Science and Economics of Climate Change

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***Abstract*[1]**

Under the Kyoto Protocol established under the United Nations Framework Convention for Climate Change (UNFCCC), the amount of CO2 emission to be reduced by respective member country has been negotiated. This paper tries to verify scientific aspect relating to climate change which should form a basis for such negotiation.

Based on the United Nations Intergovernmental Panel on Climate Change (IPCC) reports, now it has been confirmed that global-warming is actually happening and it is caused by human activities, particularly by burning fossil energy discharging CO2 into atmosphere. Traditional economic game theory predicts that an effort to restrain yourself from making private profit to protect aggregate profit in a community would inevitably fail without sound scientific evidences. Environmental science also predicts that damage to environment is likely to be underestimated by humans. Based on these theories, this paper emphasizes the importance of scientific thinking and scientific evidences in determining a future course of CO2 reduction effort in the global community.

This paper also introduces an experience in Japan that expanded economic activities without increasing energy consumption at all, as an example of making an energy effective society.

I. Introduction

Climate change has been one of the most talked about environmental issues in this century. In the regime of international law, it also has caught attentions. The Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) published in 2007 stated that "warming of the climate system is unequivocal," and "most of the observed

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[1] This article is reconstructed from the presentation made at the AALCO Climate Change Seminar held on January 16, 2013 by the author. Therefore, originally this article has been designed for the audience and not necessarily as a reading material.

increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." Based on this report, now it has been virtually confirmed that the climate change is being generated by greenhouse gases, particularly the carbon dioxide (CO2), that are emitted from human activities.

The IPCC report also states that the amount of CO2 in the atmosphere increased from 280ppm to 379 ppm, 35% of increase, since the industrial evolution took place 150 years ago. The report also states that this increase happened for the first time in the history of the earth in 650,000 years. Scientifically, it is difficult to argue that the human activities are not the main cause of such an unprecedented level of change in the atmosphere.

Therefore, the argument in the international community has inevitably been focused that how we should control the emission of CO2. Hence, the necessity to enact new international rules has arisen. The efforts have been made under the Conference of the Parties established under the IPCC since 1995. The Kyoto protocol that adopted the legal binding obligations to some of its member states to limit their CO2 emissions was one of the most important international agreements that the global community achieved in this respect.

However, the debate under the COP tends to focus in the allocation of responsibility, and not in the actual reduction of CO2. CO2 emission is made from burning fossil energies and also partly from the reduction in the forest biomass, which is a necessary process for the development of economy and the enhancement of wealth. It is natural for any country, particularly developing countries, to maintain the right to continue burning fossil energies for the further development of their economy, although it is very much obvious that such increase in the use of fossil energies would only accelerate the climate change.

Hence, it is important to share the common understanding once again on the true impact of the climate change, scientifically. Also, it is imperative to share the understanding that would be explained under economics, since economies is in its essence mathematics which no one can deny. The debate for enacting new international law in the area of climate change must be based on the solid scientific and economic proofs. Otherwise, the debate would diverge only into the allocation of responsibility which would not be able to establish an international framework that would be truly workable for the actual reduction of greenhouse gases.

II. Possibility of Global Economic Growth

First, it may be useful to share the understanding how the environmental science predicts the future of the global community if the emission of CO2 continues without any control.

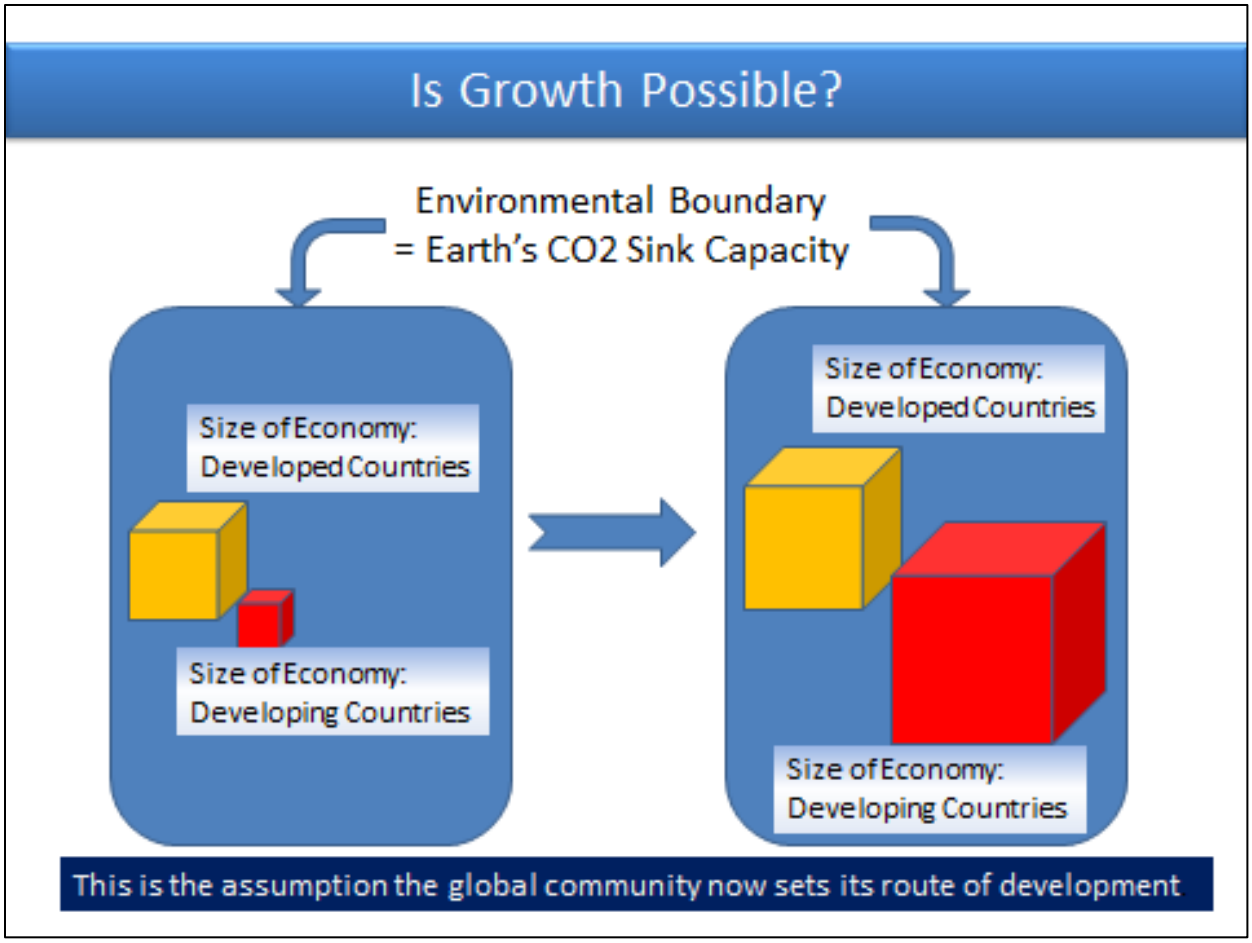
The Figure 1 explains a possible future direction of the global community in terms of CO2 emissions. First of all, it is imperative to understand that there must be a limit, the sink

capacity, up to which the planet earth can absorb CO2 emission without damaging habitual conditions of human beings. Within this limit, humans are allowed to emit CO2. However, if the emission goes beyond this point, it would invite the destruction of the entire global ecosystem under which humans would not be able to sustain their community no longer.

