85	-4.56

Russian Federation	-0.83	-0.28	-5.58	-1.61
Norway	-4.6	-2.23	-8.13	-5.01
Turkey	-0.35	-0.22	0.17	-0.14
Central Asia	-0.07	-0.24	0.83	0.98
Middle East and North Africa				
Qatar	-0.05	-0.43	-3.23	-0.31
Saudi Arabia	0.05	0.06	-4.44	-0.51
United Arab Emirates	-0.15	-0.75	-1.75	0.88
Iran, Islamic Rep.	-0.2	-0.69	-3.65	-0.58
Iraq	-0.35	-2.19	-2.37	0.81
Kuwait	-0.05	-0.81	-2.7	0.23
Algeria and Libya	-0.21	-2	-6.81	-2.3
Rest of Middle East and North Africa	-0.05	-0.33	0.47	1.57
Africa				
Nigeria	-0.33	-1.22	-5.54	-1.07
Angola and Gabon	-0.1	-1.38	-3.81	-0.07
South Africa	0.02	-0.09	-0.54	-0.52
Sub-Saharan Africa	-0.03	-0.31	-0.19	0.55
Rest of the World	0.1	-0.22	-0.17	0.22

Source: Authors' computations.

In terms of investments, the analysis suggests that the impact is likely to be minimal with most countries experiencing either a small positive or negative effect by 2030. Among European countries, France and Germany are likely to experience a positive increase in their investments, while Norway, Spain and the United Kingdom can register a small decline in their investments. Some of the oil exporting countries such as the United Arab Emirates, Iraq, Russia, Nigeria and Kuwait can also show modest declines in their investments. The United States and Korea are likely to benef positively in terms of their investments.

The analysis also suggests that changes in trade could be a negative consequence of the implementation of the Paris Treaty. Most countries in Europe are likely to experience a decline of 3.0 to 5.0 percent in their imports and exports. Countries in MENA can experience a bigger percent change in their imports than the exports. Australia, New Zealand, Japan, Korea, the United States and African countries will also be negatively impacted to varying degrees. China and to some extent India will not experience any significant shift either in their exports or imports.

In terms of the implications for various industries/sectors, the analysis suggests that fossil fuel-based sectors such as coal, gas, and oil will be adversely affected by the implementation of the

Paris Agreement. Both basic production as well as power generation using coal, oil and gas and trade are likely to experience a significant decline as countries ramp up their efforts to reduce greenhouse gas emissions. While China, India, Russia and Turkey will witness an increase in coal-fired power generation, most other countries will witness a significant decline in coal-powered generation by 2030. On the other hand, clean energy industries such as nuclear, wind and solar will experience a significant increase in their production and trade. This will have little implications for basic manufacturing industries or services. Overall, the dirty industries are likely to be majorly impacted, while clean industries show a flourishing trend as the Paris Agreement is implemented without any major implications for industrial competitiveness.

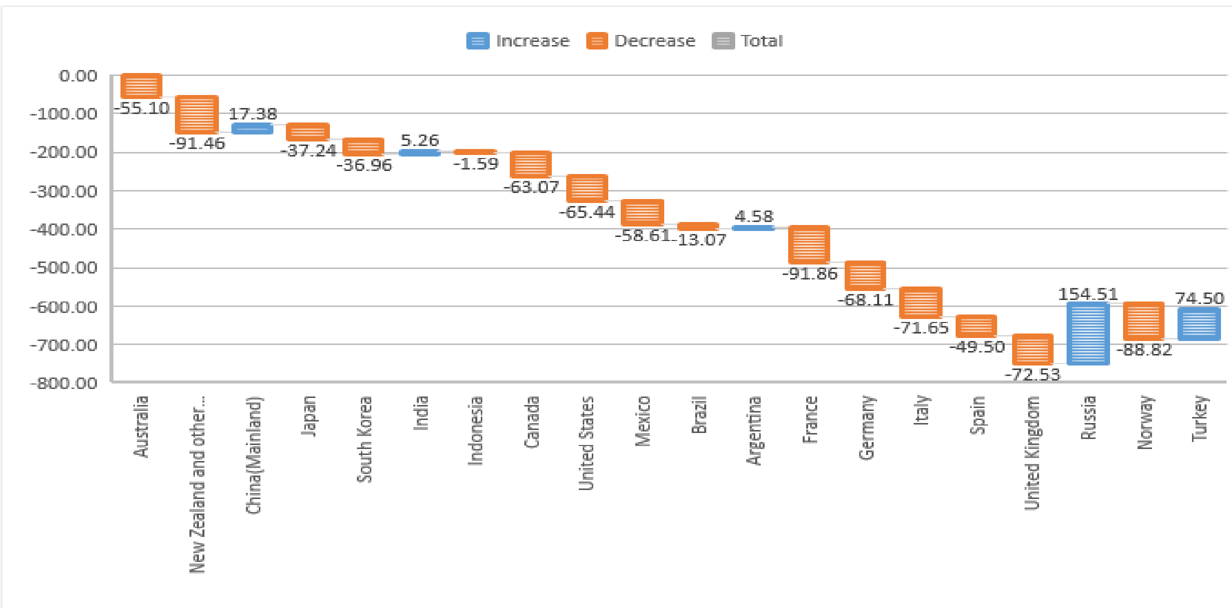
Table 2: Implication of Paris Treaty for Global Trade and Output in Various Sectors

