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THE IMPACT OF CARBON TAX POLICIES ON FUTURE CARBON EMISSIONS FROM PAKISTAN'S ENERGY SECTOR USING THE TIMES MODELING FRAMEWORK

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Abstract: Global warming and climate change have gained a lot of attention in recent times, since these phenomena lead to socio-economic instability in modern society. Mankind is now well aware of the harmful effects caused by environmental emissions. As a result, research into techniques for reducing environmental emissions is of utmost importance. This paper has discussed a methodology which can be utilized to fight this battle against climate change. More specifically, using the Pakistan Integrated Energy Model (Pak-IEM), forecasts for carbon emissions are performed out to the year 2040. A base case with no carbon tax on the energy system is used as a reference for comparison of final results. In the other two cases, the impact of enforcing a carbon tax policy on the energy sector of Pakistan is explored. The energy sector is among the primary culprits responsible for the harmful carbon emissions, and this paper shows whether a carbon tax policy would help in reducing carbon emissions in Pakistan. The results reveal that a carbon tax policy does in fact help in reducing emissions, more specifically, a reduction of 17 MtCO2 was seen as compared to a base case with no carbon tax policy.

Key Words: Pakistan, Pak-IEM, TIMES, Energy, Environment, Policy

INTRODUCTION

Pakistan is in well in line with the rest of the world in accepting climate change as an imminent reality, which is now a growing threat by the day. Due to its particular geographic aspects, Pakistan is among the most vulnerable countries to any climate change. However, Pakistan is among the smallest contributors in the environmental pollution leading to this global climate change. The country believes in a global collaborative effort to minimize the harmful environmental impacts caused by human activity; the decision makers in Pakistan keep a keen interest in ensuring future development plans are in line with a low carbon strategy.

Pakistan is located on the global map in between latitudes of 24° and 37° north and longitudes of 61° to 75° east. The country extends over 1600 kilometers from north to south and 885 kilometers from east to west, thus revealing an area of about 880000 square kilometers. Pakistan's coastline stretches to about 1046 kilometers. Due to the diverse landscape and climatic variance, Pakistan is divided as 11 geographical, ten agro-ecological and 9 major ecological zones. This diversity is a major reason in the country's extreme vulnerability to climate change. Pakistan lies on a steep incline, dropping sharply from almost 8500 meters down to sea level within a distance of less than 3000 km. This situation is augmented by the presence of huge glacial reserves in the north of the country which melt and flow through the country, supplying more than 70% of the river flows. This frozen "blue gold" is the country's most precious reserve and sustains the agro based economy aided by the unpredictable monsoon rains of the summer. The glacial melt and the monsoon rains overlap in the three month summer period providing the irrigation water needed for the arid country but also, ironically, dangerously raising the risk of flash floods in the rivers. The dense population base which resides along these flood plains and is, subsequently, directly impacted multiplies the

country's vulnerability. All this is established scientific knowledge. Climate Change is now beginning to add a new erratic and volatile ingredient into this water cocktail. It is not only augmenting the melting of the glaciers in the north but also enhancing the unpredictability of the monsoons.

Therefore, climate change impacts almost all the sectors in Pakistan especially the water resources, energy, health, forestry, biodiversity and agricultural productivity. Although a victim of the harmful effects, Pakistan is, ironically, one of the lowest contributors to the problem of environmental emissions. Currently, Pakistan contributes 0.8% of the total global GHG emission and is ranked 135th globally on a per-capita basis (Malik et al. 2010). In addition, despite the fact that Pakistan's per capita energy consumption and cumulative CO2 emissions are very low, the CO2 emissions per unit of energy consumption are relatively high. Pakistan's total GHG emissions were 310 million tons of CO2 equivalents (MtCDE) in 2008. These emissions comprised of carbon dioxide (54%), methane (36%), nitrous oxide (9%), carbon monoxide (1%) and Non-Methane Volatile Organic Compounds (0.3%) (Irfan and Attari 2011).