The left side of the Figure 1 illustrates a possible situation where the global community now actually fits. In the square shape of the earth's environmental boundary, both developed and developing countries are peacefully emitting CO2 well within the boundary. It is a matter of course that developing countries need to expand their economy to achieve at least the equal amount of economic wealth with the developed countries. Therefore, the developing countries will increase the amount of CO2 emission in line with their economic development.

The right side of the Figure 1 illustrates a possible situation where the global community will fit in the future. Along with the development of developing countries which hold larger population than the developed countries, the emitted amount of CO2 is now larger by the developing countries. Still, in this figure, the combined emission of CO2 from both the developed and developing countries is within the environmental boundary of the planet earth. In this case, there would be no problem for the global community to expand its economy by increasing the emission of CO2. However, this does not seem to be the case which is actually happening in our global community today, as we observe the change in the climate being caused by the increased amount of CO2 which is also scientifically proven under the IPCC. Nevertheless, the global community as a whole now is behaving as if this is the picture of the future of the global earth without making much effort in reducing the aggregate CO2 emission.

Figure 1.

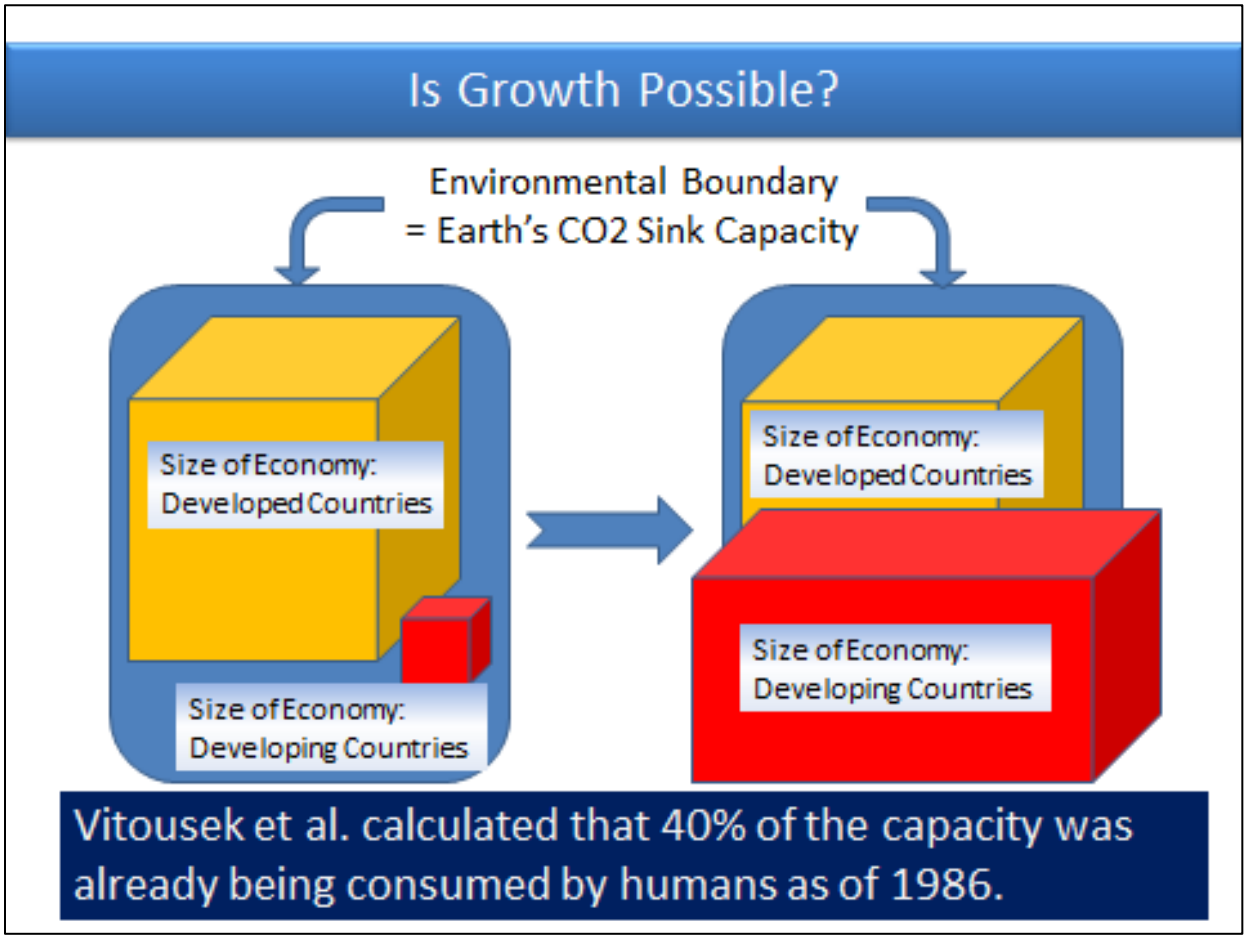


The Figure 2 illustrates the same change in the amount of CO2 emission but with the smaller size of the environmental sink capacity of the planet earth. In this Figure 2, the amount of current CO2 emission is presumed to be around the half size of the global sink capacity. It this is set as the starting point of our development, the global community will face soon or later reaching the global sink capacity boundary. If and when the CO2 emission exceeds the size of the boundary, the earth will no longer be able to sustain the human population, because the environment is deteriorated to the level where humans will no longer maintain the quality of humane life.

The problem we have regarding this figure is that we do not know how much percentage the humans have already used up the sink capacity of the planet earth. The IPCC reports do not provide any scientific figures regarding this point, as it is difficult to determine the size of the global sink capacity as a whole. The IPCC report predicts that the global temperature will rise 1.1~6.4c until the year 2100, and that the sea level will rise at least 18~59 cm during the same period. Such changes will affect the human society negatively and significantly. However, there

has been no scientific agreement that how much rise in the global temperature would be tolerable.[2]

Figure 2.



However, there have been quite a few attempts by scientists to measure the global environmental capacity. One good classic example is the efforts made by Vitousek et al. in

[2] Cancun Agreement adopted at the IPCC COP16 in 2010 set the target to contain the rise of temperature within 2 °C. "Further recognizes that deep cuts in global greenhouse gas emissions are required according to science, and as documented in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, with a view to reducing global greenhouse gas emissions so as to hold the increase in global average temperature below 2 °C above preindustrial levels, and that Parties should take urgent action to meet this long-term goal". This could be accepted as the figure that would represent the sink capacity of the planet earth but the scientific debate has not converged yet.

