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The Exponential-based Carbon Credit Cap in Carbon Cap-and-Trade Markets

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ABSTRACT: The concept of carbon markets as developed in 1997 by the Kyoto Protocol was a good idea whose adoption and implementation by all counties and states would have significantly reduced the rate of emission of greenhouse gases into the atmosphere. The Carbon markets were proposed to be based on cap-and-trade whose forces of supply and demand would discourage the increase or steady emission of greenhouse gases and force companies to, gradually, revert to the use of clean energy in production. This would promote the net zero carbon emission target. The carbon markets were designed to have a cap whose nature is a specific number for all entities. The number represents the carbon quantity whose regulator would keep reducing until the net zero carbon is achieved. This nature of the cap encourages large emitters of greenhouse gases to shift to other jurisdictions that have soft regulations. It also encourages restructuring into smaller companies whose net emissions could be almost the same or more than before. In this paper, we have proposed an exponential-based cap that would leave little or no room for such market strategies. We have also demonstrated how the proposed cap can be implemented.

KEYWORDS: carbon credit, carbon markets, exponential-based cap, cap-and-trade, global warming

I. INTRODUCTION

The adverse effects of climate change are now here with us. It is mostly felt by the countries in the topical regions. There has been a decrease in agricultural production, an increase in sea level displacing people living near the shows of major water bodies, and adverse effects on the economic situation of people living in developing countries. Animals living in tropical regions have also been affected. See [6,7,8]. All these effects among others affect the livelihoods of humans as well as those of animals and plants which we depend on. A move by the Third Conference of Parties (COP 3) of the United Nations Framework Convention on Climate Change (UNFCCC) to develop the Kyoto Protocol that initiated the concept of carbon trading intending to reduce global warming was the best move in the right direction in salvaging the current worse situation. See [1]. The conference resolutions led to the birth of Carbon markets whose aim was to reduce global warming by reducing the emission of carbon dioxide and other global warming gases into the atmosphere. The carbon market gained traction and most jurisdictions adopted the Idea and passed policies that would see them regulate carbon emissions. Even the major carbon emitters like China and the United States of America adopted the Idea and benefited economically in terms of their GDP and domestic decarbonization. See [5]. This reduced the quantity of emission of gases by some margin and companies changed to low-carbon emission technologies. See [4].

Despite Carbon trading being a milestone towards the reduction in emission of global warming it faced a lot of challenges. Some of them were carbon leakage and prolonged negotiations that delayed implementation. See [2]. There has also been a lack of sound policies, regulations, and laws to support the system. Some jurisdictions experienced a lack of professionals and understanding of carbon finance to push the carbon market agenda. See [9]. The report by the Kyoto Protocol too had some loopholes that would hamper efficient regulation and reduction of emission of carbon into the atmosphere. The possibility of having questionable carbon claims and false self-reporting of emissions is one of them. Another key loophole is one that was created by the nature of carbon markets, cap-and-trade. The cap was supposed to be a specific number that the companies or rather countries have to buy and sell their carbon credits within the given quantity. This type of cap gives the players room to redistribute their investments and explore other areas where the carbon policies are not strict. They would also disintegrate large companies and operate as several small companies with the ability to get a lot of carbon credits. Eventually, the amount of carbon emitted into the atmosphere would remain the same or increase. For this reason, this paper proposes an exponential cap that would not only discourage the redistribution of investment into other territories but also ensure that low emitters cut their emission and revert towards green energy as well. The cap would also require the leading emitters to cut their emission by a bigger margin compared to the least carbon emitter.

II. THE EXPONENTIAL-BASED CAP MODEL

In this section, we will provide a general model and then illustrate how we can apply the model to a relevant dataset.

A. *General Model*

The exponential-based model is generated from the most recently collected data having amounts of greenhouse gas emissions by various entities. The entities could be individual companies, countries, or regions defined by a regulator. The model is based on the following assumptions:

- The entities reporting carbon emissions are grouped and their emissions reported to a regulator
- There is accuracy and honesty in reporting the number of greenhouse gasses emitted
- There is a regulator governing several entities
- The entities are arranged in descending order