Moving on to emissions by different sectors, the energy sector (including transport) is the most dominant contributor to GHG emissions in Pakistan totaling 157 million t CO2 in year 2007-08 which accounts for over 51% of country's total emissions (0.45 % of world's total). Other sectors include Agriculture and Livestock - 39%, Industrial Processes - 6%, LULUCF - 3%, and Wastes - 1%.(Khan 2010) Thus, almost 90% of Pakistan's GHG emissions came from the Energy and Agriculture-Livestock sectors and, subsequently, this is the area where the thrust of Pakistan's mitigation efforts needs to be focused.

This paper will therefore address the impact of carbon tax policies on future carbon emissions from Pakistan's energy sector. The idea is to establish a conclusion with proof, on whether enforcing carbon taxes can actually reduce carbon emissions in Pakistan. If so, the same ideology can be proposed for use globally in an attempt to reduce the global climate change scenario. In order to study the effect of such environmental policies, The Integrated MARKAL-EFOM System (TIMES) model will be used. More specifically, the Pakistan Integrated Energy Model (Pak IEM), which is based on the TIMES model will be analyzed and utilized to address the effects of carbon tax policies on Pakistan's energy sector. The authors believe that establishing a sound methodology to analyze environmental policies in one country, can lay the groundwork for similar future work to be pursued in other countries that wish to reduce their carbon emissions respectively.

The Integrated Markal-Efom System (TIMES)

TIMES is a partial equilibrium based, techno-economic optimization model generator for energy systems of varying magnitudes and complexities. This tool allows for estimating the future performance of an energy system widespread over local, national or global level. These estimates are projected over a multiple period time horizon, allowing for a more dynamic analysis of the energy system performance (Loulou and Goldstein 2005). The scope of the TIMES model is not limited to whole energy sectors, rather this can also be utilized for the comprehension of single sectors explored in great depth and detail. An example could be a specific analysis of the transport sector of any region over a predefined time horizon. To initiate this analysis process, the user enters estimates of energy demand as a point of reference, such as the estimated petrol consumption by cars in a particular region. Moreover, the user enters the existing data on energy related infrastructure along with technical details of prospective future energy technologies. Furthermore, the current and expected sources to supply the primary energy are also entered into the model for the region to be analyzed. By utilizing these inputs by the user, TIMES optimizes the energy system settings to determine a least cost pathway for fulfilling the energy demand (Gargiulo 2009). In order to do so, the model makes tradeoffs between different energy technologies, makes investment and operational choices as well as choosing an optimal mix of the different energy sources disclosed by the user. The choices the model makes in energy infrastructure, fuel and type are based on their impact on the economic and environmental criteria. Therefore, TIMES is said to be a vertically integrated model of the entire energy system.

This model is not just limited to the analysis of energy system rather it can be effectively utilized to model the environmental aspects and emissions related to the energy sector. This paper will highlight how TIMES is used to analyze the variation in carbon emissions by introducing carbon tax policies upon the energy sector of Pakistan.

Pakistan Integrated Energy Model (PAK-IEM)

The Pak-IEM is model developed using the TIMES modeling framework and it is a comprehensive representation of Pakistan's complete energy system. This includes the whole range initiating from the primary energy sources to processing facilities to the supply chain and the final energy form demanded by the consumers in Pakistan(International Resourch Gorup 2011). This model can be used to analyze the impact of possible strategies and policies to fulfill the prospective energy demand in the years to come. This allows a planning capability to prepare today in an optimal setting to conveniently meet the future energy needs of Pakistan. In addition, this model also allows for a comprehensive assessment of environmental strategies to allow decision makers to come up with effective carbon mitigation policies (International Resource Group 2011).

This paper will utilize this model, the Pak-IEM, to explore the impact of enforcing different carbon tax policies on the energy system of Pakistan. This will allow comprehension on the need for carbon tax policies and how effective they can be in ensuring Pakistan stays on top of its goal of winning the battle against climate change. In the following section, the results and discussion concerning the level of emissions from the energy sector will be presented. All emission forecasts will be done out to the year 2040.

The authors aim to share insight on the importance of carbon tax policies on Pakistan's energy sector, and in doing so feel such methodologies can be equally effective all over the globe in countries striving to minimize the impact of climate change.

Using the Pak-IEM, impact of different tax policies is explored, to understand the importance and need of such policies. To be able to deduce conclusions concerning carbon mitigation, the authors choose to explore 3 different scenarios, each reflecting on a different carbon policy. In the following text the nature of these 3 cases will be described along with their effect upon the forecast of future carbon emissions from the energy sector. All emission forecasts are performed out to the year 2040.