1986.[3] Vitousek used the amount of renewable photosynthesis as the criterion of sustainability, and concluded that as much as 40%, as a high estimate, of such photosynthesis might have been already being consumed by human activities at the time of his calculation in 1986. The figure implied that the economic activities of human beings can grow only 2.5 times at maximum. Similar efforts have been made by a number of scientists but so far there has been no decisive figures widely accepted as confirmed.

III. Tendency to Underestimate the Impact of Environmental Degradation

The Figure 3 depicts the environmental degradation from a different angle.

Empirically, it is very often observed that environmental degradation does not deteriorate at the same rate of development or exploitation. A good example is the case of biodiversity decrease against the loss of habitat area. It is known that the number of species in tropical forest does not become half when the habitat area is reduced to the half of the original size. At the point, the number of species in the forest is still mostly preserved. However, when the exploitation of forest goes over a certain point, the extinction of species become suddenly accelerated and will be totally extinct when all habitat area is lost.

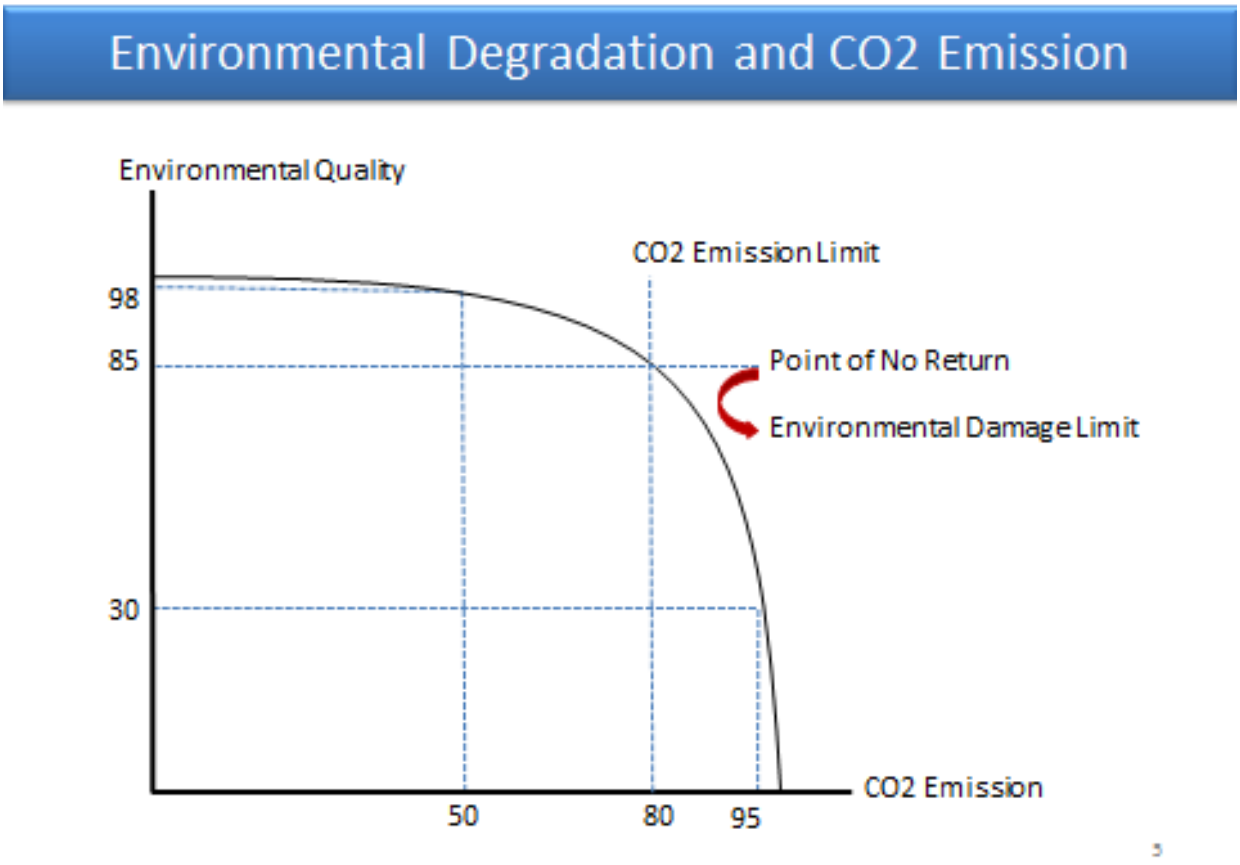
It is presumed that a similar course of environmental degradation would occur in the case of global housewarming as well, because the nature, including humans, could adapt to the environmental change to some extent. However, when the temperature goes over a certain point and becomes unbearably high in huge areas on the earth where desertification would take place, the nature including human population would have to face catastrophic disaster. There may be other places where the temperature is currently unbearably low, such as the Antarctic, and the population may move in to such areas from the environmentally damaged places. However, there would be a time when the aggregate impact to the natural environment becomes seriously negative as a whole. From that point afterwards, the human population reduction would be accelerated.

The Figure 3 illustrates this tendency between the environmental degradation and its impact to the human society. The horizontal axis represents the percentage of CO2 in the atmosphere and the vertical axis represents the amount of environmental quality which enables the human to sustain its population. The curve touches the horizontal axis when the environmental quality becomes zero where no human beings would be able to survive any longer. The curve touches the vertical axis where environment is kept intact in relation with the amount of CO2 in the atmosphere. The point actually corresponds to a time when industrial revolution

[3] Vitousek, P. M., Ehrlich, P. R., Ehrlich, A. H., Matson, P. A., 1986. "Human Appropriation of the Products of Photosynthesis." BioScience 36(6), 363-373.

had not begun in the 19th century. Then, the Figure 3 explains that the environmental quality does decrease in line with the increase of CO2 in the atmosphere, but the pace does not match to each other. In the Figure 3, the environmental quality is supposed to decrease only by 2 percent when the amount of CO2 reached the 50 percent of the catastrophic level. Probably at this point, humans may not realize how significantly the atmosphere has been damaged by the increase of CO2, because the environmental degradation is not seriously noticeable at this point. People would perceive that the same amount of increase, i.e., another 50 percent of increase in the atmosphere would degrade another only 2 percent of environmental quality; therefore, they do not take serious measures to curve the CO2 emission.

The Figure 3.



