

Global Climate Change: The Empirical Study of the Sensitivity Model in China's Sustainable Development, Part 2

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In the evolution of CO₂ emission intensity, population, total CO₂ emission, annual gross domestic product growth, emission intensity, and emission per unit energy index is mainly an empirical issue that cannot resolve with certainty from the experience of a group of countries during a given period of time. The present empirical study reveals that the listed variables cannot be evaluated unambiguously using either variation in carbon emission factor or product of many factors put together as the criteria. Different levels of CO₂ emission intensities in different regions resulting from different causes are not a constant or evaluated using constant variables. The article focuses on the challenges of climate change on development in recent times—observed and future climate change and variability, which are a factor of the energy mix utilization within China for some years ago, thus establishing methodology that linked greenhouse gases effect and climate change by Sensitivity Model Prof. Vester in China, in an attempt to evaluate a sustainable indicator in greenhouse gases and change effects.

Keywords: CO₂ emission, emission intensity, global climate change, round/year sensitivity model, variability

INTRODUCTION AND BACKGROUND

The International Panel on Climate Change (2001) concludes that: “*There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities. Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war.*” Future levels of

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global greenhouse gas (GHG) emissions are the products of a very complex and ill-understood dynamic system driven by forces, such as population growth, socio-economic development, and technological progress. It is a specific application of a frequently used approach to organize discussion of the drivers of emissions through the so-called IPAT identity that relates impacts (I) population (P) multiplied by affluence (A) and technology (T). The same approach can be used for other emissions, such as SO₂. However, the driving forces might be different for some species of anthropogenic emissions (Kaya, 1990; Yamaji et al., 1991). Thus, to predict emissions accurately is virtually impossible. However, near-term policies may have profound long-term climate impacts. The assessment of climate change dictates a global perspective and very long time horizon that covers periods of at least a century. China is adopting EU standards for pollution emissions from cars with an approximately 8- to 10-year lag Gallagher (2003). Diesendorf (2003) reports that China has reduced sulfur emissions and even carbon emissions in recent years. Although concurring with Diesendorf (2003), while ambient air pollution has been reduced in several major cities and sustainable development, however, the gloom over China's environment may be overstated. China is an ideal test case of the controversial idea of the Environmental Kuznet Curve (EKC), according to which economic growth precedes environmental improvement. Although current environmental trends in China are serious and deteriorating in many areas, some unappreciated signs of improvement are appearing. Wang et al. (2005) and Baumert et al. (2006) showed that the change in economic policy in 1979 and the changing fuel mix have helped to reduced energy intensity and hold back the growth in emission, respectively, but gross domestic product (GDP) and population effect outweighed these in all cases. Finally, Liu and Ang (2007) reviewed a large number of studies using various approaches to decomposition analysis and discussed their strengths and weaknesses; it focused on energy use and CO₂ emissions, e.g., driving forces, state and responses influences development "Policies." Clearly, it has shown that while some research being carried out in China has been done in isolation to single or combined variable factors, none have been so robust, interactive, and comprehensive as the sensitivity model (SM), which also gives room for intervention at certain periods for better policy implementation and sustainable development. As the prediction of future anthropogenic GHG is becoming impossible, alternative GHG emissions scenarios, such as SM, have become a major tool for the analysis of potential long-range developments of the socio-economic system and corresponding emission sources. 'The sensitivity model provided a suitable approach for modeling interlocking repercussions of climatic change and natural disaster. In contrast to alternative approaches, it offers a special advantage: its cybernetic methodology takes account of the holistic character of systemic structures and means non-quantifiable factors (risk perception, the quality of the natural landscape) can be modeled'.