Following 3 cases are explored:

1. Base Case (No Carbon Tax)
2. Case 1:Carbon tax ($20 - $30)
3. Case 2:Carbon tax ($150 - $250)

Base Case:

The model is run without any constraint on emission levels to set a reference emissions level. This reference level will allow for a comparison with the following cases and a better comprehension on the impact of introducing a carbon tax policy. The model is run using Versatile Data Analyst Front End (VEDA FE), without enforcing any particular policy constraint. Once the run is complete, the file is loaded in Versatile Data Analyst Back End (VEDA BE) so the results can be viewed in graphical as well as tabular form.

Sector	2015	2016	2020	2025	2030	2035	2040
Agriculture CO2	6963.31	7296.51	7997.21	9089.95	10032.27	11028.48	12138.84
Commercial / Other Govt CO2	1124.00	1205.41	1473.39	1757.19	2063.51	2411.53	2817.19
Industry CO2	62193.84	65941.88	81791.05	112913.09	155958.36	213468.64	297824.29
Power Plants CO2	17821.40	14511.19	11122.51	9363.44	8872.45	4039.42	8872.45
Residential CO2	2.42	186.19	2.72	3.08	3.46	3.89	4.41
Transport CO2	28926.31	30574.59	34406.34	43136.02	54968.00	63362.48	75926.71
Total CO2 Emissions	117031.28	119715.77	136793.22	176262.77	231898.05	294314.44	397583.89

Table 1

Table 1 shows the result of the forecast for the base case, which reflects on carbon emissions by the energy sector without any constraint upon it. The table reveals industry and transport appear to be the most environmentally harmful among the other sectors. The figure below is a graphical representation

of the same data. It seems without any constraint carbon emissions will continue to rise to high levels in the year 2040.

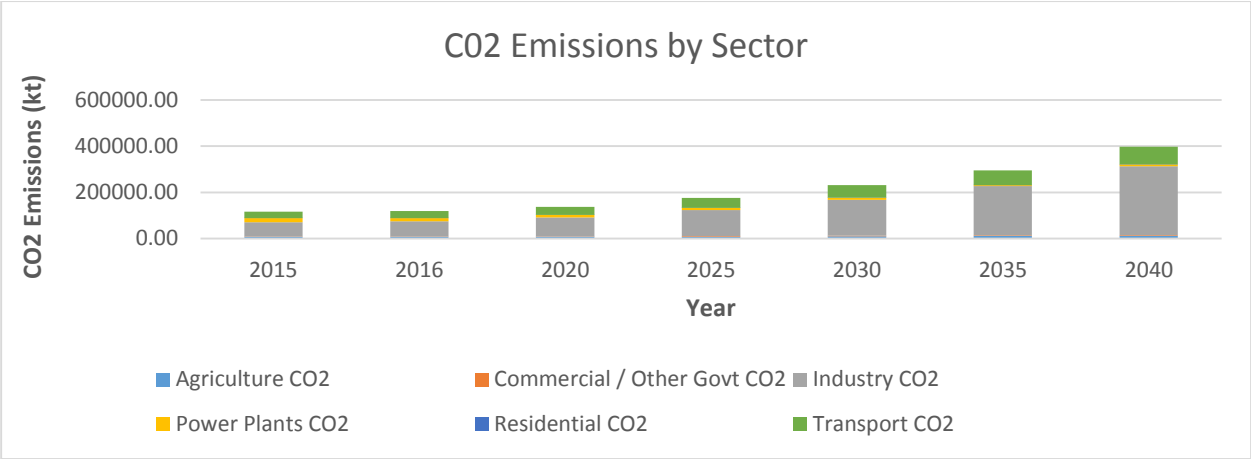

Figure 1

Case 1: Carbon tax ($20 - $30)

In this second case, the first carbon tax policy is enforced upon the energy sector. As per the allotted settings, $20/ton of carbon dioxide emissions is added in the year 2020, whereas $30/ton is introduced in the year 2030. Table 2 shows the emission forecasts based on this policy.