However, if the rate of CO2 accumulation continues at the same rate as before, this time the environmental degradation would be very much accelerated. The Figure 3 shows that the environmental quality would dramatically deteriorate after "the point of no-return" where the environmental quality still maintains 85 percent of its original level. If the pace of CO2 increase has been constant up to this point in line with the industrial and economic development of human

activities, it would be hard to imagine that the humans would suddenly change the emission attitude. The CO2 emission would continue at a similar pace as before. Then, by another mere 15 percent increase of CO2 emission, the environmental quality dramatically drops to the 30 percent of its pre-industrialization level, and the humans would become totally extinct by another tiny 5 percent of increase this time.

The Figure 3 tells us that humans tend to underestimate the true impact of environmental degradation. There would be a point of no-return, after which any attempt to prevent the environmental damage is already too late to make effect. Hence, it would be necessary for us to take precautionary measures for this type of environmental degradation, because otherwise it would be certain that human activities would overshoot the point of no-return.

The problem here is again that we do not know where we are at present, and we do not know how much percent of CO2 increase in the atmosphere is the point we could define as the point of catastrophe. There have been a number of scientific attempts to identify these points but there have been no confirmed points so far even in this century.

IV. Likeliness of Disaster from Non-Cooperation under the Game Theory

The game theory in economics often predicts unwelcoming results among members in a community. Prisoners' dilemma is the most well-known type which is represented in the Figure 4 below.

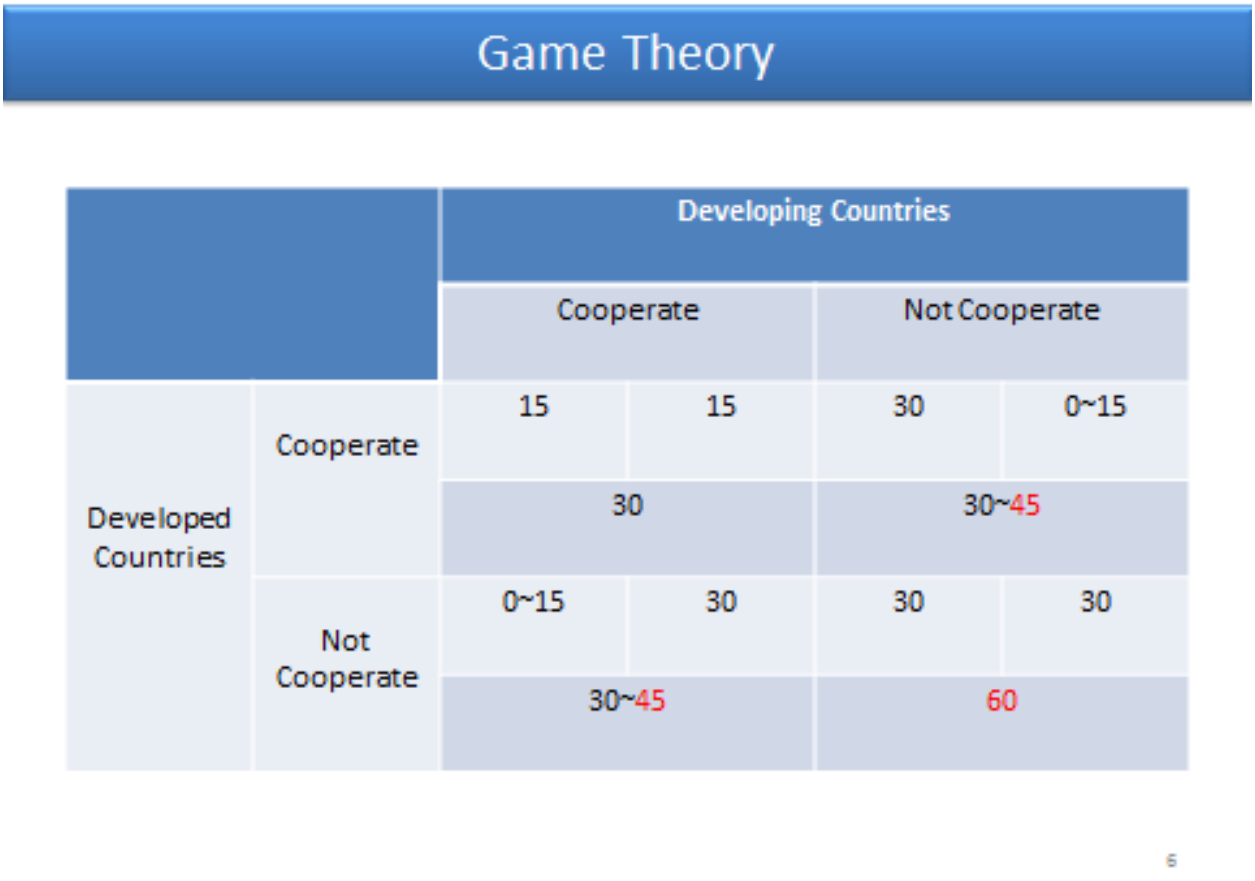
The Figure 4 illustrates possible outcome between developed and developing countries in relation with allocation of CO2 emission right. In this Figure 4, the total possible amount of CO2 that could be emitted in the future is presumed to 30 units[4]. Each group of countries has two options, cooperate or not cooperate. Information regarding the possible maximum amount of CO2 that could be allowed to be emitted, 30 units, is equally known to each side[5]. If they cooperate each other by confining their respective emission to 15 units each, then the aggregate amount of CO2 emission would be limited to 30 units. This is a successful scenario. However, it is also possible for one group, for example the developing countries, to claim that the entire 30 units should be given to them and that the developed countries should not emit any more. Under this scenario, if the developed countries give all emission right to developing countries, then the scenario becomes successful. However, if they maintain emitting 15 units based on the preposition that the other group would also cooperate and emit only 15 units, then the aggregate

[4] This corresponds to the point of no-return amount stated in the Figure 3. In the Figure 4, the current level of emission is presumed to be at 50 units as supposed in the Figure 3.

[5] However, the exact amount of emission each side would actually make is not known to each side. They are put in a situation that they could trust or doubt how their opponent would behave.

amount would reach 45 units and the scenario becomes a failure. The opposite scenario can also be considered. The developed countries may ascertain that they should be entitled to further emit CO2 because the economic development and improvement of welfare of their citizens would definitely be necessary. If the developing countries agree to give emission right only to developed countries for some reasons, this could become a successful scenario. However, if the developed countries maintain their right to discharge 15 units, the scenario becomes a failure because the total emission reaches 45 units. [6]

Figure 4.



[6] This scenario may be understood better if we consider the current level of emission has already reached at the point of no-return until which only developed countries already used the right to emit 30 units in the past. In such a case, as a possible interpretation into a reality, a natural conclusion would be a total ban for each group of countries to emit any extra amount, as the 30 units have been already spent by the developed countries.