	in Output	in Trade
Crops	-0.2	-0.3
Processed Food	-0.3	-0.7
Textiles	-0.2	-0.6
Meat	-0.4	-1.1
Fish	-0.1	-0.5
Forest	0.1	2.6
Coal	-5.8	-23.5
Oil	-4	-5
Gas	-13.2	-13.4
Petroleum and Coal	-4.7	-10.2
Electricity Transmission	-5.8	-9.4
Nuclear Power	16.5	20.2
Coal-fired Power	-19.7	-42.9
Gas-fired Power	-11.8	-23.6
Wind Power	18.7	18.4
Hydro Power	13.2	16.6
Oil-fired Power	-3.5	-27.9
Other Power	11.6	12
Gas-fired Power (Peak Load)	-8.5	-16.6

Hydro Power (Peak Load)	8.7	1.8
Oil-fired Power (Peak Load)	-1.9	-3.7
Solar Power	-1.2	2
Light Manufacturing	-0.4	-0.7
Heavy Manufacturing	-0.3	-0.9
Services	-0.4	-0.9

Source: Authors' computations. The results here consider the implementation of the basic INDC scenario discussed above.

Figure 9: Coal-fired Power Generation across countries by 2030



Source: Authors' computations. The results here consider the implementation of the basic INDC scenario discussed above.

It is well recognized now that renewable energy deployment must be accelerated, if one were to limit global temperature rise to 2°C. To achieve the Paris Agreement goals, governments must address the most severe disincentives and energy market distortions by improving policies to level the playing field between fossil fuels and nuclear power on the one hand, and renewable energy on the other. Reduced costs for renewable energy technologies will not only make global energy transition possible, but also less expensive than the alternatives. Per a recent IRENA report (IRENA, 2015), with the right regulatory and policy frameworks, solar and wind technologies can still unlock significant additional cost reductions by 2025 and beyond. The analysis finds that the cost of electricity for solar and wind power technologies will fall between a quarter and around two-thirds by 2025.

The results for Scenario 2 are presented in Table 3. The findings suggest that the reduction in GDP resulting from the implementation of the Paris Treaty would be considerably nullified by a reduction in the price of renewables by 25 percent. For example, France, Germany, Italy and the United Kingdom are likely to experience a much smaller decline in their GDPs compared to the business as usual scenario (Scenario A). Similarly, the United States will witness a decline in GDP of 0.28 percent in scenario 2 as compared to 0.62 percent in the baseline scenario.

Table 3: Scenario 2: Implication of Paris Treaty for Global Trade and Output in Various Sectors with 25 percent reduction in price of renewables

Region/Country	percent Change in GDP	percent Change in Investment	percent Change in Imports	percent Change in Exports
Australia	-0.64	-0.27	-3.01	-1.83
New Zealand	-0.53	1.43	-2.76	-3.98
East Asia				
China (Mainland)	0.17	0.18	1.19	0.62
Japan	-0.01	-0.27	-1.47	-2.74
Korea, Rep.	0.34	1.53	-0.79	-1.58
Indonesia	0.22	0.47	0.27	-1.29
South Asia				
India	0.01	-0.13	-0.33	0.62
Rest of South Asia	0.33	0.99	0.39	-0.67
North America				
Canada	0.3	0.45	-0.1	0.77
United States	-0.28	1.39	-0.9	-2.46
Mexico	-0.93	0.27	-0.56	-0.02
Latin America and Caribbean				
Brazil	0.47	0.45	-0.04	-0.15
Ecuador	0.61	6.72	1.22	2.49
Venezuela, RB	0.23	-0.61	-5.35	-0.15
Argentina	0.03	0.14	0.05	0.01
Other Latin American	0.37	0.26	-0.27	0.51