The exponential function is given by

$$y(x) = ab^x \quad \ldots (2.1$$

where $a > 0$ is a constant determined by the quantity of greenhouse gases emitted by the largest emitter and $b > 0$ is a base. To generate the model, we first linearize it using the logarithmic transformation. We then apply logarithm functions on $y(x) = y = ab^x$ to get $\ln y = \ln a + x \ln b$. The linear equation becomes

$$Y = A + Bx \quad \ldots (2.2)$$

where $Y = \ln y$, $A = \ln a$ and $B = \ln b$. We apply the model to a dataset composed of the name or identity number of the entity and the amount of greenhouse gases being emitted during a specific period. Data is then arranged in descending order. Thereafter, the position of the entity minus 1 is used as a code to represent its corresponding value of x-variable. For instance, the value of the x-variable of the first, second, and third second largest emitters of greenhouse gasses would be 0, 1 and 2 respectively. Using an appropriate tool, the data is fitted to a linear model, the parameters $A = \ln a$ and $B = \ln b$ read and the model in equation (2.1) is generated after a few algebraic manipulations. This model can then be used to create a cap for the carbon credit.

B. *Implementation of the Model*

To implement the cap, a small shift parameter, h, is added to the function to get

$$g(x) = ab^x + h \quad \ldots (2.3)$$

where $h > 0$. The function (2.3) defines the initial cap that is set by the regulator. The successive caps are determined by varying the parameters k and s in the function

$$C(x) = k \cdot ab^x + (h - s) \quad \ldots (2.4)$$

where $0 < k < 1$ and $s > 0$.

The parameter k ensures that the leading emitters of greenhouse gases reduce their emission by a relatively bigger margin than the rest while the parameter s ensures that the smallest emitters of carbon reduce their emissions as well. Once the initial cap defined by function (2.3) is created, the regulator will be varying the values of k followed by s leading to a reduction in the level of carbon credits for each entity after each regulation cycle. This kind of cap does not encourage the division of companies emitting larger quantities of greenhouse gases into smaller ones in other jurisdictions because the credit seal is almost closer to everyone in the market.

C. *Application of the Model*

We have used the data on greenhouse gas emissions by country from the Emissions Database for Global Atmospheric Research of the European Commission. See [3]. For the sake of the application of the model, we used the data on the emission of gases by country for the year 2022.

The data was pre-processed by removing all columns other than the country and the year 2022 columns. Aggregated rows were also removed. The quantities of emissions were then arranged in descending order. The top 5 countries were China, the USA, India, Russia and Brazil. Their emissions were about 15684 megatonnes (Mt), 6017Mt, 3943Mt, 2579Mt and 1310Mt respectively. See [3]. Their corresponding position which was used as the independent variable,x, was 0,1,2,3 and 4 respectively. The corresponding emissions are used as the dependent variable, y. The data was transformed using functions $Y = \ln y$ and then fitted into a linear function (2.2) using Python's Scikit-learn, Numpy, and Pandas libraries. The function was

$$Y = 9.2694 - 0.42906x \quad \ldots (2.5)$$

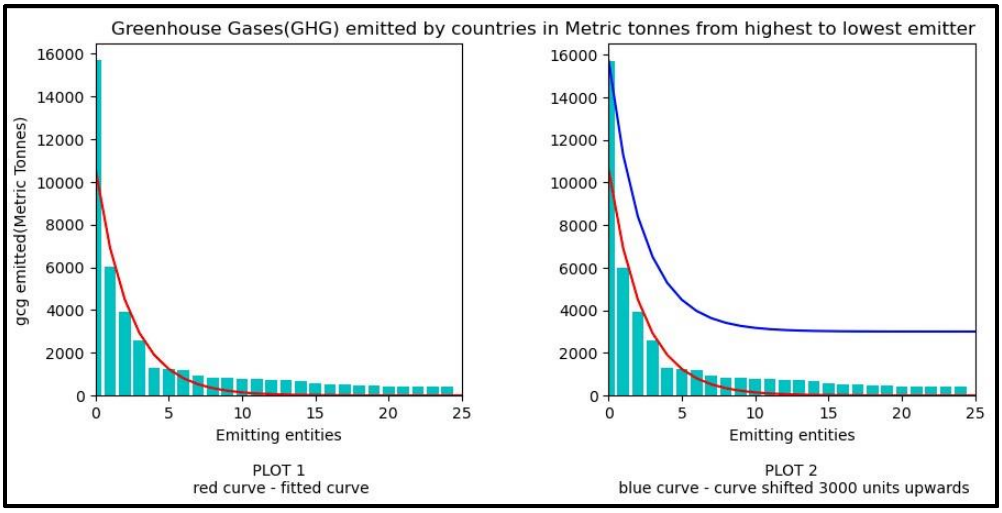
Using the transformations, $A = \ln a$ and $B = \ln b$ where $A \approx 9.2694$ and $B \approx -0.42906$, the values of a and b are computed; $a \approx 10608.33$ and $b \approx 0.6511174$. The fitted exponential function is as follows:

$$y = 10608.33(0.6511174)^x \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (2.6)$$

The function (2.6) will vary from one regulator to another based on the quantity of greenhouse gasses emitted by the entities under that regulator. The fitted curve and the amount the greenhouse gasses emitted by the first 25 countries are shown in plot 1 of Figure A.