In many of the actual cases in the international community today, however, negotiations often become deadlocked. All countries would not easily give up and they try to achieve a maximum outcome always. As already seen in the actual Kyoto Protocol negotiations, developing countries assert that they should be entitled to emit without any forced emission limit. A number of developed countries also try to retain their right to further develop and grow economically without accepting any confined figures of CO2 emission. Such a case is illustrated in the Figure 4 as the worst scenario. The game theory explains that the most logical option for any participants in the game would be the one aiming the maximum possible individual outcome. In the Figure 4, both groups of countries would try to gain the entire 30 units of emission at least as a first step. Then, the outcome would be the catastrophic emission of 60 units.

This is how the game theory predicts the outcome of negotiations. As long as each participant takes an option logically and independently, the unavoidable outcome would be a total failure.

The problem in considering the actual situation in relation with such scenarios under the game theory is again the fact that we do not know where we are now, and that we do not know how much amount would be allowed after all for us aggregately. Under such ambiguous situation, the will to restrain themselves from emitting CO2 would be very difficult to be formed. They simply hope that the capacity would be large enough for their individual emission and keep their course of development, because if they constrain themselves and others do not and if the earth happens to be actually capable of such emission, it could be a total failure for them in the international business competition.

Hence, in order for the international community to avoid such kind of catastrophic failure, the evidences provided under science as non-resistible figures are definitely needed. As stated earlier, unfortunately, at this moment there are no confirmed figures, even though there have been a number of serious attempts by scientists to provide solid evidences. It is hoped that the next report of IPCC would be able to provide some kind of proper basis on which all countries in the global community could calmly, peacefully but determinately negotiate the actual amount of emission respectively.

V. Science and Economics in Relation with Reality

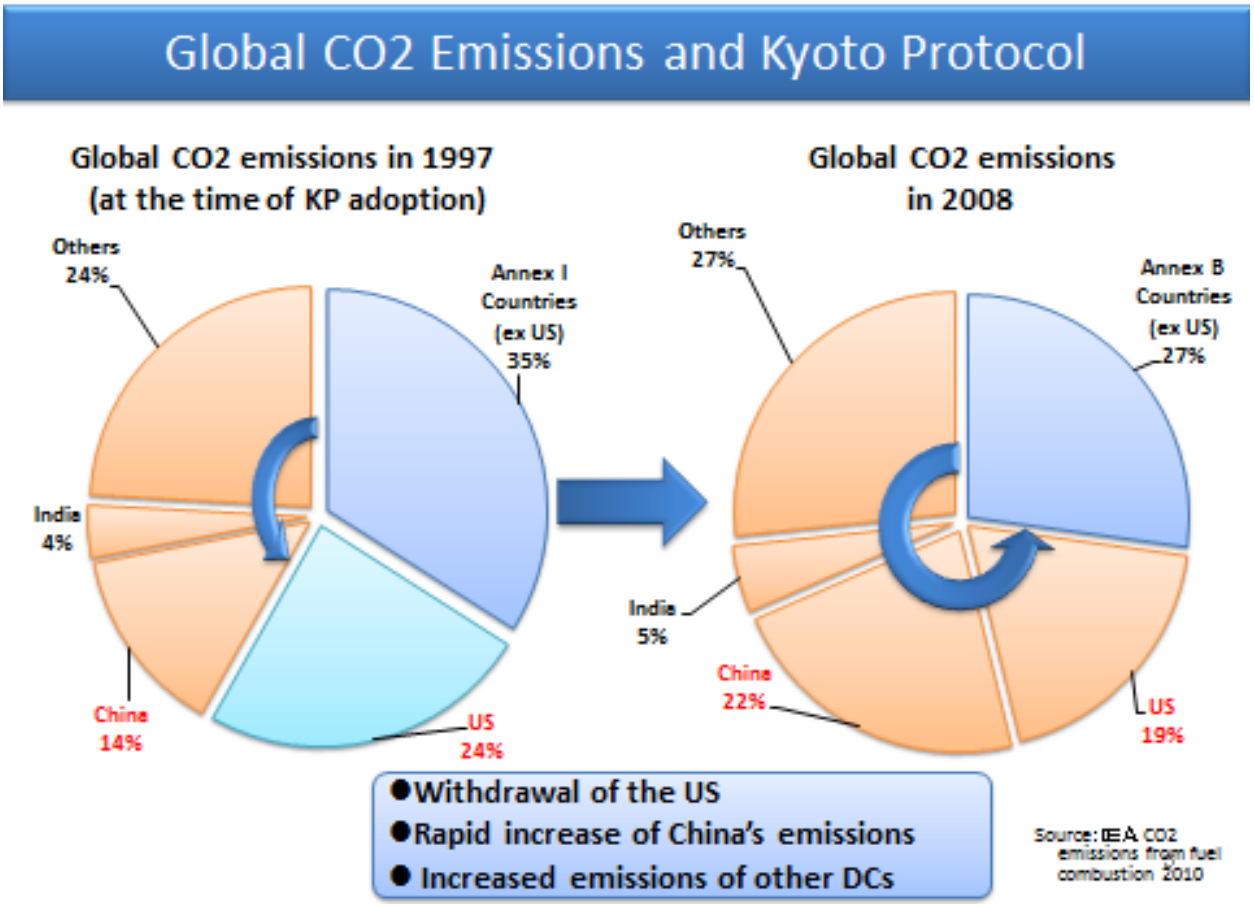
With science and economics background stated above, now let us see the actual situation in relation with the CO2 emission in the global community.

In 1997 when the Kyoto Protocol was adopted, the portion of CO2 emission covered by the participants, mostly by EU, USA, Japan and other industrialized countries, was 59 % of the

global aggregate emission. At that time, still the industrialized countries were dominant in the global economy and the efforts by them only was hoped to make certain effect in controlling CO2 emission. The 59 % coverage was considered at least a good first step.

However, the United States, the largest emitter then, later refused to ratify the Protocol. This made the portion covered by the Kyoto Protocol only 35 % in the total CO2 emission in the world. At the time, it became doubtful if the Kyoto Protocol would become a truly workable system in the global community to effectively contain the global warming.

The Figure 5.



On top of the US withdrawal from the Kyoto Protocol, there was a significant increase of CO2 emission from developing countries. As illustrated in the Figure 5, developing countries consisted 42 % of the CO2 emission in the world in 1997 when the Kyoto Protocol was adopted. However, as the development and economic growth were promoted, the portion reached 54 % in

2008, which made the coverage of the Kyoto Protocol only 27 % of the global CO2 emission. It has become quite obvious that the efforts to reduce CO2 emission by these 27% countries only would not provide effective reduction of CO2 emission. The Kyoto Protocol may delay to some extent the pace of CO2 emission but the total amount of CO2 will continue increasing by the economic activities of the rest of 73 % vast majority countries not covered by Kyoto Protocol.

Moreover, Canada, another G7 member country, withdrew from the Kyoto Protocol in 2012, and Japan, New Zealand and Russia decided not to participate in the second commitment period which will be implemented from 2013 till 2020[7]. During this second commitment period, the amount of CO2 emission to be covered by the Kyoto Protocol will be only 13.4 %.