Central America and Caribbean	0.15	0.78	0.05	-0.27
Europe and Central Asia				
France	-1.01	0.72	-3.94	-5.55
Germany	-0.55	1.99	-2.42	-2.52
Italy	-0.65	0.86	-2.82	-4.02
Spain	0.35	-0.16	-1.15	-1.96
United Kingdom	-0.72	-0.02	-2.24	-3.03
Other European Union 27	-0.91	1.04	-3.31	-3.92
Rest of Europe	0.06	1.99	-2.46	-3.11
Russian Federation	-0.57	1.42	-5.13	-1.35
Norway	-4	-1.77	-7.45	-4.41
Turkey	-0.17	-0.17	0.26	-0.45
Central Asia	0.1	0.1	0.78	0.91
Middle East and North Africa				
Qatar	-0.05	-0.45	-3.41	-0.32
Saudi Arabia	0.06	0.1	-4.35	-0.5
United Arab Emirates	-0.15	-0.72	-1.66	0.89
Iran, Islamic Rep.	-0.16	-0.47	-3.64	-0.61
Iraq	-0.16	-0.78	-2.11	0.91
Kuwait	-0.05	-0.78	-2.64	0.24
Algeria and Libya	-0.21	-1.98	-6.78	-2.31
Rest of Middle East and North Africa	-0.02	-0.2	0.52	1.55
Africa				
Nigeria	-0.3	-1.31	-5.56	-1.13
Angola and Gabon	-0.03	-1.09	-3.75	-0.06
South Africa	0.03	0.04	-0.45	-0.55
Sub-Saharan Africa	0.29	0.45	0.01	0.65
Rest of the World	0.15	-0.01	0.03	0.17

Source: Authors’ computations. Results from Scenario B.

Similarly, in terms of investments, countries are likely to benefit much more with the reduction in the price of renewables than otherwise. Most European countries will experience a spurt in their investments. Countries like Australia, the United States, the United Kingdom, and Spain will register a small decline in their investments. In trade, the majority of the countries show a decline in their exports and imports in scenario 2 but to a smaller extent as compared to scenario 1. In other words, trade disruptions are likely to be minimum with the reduction in the price of renewables.

Table 4: Implication of Paris Treaty for Global Trade and Output in Various Sectors with reduction in price of renewables

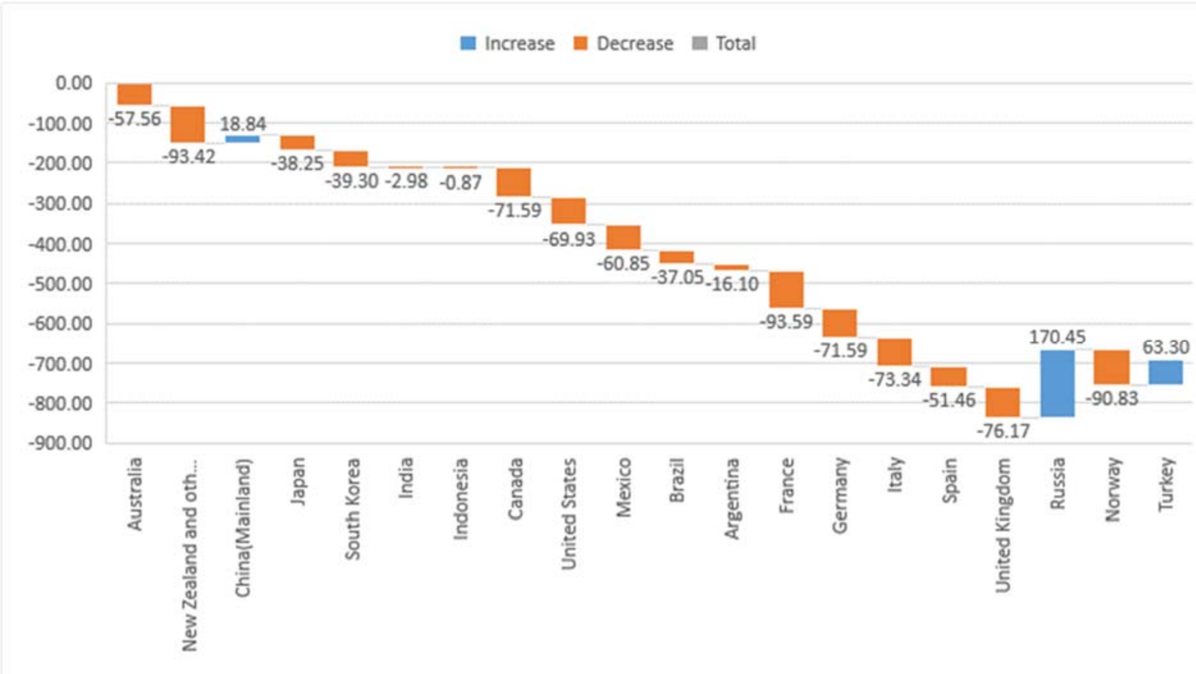
Sector/Industry	**percent change in Trade**	**percent change in Output**
1 Crops	-0.18	-0.04
2 Processed Food	-0.44	-0.06
3 Textiles	-0.32	0.05
4 Meat	-0.66	-0.12
5 Fish	-0.05	0.14
6 Forest	2.92	0.43
7 Coal	-29.06	-5.34
8 Oil	-4.21	-3.58
9 Gas	-15.24	-11.16
10 Petroleum and Coal	-9.20	-3.90
11 Electricity Transmission	0.84	2.15
12 Nuclear Power	76.52	68.42
13 Coal-fired Power	-62.72	-39.64
14 Gas-fired Power	-41.46	-27.77
15 Wind Power	68.28	75.95
16 Hydro Power	65.24	59.04