BACKGROUND

China continues to be the world's second largest energy consumer after the United States, and its impact on the global energy economy will likely remain strong in the coming decades. According to the International Energy Outlook 2007, released in May, China consumed 40% less energy than the United States in 2004 but is expected to consume 11% more by 2030. Of China's energy use in 2030, 65% is projected to be provided by coal, 22% by oil, 6% by natural gas, 5% by renewables, and 2% by nuclear power. In China, as well as in the United States, oil use is dominated by the transportation sector. In 2030, 47% of China's oil use will be for transport and 42% for industry. Coal will remain the dominant fuel in China through 2030, with its use concentrated in the industrial and electric power sectors. Consequently, China will remain the world's largest producer and consumer of coal. In the electric power sector, China's use of coal is projected to grow at an average rate of 3.5% per year between 2004 and 2030 (IEA, 2005).

Higher fossil fuel prices, energy security concerns, improved reactor designs, and environmental considerations are expected to improve the prospect for new nuclear power capacity in many parts of the world. In China, electricity generation from nuclear power is projected to grow at an average annual rate of 7.7% from 2004 to 2030. In the 58 gigawatts of additional installed nuclear generating capacity projected in the developing economies of Asia, 36 gigawatts are projected for China. With heavy reliance on fossil fuel, China will continue to have a major impact on the global environment. By 2030, energy-related CO₂ emissions in particular are projected to grow by 26% of the world total. Coal-related emissions in particular are projected to grow by an average of 3.3% annually. By 2030, China is projected to account for 48% of the total coal-related emission worldwide (IEA, 2005).

CLIMATE CHANGE

In early June 2008, China unveiled the National Climate Change Program as part of China's obligation under the United Nations Framework Convention on Climate Change. Under the plan, China will use hydropower, nuclear energy, and biomass fuels and gas to help cut 950 million metric tons (CO₂ equivalent) per year of the greenhouse gas emission by 2010 upwards. Specifically, China expects development of hydropower resources to cut the emissions by 500 million tons by 2010, nuclear energy development to account for 50 million tons of reduction, biomass energy to help reduce emission by 30 million tons, and other renewable power generation (solar, wind, geothermal, and tidal energy) to reduce emissions by 60 million tons. Additionally, China expects more efficient thermal electricity production and transmission to reduce emissions by 110 million tons, and the re-use of coal-bed and coal-mine methane for electric power generation to lower them by 200 million tons (Sinton and Nathaniel, 2006).

China is the biggest producer and consumer of coal in the world. More than 70% of the total energy in China is produced by coal combustion (see Figures 1 and 2). Despite investment into renewable and nuclear power, this heavy dependence on coal is expected to continue for the next 50 or more years. The available statistics on China's dismal air quality are dated, anecdotal, or limited in scope—China has not publicly disclosed CO₂ or mercury emissions data since 2001. Overall, air pollution trends represent growing economic, ecological, and human health threats both within and

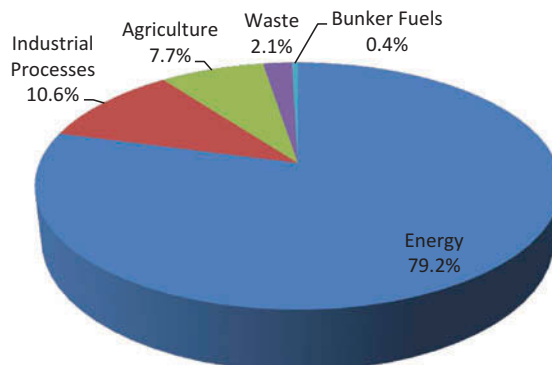


FIGURE 1 Carbon dioxide percentage emissions from different China's usage distribution without land use and forest.

Source: World Resource Institute (Climate Analysis Indicator Tool 2.0 Beta).

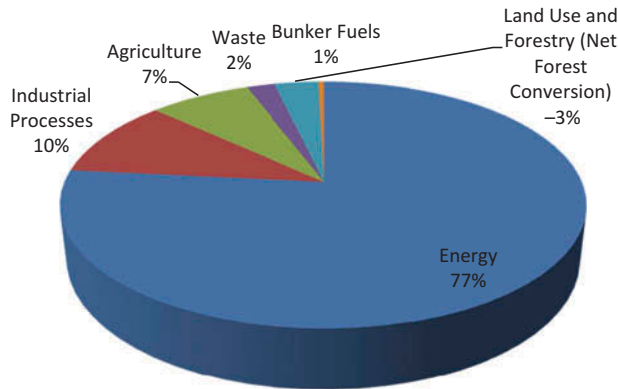


FIGURE 2 Carbon dioxide percentage emissions from different China's usage distribution with land use and forest.