The IPCC report stated that developed countries need to reduce their CO2 emission by 25 -40 % of the 1990 level by 2020 for a 50% chance to limit the temperature increase within 2c degree since the industrial revolution. It is presumed that these mitigation efforts to be made by these 13.4 % countries would reduce about 14% - 19 % compared to the level emitted in 1990. This is far below the target figure recommended by the IPCC. Based on the fact that the amount of CO2 emission form the developing countries have dramatically increased, it would be very difficult to predict that the current Kyoto Protocol system would achieve a target to contain the temperature increase by 2c degree by the end of this century.

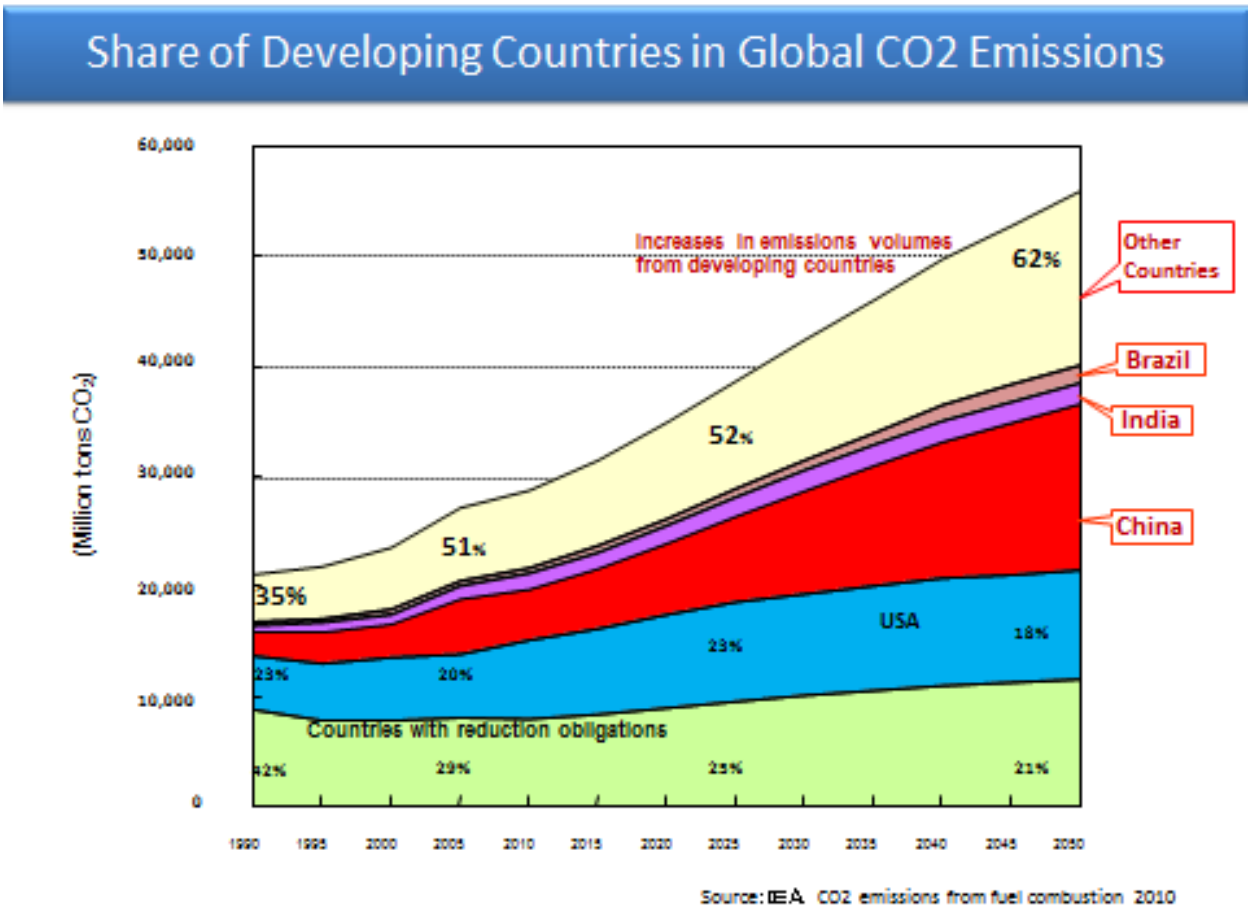
Views are being expressed from the both sides politically. However, it is not the objective of this paper to discuss the legitimacy or justification of their statements. This paper will not verify if developed countries or developing countries are to be blamed for such insufficient efforts in reducing CO2 emission. The point which this paper emphasizes is that it is the fact that the current pace of CO2 reduction is not effective enough to control the climate change as scientifically suggested under the IPCC report. Also, it should be emphasized that the conflicting behaviors between developed and developing countries look like it is predicted under the economic game theory that the actual actions taken by competitive participants are doomed to be a failure, particularly when proper scientific information and targets are not confirmed.

The Figure 6 illustrates the future portion of CO2 among major emitters in the world as predicted by the International Energy Agency. The figures stated in the Figure 6 show that the majority of CO2 emission was originated from developed countries in 1990s when the Kyoto Protocol was discussed and signed. However, in 2050, as much as 62% of the total global emission will be discharged from the group now termed as developing countries.

Since the global warming is a scientific natural phenomenon, the amount that matters for achieving the 2c degree target is the aggregate amount of CO2 emitted globally. The nature does not distinguish the CO2 emission from developed countries or developing countries. They are equally harmful to the global environment.

[7] The first commitment period was implemented from 2008 till 2012.

The Figure 6.