17 Oil-fired Power	-47.90	-13.47
18 Other Power	-10.90	-7.43
19 Gas-fired Power (Peak Load)	-19.74	-9.98
20 Hydro Power (Peak Load)	45.72	30.63
21 Oil-fired Power (Peak Load)	0.32	1.16
22 Solar Power	50.42	45.89
23 Light Manufacturing	-0.24	-0.02
24 Heavy Manufacturing	-0.39	0.07
25 Services	-0.54	-0.07

Source: Authors' computations. Results from Scenario B.

In scenario 2, in terms of the impact on various industries/sectors, the analysis suggests that fossil fuel-based power generating sectors such as coal, gas, and oil are expected to be hit negatively with the drop in the price of renewables. On the other hand, clean energy sectors will gain positively with significant increase in their production and trade. The impact on manufacturing sectors will also be less pronounced than in the business as usual scenario. Thus, the reduction in the prices of renewables is expected to result in the decline of fossil fuel-based power generation, with most countries except Russia and Turkey witnessing significant to modest declines in their coal-fired power generation (Figure 10).

Figure 10: Change in Coal-fired Power Generation across countries by 2030 with reduction in price of renewables



Source: Authors' computations. Results from Scenario B.

With implementation of the Paris Agreement, the global average emissions are expected to reduce by 167 metric tons of CO_2 in 2030, based on the model results. The Paris Accord has a potential of total reduction of emissions by 4,489 metric tons of CO_2. Even with conservative carbon pricing estimates, the benefits from emissions reduction may far outweigh the losses in GDP.

6. Conclusions

This paper is one of the first comprehensive attempts to estimate the economic impacts of implementation of the Paris Climate Agreement in terms of its implications for welfare, GDP, investments and trade for major countries and regions including the G-20 countries and oil-exporting countries.

The analysis suggests that the economic impacts will be mostly felt in Europe including the European Union if the Paris Agreement is fully implemented. European countries are likely to undergo a welfare loss of 1.0 to 1.5 percent by 2030. Among non-European countries, Australia, New Zealand and Mexico will also be impacted with an expected welfare loss of about 1.5 percent. Interestingly, since the commitments of some of the major emitters such as China and India will not take effect by 2030, they will experience minimal impacts in their welfare, while the United States is expected to witness a decline of about 0.7 percent in its welfare by 2030. Most countries in Asia, Latin America, and MENA will have negligible impacts. The sectoral analysis suggests a significant loss for fossil fuel-based sectors in terms of production and trade while significant gains are expected for clean energy sectors.

Moreover, the results also indicate that a fall in the prices of renewables would considerably soften the economic impact of the Paris Agreement. The economic impacts for Europe especially in terms of GDP loss will almost be halved for the majority of the countries. The associated investment gains would be significant and trade disruptions substantially minimized. In terms of specific sectors, a fall in the price of renewables will give further boost to clean energy sectors such as solar and wind at the cost of the fossil fuel-based sectors. Coal-fired power generation would also be significantly reduced.