Sector	2015	2016	2020	2025	2030	2035	2040
Agriculture CO2	6963.31	7296.51	7997.21	9089.95	10032.27	11028.48	12138.84
Commercial / Other Govt CO2	1124.34	1205.86	1474.00	1757.91	2062.68	2411.53	2817.19
Industry CO2	60883.58	64459.59	80212.72	111679.84	155958.36	213342.48	297741.94
Power Plants CO2	17815.37	14374.07	11003.18	7570.87	4615.04	3524.78	3124.45
Residential CO2	2.42	2.48	2.72	3.08	3.46	3.89	4.41
Transport CO2	28894.16	30542.44	33314.64	39566.30	47534.74	58410.12	75926.71
Total CO2 Emissions	115683.18	117880.96	134004.47	169667.95	220206.55	285196.49	388629.09

Table 2

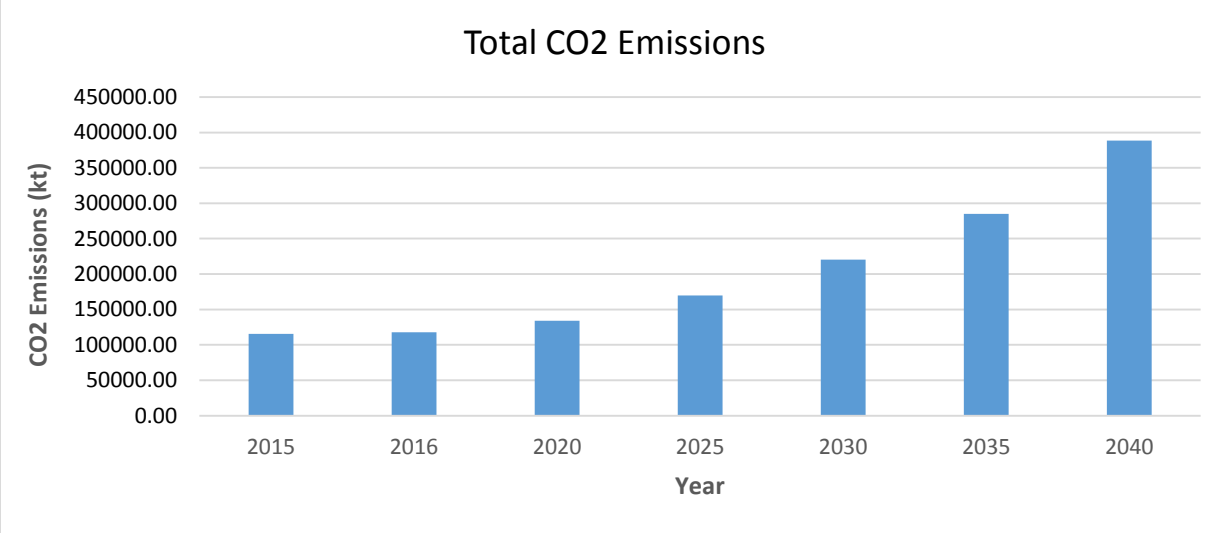

Figure 2

Case 2: Carbon Tax ($150- $250)

In this final case, a higher carbon tax is introduced, specifically $150/ton CO2 in 2020 followed by $250/ton CO2 in the year 2030. This case is introduced for a clearer comparison between the extreme scenarios, the initial one without any carbon tax and this case with a comparatively high carbon tax.

Table 3 shows the emissions forecasts for this case, and again sector specific emissions results can be seen.

Sector	2015	2016	2020	2025	2030	2035	2040
Agriculture CO2	6979.23	7185.75	8020.41	9082.98	10023.45	11037.08	12129.60
Commercial / Other Govt CO2	1124.35	1193.94	1474.66	1758.57	2063.06	2411.53	2817.19
Industry CO2	60537.68	64113.35	80083.37	110852.82	153575.20	210016.02	291239.99
Power Plants CO2	15799.66	10895.73	6153.88	2360.35	557.42	278.95	107.53
Residential CO2	2.42	2.48	2.72	3.08	3.46	3.89	4.41
Transport CO2	25158.99	26221.13	30242.60	37009.21	45486.18	57874.92	75279.83
Total CO2 Emissions	109602.32	109612.38	125977.64	161067.01	211708.77	281343.44	381471.01