Having set the basic cap function, (2.6), the regulator will set the first cap by varying the variable h and k of function (2.4). At this point, $s = 0$. For illustration purposes, we have set $h = 3000$ and $k = 1.2$. The resultant graph after a shift of 3000Mt up is shown in plot 2 of Figure A. The graph is in blue. The new function becomes

$$y = 1.2 \cdot 10608.33(0.6511174)^x + 3000 \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . (2.7)$$



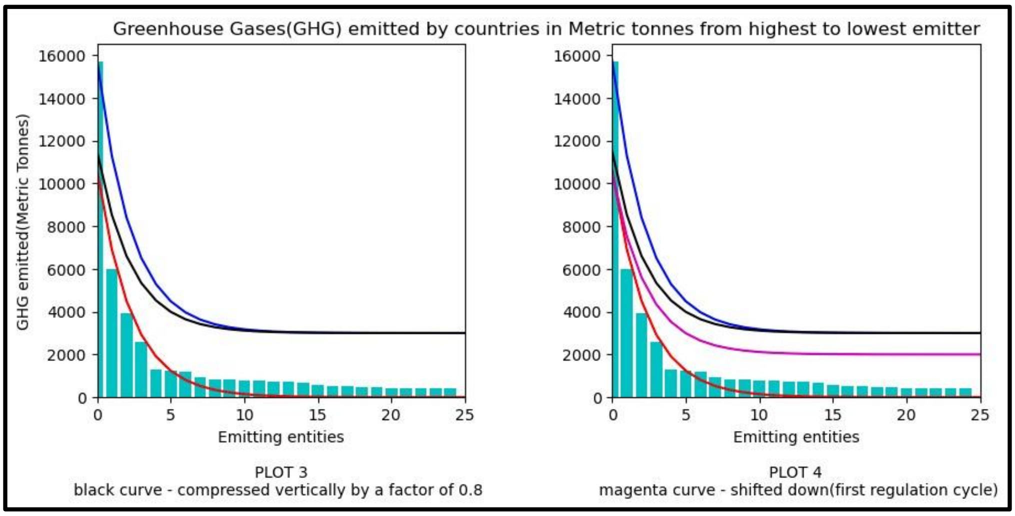
A. *Greenhouse gas emission with the cap being set by the blue curve in plot 2. Plot 1 shows the emission by the first 25 countries and the initial fitted exponential curve.*

The vertical shift ensures that all entities emitting greenhouse gases especially, those that that emit the smallest quantity can trade carbon credits.

To create the first regulatory cycle, the regulator suitably alters the constant k of the function in equation (2.4) by reducing it. This is achieved by increasing the value of s. In our case, the new value of k is 0.8 while the new value of s is 1000. The black curve in plot 3 of Figure B highlights the effect when the value of k is decreased while the magenta curve in plot 4 of Figure B shows the changes when a vertical shift of 1000Mt is applied to the black curve. The new function becomes

$$y = 0.8 \times 10608.33(0.6511174)^x + (3000 - 1000). \dots \dots \dots \dots \dots \dots .. (2.8)$$

The new value of k ensures that the largest emitters of carbon decrease their emission by a larger margin than others while the new value of s ensures that the low emitter of carbon also decreases their emission or their carbon credit. The regulator can then have several cycles of regulation till it becomes expensive for greenhouse gas emitters to continue using their current technologies. They gradually shift to green energy due to the high cost of operation with minimal operation brought about by the reduction of carbon credit. Eventually, zero net carbon is achieved.



B. *Greenhouse gas emission with the first cycle of regulation set by the magenta curve in block 4 after a vertical compression shown by a black curve in plot 3 and vertical shift downwards by 1000 Mt shown by the magenta curve*

III. CONCLUSION

In this paper, we have described the significance of carbon markets and highlighted its challenges by reviewing the existing literature. We have also proposed an exponential-based cap that addressed the possible problem of disintegration of larger greenhouse emitting entities into smaller ones and migration to other jurisdictions with soft regulations. We have also illustrated how the exponential cap can be generated and used by regulators to control the carbon markets.

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