The findings therefore point in the direction of improving the investment regime for renewable energy which in turn would make the economic costs of implementation of the Paris Agreement far more manageable. Investments in R&D could also help in speeding up innovation in technology which in turn would reduce the price of renewables considerably. Overall, all this could also spur more ambitious NDC submissions by countries as a follow-up to the commitments agreed in Paris.

It is important to highlight two major limitations of the current paper. First, the stylized nature of the policy experiment needs a careful interpretation of the results. In the paper, a "what if" scenario is developed to explore implications of INDCs, i.e., if INDCs were implemented in the global economy as represented by our 2011 base year. However, the INDCs, by their very nature, would be implemented over a period, which would undoubtedly take many policy reforms and approaches to achieve the goals. This contrasts very much with the approach used here and represents one of the major weaknesses of static CGE models that are mostly used in climate policy analysis. The use of a dynamic CGE model would have partially addressed some of these concerns.

Second, implementation of the INDCs is likely to impact the workings of energy markets across the globe. However, such impacts are likely to be transferred in the form of welfare change which depends on a number of factors that are particular to the model used here. For example, the degree to which changes in higher energy cost of production are passed on to consumers depends on the relative price elasticities of supply and demand. These elasticities therefore play a critical role in evaluating the impact of INDCs. In addition to demand elasticity, inter-fuel substitution is key to the price responsiveness of firms' demand for oil and other energy sectors. Thus, proper representation and validation of these parameters is paramount to proper documentation of the policy impacts of INDCs. Finally, one observes that the benefits from cutting emissions as per the Paris Accord may potentially outweigh the costs in terms of slowdown in GDP.

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Annex 1. INDC Ambition by 2030 by Country

Country	Emission Rank (2010)	INDC Target by 2030 (percent change)	Per Capita Emission (2010)
Afghanistan	98	0	1.1
Angola	60	-24	3.7
Albania	145	2	3.1
Andorra	177	-27	6.5
United Arab Emirates	34	-14	28.8
Argentina	28	-3	7.9
Armenia	146	115	2.7
Antigua and Barbuda	174	26	7.5
Australia	17	-38	25.3
Austria	57	-33	10.2
Azerbaijan	82	-18	6
Burundi	155	783	0.5
Belgium	45	-37	12.1
Benin	130	9	1.4
Burkina Faso	103	108	1.8
Bangladesh	43	68	0.9
Bulgaria	75	-9	8.3
Bahrain	99	20	23.7
Bahamas	161	-13	9
Bosnia and Herzegovina	109	46	6.8
Belarus	56	17	9.7
Belize	171	-10	3.2
Bolivia	90	-15	3.7
Brazil	7	0	5.2
Barbados	168	-21	6.1
Brunei Darussalam	125	18	37
Bhutan	167	-7	2.9
Botswana	116	-38	10.4
Central African Republic	96	-22	7.3
Canada	11	-25	21
Switzerland	81	-58	7
Chile	53	18	5.7

China	1	30	8.4
Côte d'Ivoire	120	-15	0.9
Cameroon	104	94	1.4
Congo, Dem. Rep.	83	15	0.7
Congo, Rep.	142	3	2.2
Cook Islands	196	4	2.4
Colombia	38	2	4.3
Comoros	189	53	0.3
Cabo Verde	175	6	1.3
Costa Rica	126	-46	3.2
Cuba	78	40	5
Cyprus	139	-43	9.3
Czech Republic	44	-25	13.2
Germany	8	-37	11.9
Djibouti	169	21	1.9
Dominica	185	-73	3.2
Denmark	73	-40	11.6
Dominican Republic	95	-8	3.3
Algeria	39	-9	5.2
Ecuador	76	-45	4.1
Egypt, Arab Rep.	29	3	3.7
Eritrea	148	-29	1.4
Spain	27	-14	7.6
Estonia	118	-37	15.1
Ethiopia	46	-25	1.5
Finland	66	-35	14
Fiji	163	9	3.3
France	18	-36	8.5
Micronesia	191	-31	1.3
Gabon	151	30	4
United Kingdom	15	-38	10
Georgia	135	190	2.8
Ghana	117	59	0.9
Guinea	121	-35	1.7
Gambia, The	165	-39	1.5
Guinea-Bissau	166	-30	1.4
Equatorial Guinea	150	-39	8.5
Greece	48	-19	11
Grenada	181	-11	3.2