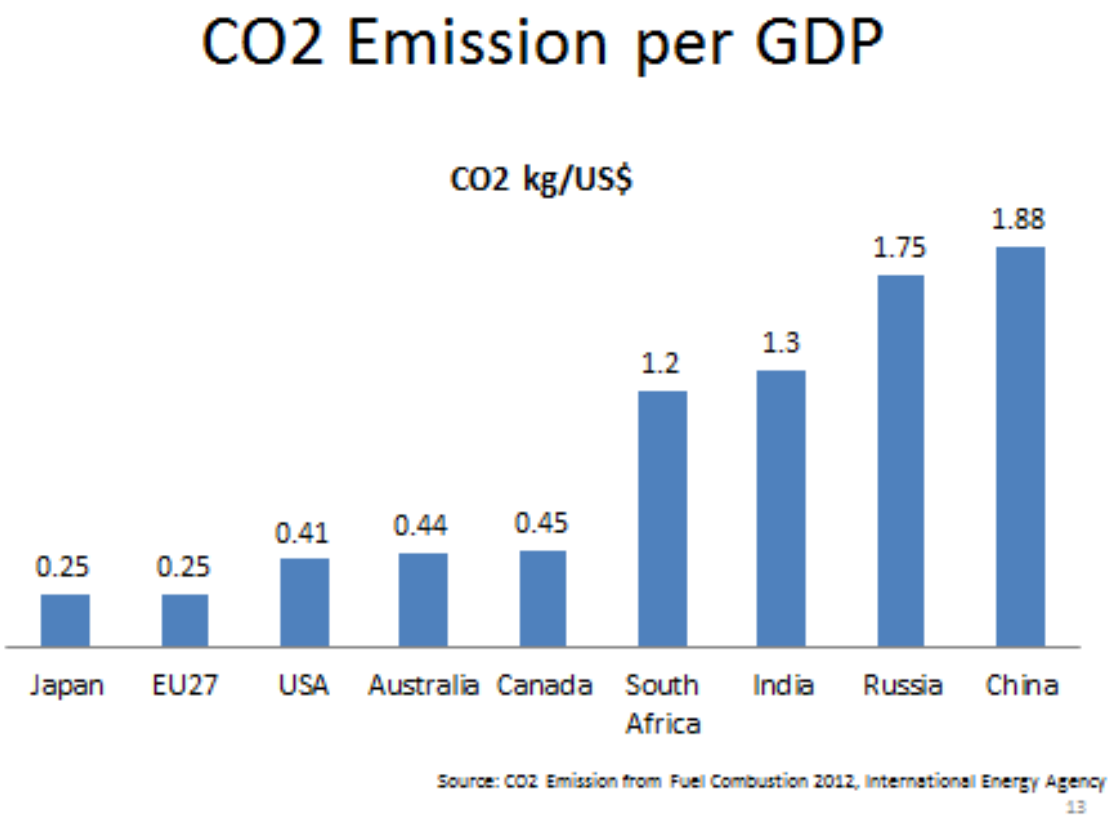
Political debate must be open for any countries to decide the allocation of responsibility in CO2 reduction. However, if the global warming needs to be stopped, it is the aggregate amount of CO2 emission that should be controlled. Even if it is presumed that the developed countries are 100 % culpable for the global warming taking place so far and even though they completely stop emitting CO2, the global warming will not be contained at all because the portion emitted from the group of developing countries alone will increase the CO2 density in the atmosphere. Therefore, from the scientific point of view, there has to be a system to control the aggregate amount of CO2 emission if the global warming truly needs to be halted.

The Figure 7 illustrates the CO2 emission from a different angle.

The CO2 is emitted mostly by combusting fuels needed for economic activities. Therefore, it is ideal if the economic growth is achieved without much using fuel energies. Among the major CO2 emitter in the world, there are significant differences in their way of

economic development by burning fuels. The Figure 7 indicates that Japan and EU emit only 0.25 kg of CO2 in generating 1USD economy, while developing countries are emitting higher amount for generating the same. Even among developed countries, the efficiency difference is not small. For example, the USA is emitting as much as 64% more CO2 than Japan or EU. Since these countries are major emitters of CO2 in the global community today, the amount of total CO2 emission will be dramatically reduced if these countries could achieve the same level of GDP generating fuel efficiency. Then, how did Japan or EU achieve such energy efficient system? The Figure 8 and 9 explain how the efforts were made in Japan.

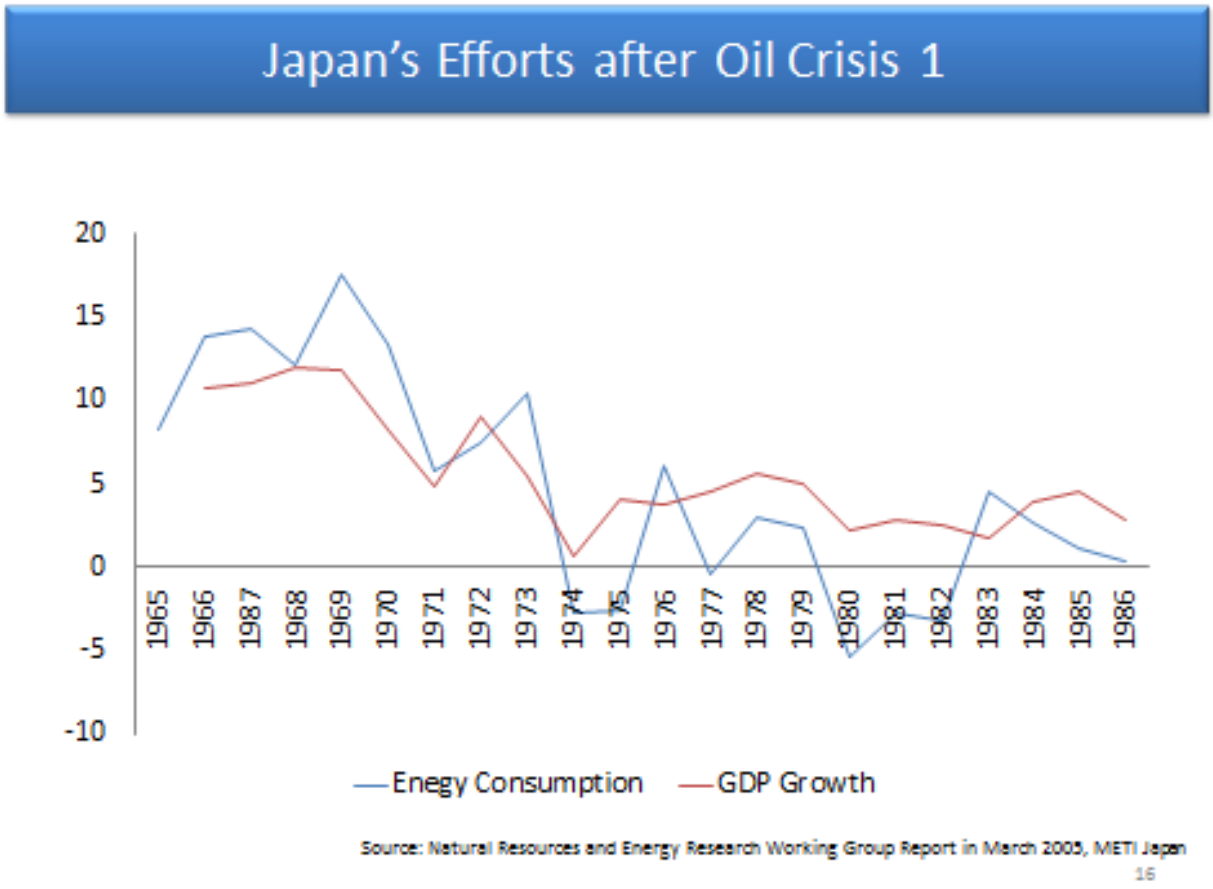
Figure 7.