Table 3

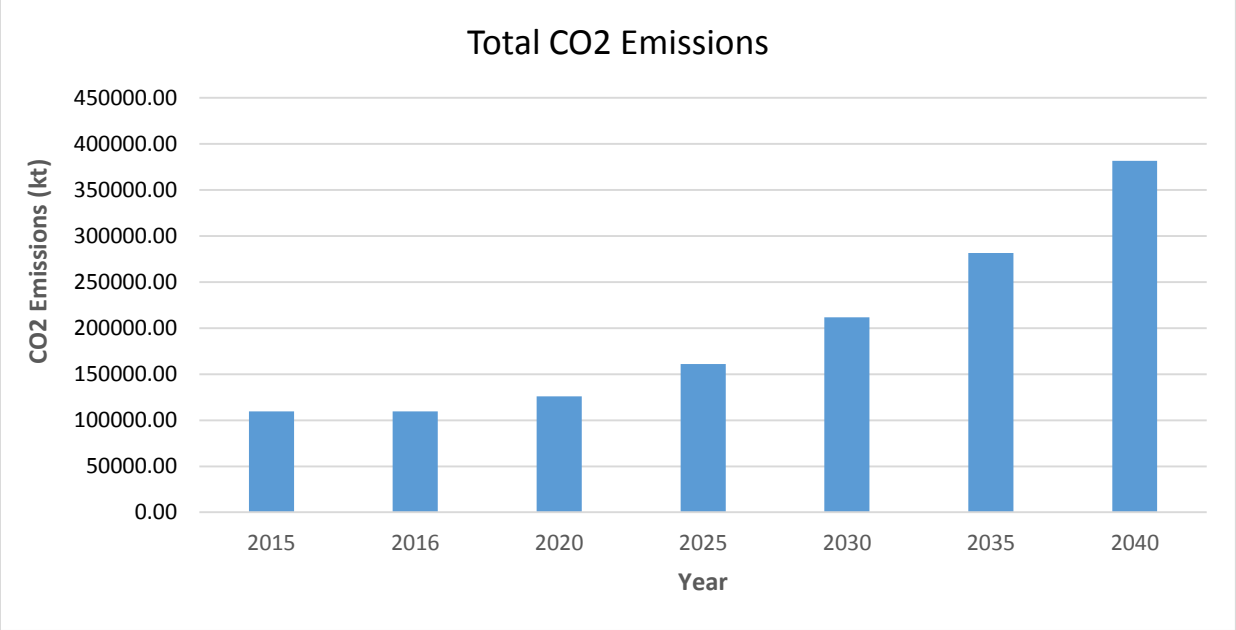

Figure 3

DISCUSSION OF RESULTS & COMPARISON

Sector	2015	2016	2020	2025	2030	2035	2040
Base Case	117031.28	119715.77	136793.22	176262.77	231898.05	294314.44	397583.89
Case 1	115683.18	117880.96	134004.47	169667.95	220206.55	285196.49	388629.09
Case 2	109602.32	109612.38	125977.64	161067.01	211708.77	281343.44	381471.01

Table 4

Table 4 shows the comparison between a base case and the other two cases of varying amounts of carbon tax. As shown in table 4, the amount of carbon emissions in the year 2040 for a no carbon tax policy is around **398 MtCO2**. Following the introduction of a carbon tax as per case 1, the projected carbon emissions in year 2040 come down to about **389 MtCO2**. Finally, in case 2, with a higher carbon tax enforced upon the energy system settings, the projected carbon emissions come further down to around **381 MtCO2**. This reflects on a maximum decline in carbon emissions of **17 MtCO2** when compared to the base case without any carbon tax. These results prove the question put forward earlier in this paper by the authors, whether introducing a carbon tax policy would lead to a reduction in carbon emissions.

CONCLUSION

Although the authors have studied and analyzed the climate change aspects of Pakistan alone, but they firmly believe this same methodology can be utilized by other countries all over the globe. The results of this paper prove that carbon tax policies do in fact impact the extent of emissions let out into the atmosphere. Such positive strategies to minimize harmful emissions should be adopted by decision makers, to slow down the process of global warming. As a result, society is bound to benefit with better health and prosperity.

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