Guatemala	110	17	1.8
Guyana	159	-21	4.7
Honduras	122	29	2.2
Croatia	100	-1	6.8
Haiti	140	45	1
Hungary	71	2	6.9
Indonesia	9	1	3.5
India	4	48	2.5
Ireland	74	-30	13.9
Iran, Islamic Rep.	10	16	10.1
Iraq	41	-6	5.1
Iceland	156	-60	15
Israel	61	-28	10.6
Italy	20	-25	8.5
Jamaica	143	63	3.3
Jordan	102	18	4.5
Japan	6	-14	9.9
Kazakhstan	30	-18	18.1
Kenya	70	45	1.7
Kyrgyzstan	123	-38	3
Cambodia	97	-22	2.2
Kiribati	193	-37	0.9
Saint Kitts and Nevis	180	26	7.3
Korea, Rep.	16	-18	12.5
Kuwait	50	-4	36.6
Lao PDR	137	-18	1.9
Lebanon	114	28	5.1
Liberia	152	-42	1.5
Saint Lucia	178	24	2.9
Liechtenstein	184	-47	6.4
Sri Lanka	108	14	1.3
Lesotho	157	-17	2.3
Lithuania	115	16	6.9
Luxembourg	131	-48	24.3
Latvia	134	17	5.9
Morocco	63	39	2.4
Monaco	192	-46	2.5
Moldova	127	-21	3.5
Madagascar	92	-47	1.6

Maldives	170	83	3.5
Mexico	12	-27	5.6
Marshall Islands	188	-48	3.7
Macedonia	133	24	5.9
Mali	77	-20	3.8
Malta	162	-38	7.4
Myanmar	51	-6	2
Montenegro	158	-31	7.1
Mongolia	107	38	10
Mozambique	94	-35	1.4
Mauritania	138	0	3.3
Mauritius	154	51	3.9
Malawi	144	-15	0.6
Malaysia	32	30	10.2
Namibia	132	-10	5.6
Niger	87	-12	2.4
Nigeria	36	68	1.3
Nicaragua	124	-8	2.7
Niue	198	24	4.1
Netherlands	37	-41	12.8
Norway	80	-54	11.3
Nepal	91	-8	1.3
Nauru	195	52	6.1
New Zealand	62	-22	18
Oman	64	-34	26.2
Pakistan	26	-8	2.3
Panama	129	2	3.8
Peru	52	-44	3.3
Philippines	40	-12	1.9
Palau	194	-43	4.1
Papua New Guinea	128	26	2
Poland	23	-24	10.8
Portugal	68	3	6.9
Paraguay	93	577	5.4
Qatar	47	-9	72.1
Romania	49	12	5.9
Russian Federation	5	34	16.2
Rwanda	149	-31	0.6
Saudi Arabia	14	5	22.6

Sudan	113	-42	2.4
Senegal	111	21	2
Singapore	79	41	11
Solomon Islands	183	-49	0.5
Sierra Leone	153	-24	1
El Salvador	136	22	2
San Marino	186	-26	7.4
Somalia	105	-41	2.9
Serbia	67	10	8.1
São Tomé and Príncipe	190	-16	1
Suriname	160	20	6.7
Slovak Republic	84	-21	8.6
Slovenia	119	-17	9.6
Sweden	72	-30	7
Swaziland	164	-1	2.3
Seychelles	173	2	8.2
Chad	106	-17	2.3
Togo	147	57	1.2
Thailand	22	-3	6.5
Tajikistan	141	67	1.2
Turkmenistan	65	37	15.2
Tonga	187	-9	2.1
Trinidad and Tobago	58	12	62.8
Tunisia	88	44	3.6
Turkey	24	97	5.7
Tuvalu	197	-46	2
Tanzania	69	-44	1.5
Uganda	86	17	1.2
Ukraine	25	63	8.8
Uruguay	85	-25	11.9
United States	2	-39	22.5
Uzbekistan	35	-22	7.9
Saint Vincent and the Grenadines	182	29	2.8
Venezuela, RB	33	7	9.5
Vietnam	31	81	3.3
Vanuatu	176	-29	2.4
Samoa	179	2	2

Yemen, Rep.	101	-7	1.2
South Africa	19	-13	10.1
Zambia	89	-24	2.7
Zimbabwe	112	97	1.8