The Figure 8 illustrates the relationship between energy consumption and GDP in Japan from mid-60s till mid-80s. Until oil crisis happened in 1974, Japan grew its economy by consuming a large amount of petroleum for industries. From 1965 to 1973, the GDP growth rate of Japan was very high averaging 9.2%. During the same period, the energy consumption grew by 11.9 % in average. This type of high economic growth achievement may correspond to the high and rapid economic growth of newly industrialized countries in the 21st century. However,

the oil crisis happened in 1974 totally changed such growth pattern in Japan. The energy consumption grew almost nil by 0.2 % in average from 1974 till 1986. This is a huge drop from the figure during the previous period of 11.9 %. During the same period, the GDP of Japan grew by 3.4 % in average. In other words, Japan's GDP became 60% larger in 13 years without increasing the consumption of energy. The Figure 9 below illustrates the growth difference between energy consumption and GDP. It is quite clear from this Figure that Japan's GDP grew without increasing the consumption of energy.

The Figure 8.

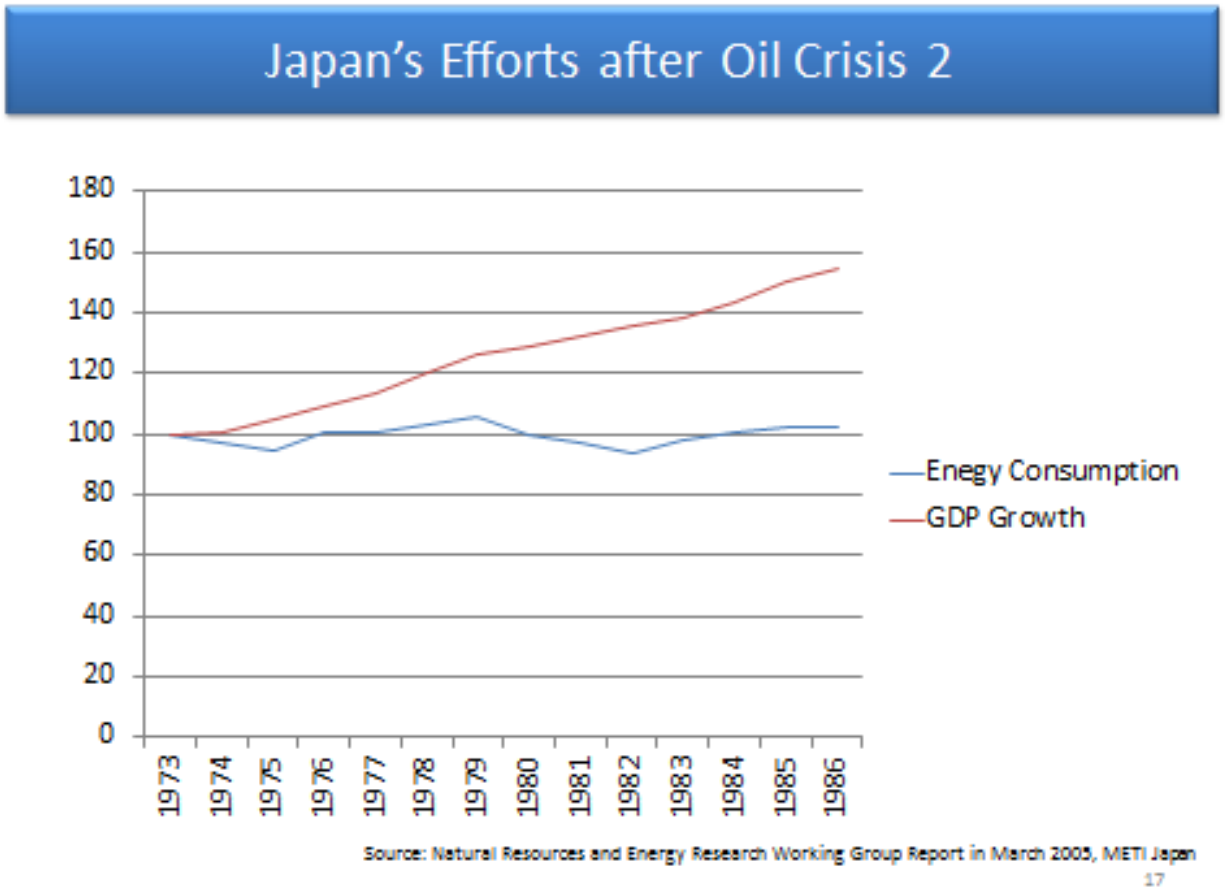


The measures taken in Japan to achieve this energy efficiency vary and spread in many sectors. For example, the general public tried to turn off home electric devices as much as possible. In offices, workers set the summer air conditioner temperature at 28c degree and endured the heat in summer and coldness in winter. They tried to walk stairs without using lifts, and room lights were turned off during day time. Manufactures also tried to invent products that consume less energy because the general public preferred to purchase such energy cost effective new products. As a result, the Japanese automakers succeeded in manufacturing automobiles

that runs longer distances with smaller amount of gasoline than any other cars produced in the world.

Thus, the GDP of Japan grew 60 % without increasing the amount of energy consumption. As stated above, the most of the efforts, such as turning lights off in offices during day time, can be easily imitated in other parts of the world as well. If all countries introduce new ways to economize energy consumption suitable to each country, quite a large amount of CO2 reduction could be achieved[8].

The Figure 9.



[8] For example, as the Figure 8 illustrates, India emits 1.3 kg of CO2 in producing 1USD GDP while Japan and EU emit only 0.25 kg. Therefore, if the same level of energy efficiency is achieved in India, India will be able to maintain the same level of economic activities by consuming only 19 % of energy currently consumed.

VI. Conclusion

Scientifically, it is the amount of total CO2 emission that is to be reduced by the global community, if the current global warming is to be controlled within a sustainable level before it becomes too late. On the contrary, the debate in the international community, particularly under that of FCCC, has been focused on the level of responsibility for individual countries. Political debate and identification of proper level of responsibility in each individual member country would be certainly important. However, if such negotiation is not based on solid scientific evidences, it would be very difficult to imagine that the global community could form consensus in reducing CO2 emission sacrificing possible economic development in individual countries, as economic theories predict.

Unfortunately, at this moment there are no confirmed figures as to identify the total sink capacity of the planet earth or the maximum amount of CO2 that would be allowed to be discharged. In a way, Kyoto Protocol sets such a target amount to be reduced by member states; however, the portion to be covered under Kyoto Protocol is only 13.4% out of the total amount needed to be reduced. This means that the aggregate amount of CO2 emission would actually increase even the current Kyoto Protocol is fully implemented, because the other 86.6% is free to be emitted. This must be a proof that the global community is not serious enough at this moment in reducing CO2 emission. At the same time, it also must be a proof that the global community does not seriously believe that the target set under Kyoto Protocol is scientifically and truly viable.

It is sincerely hoped that the coming Fifth Report of IPCC would provide some strong evidences that no country can deny in accepting the aggregate amount of CO2 emission limit that has to be shared in the international community.

[end]