Source: World Resource Institute (Climate Analysis Indicator Tool 2.0 Beta).

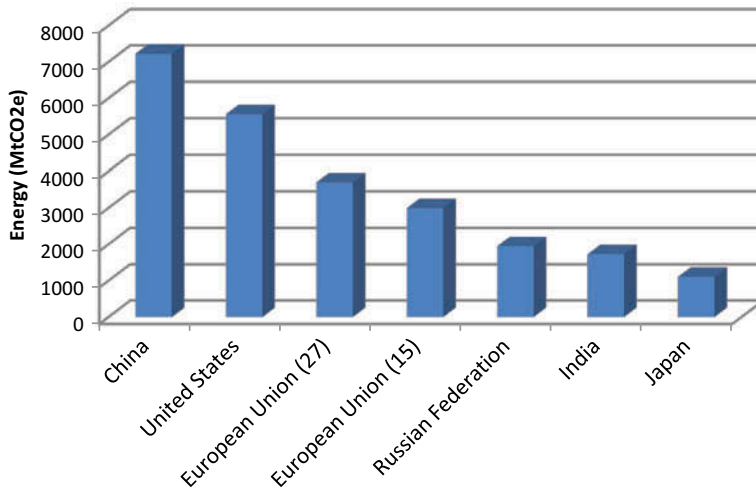
outside China (CNSB, 2005). Some 300,000 to 400,000 people die prematurely in China every year due to respiratory illnesses triggered by air pollution. Coal burning in China emits 25% of global mercury and 12% of CO₂ and China's State Environmental Protection Agency estimates that nearly 200 cities in China fall short of the World Health Organization Standards for airborne particulates.

Despite China's abundant coal resources, the country is actually experiencing a coal shortage, because demand increases fast enough to outpace supply (Mai, 2005). This demonstrates China's strong dependence on coal, and suggests that commitments to reduce the usage of coal can be seen as a threat to China's energy security. Improving energy efficiency, diversifying energy, and reforestation can all be considered as so-called 'No Regret' options. The per capita energy consumption will probably match the current global average by 2020 (Harris and Hongyuan, 2005). Even though the Chinese government has ambitious goals for reducing energy substitution, coal will continue to be the dominating energy source. Urbanization, population increase, and economic growth are all factors that point in the direction of a continued increase in China's CO₂ emission in the years to come.

WORLD ENERGY OUTLOOK

The chart below (Figure 3) shows that, in spite of the advancement in technology over the decade, the paradigm shift is tilting to Asia, and most especially China. The reason is not far-fetched since all of the Asian nations, with exception to Japan, which is a developed country, are not under the Kyoto agreement or obligated to reduce CO₂ emission. Hence, the over reliance on dirty energy, such as coal, and outdated technology usage most especially in China, which has opened its door for the sole benefit of development at the expense of the environment, and this is what really necessitates the application of the sensitivity model in this study in an attempt to make a robust study and application of management of the entire energy sector as well as China consolidating on financial prowess and sustaining the vital environmental ecosystem.

The distribution and over-reliance on energy, as seen in Figure 1, with a large percentage attributed to transportation and other related technological processes, cannot be over-emphasized as China is becoming or has become the manufacturing base of the world, thereby emitting the largest chunk of CO₂ in the world. Because of this factor and influence of the Kyoto Protocol (1997), the one major step the Chinese government is taking in replenishing or reducing the



World's Highest Energy Consumer to year 2009

FIGURE 3 The world's seven highest energy consumers to year 2009.
Source: World Resource Institute (Climate Analysis Indicator Tool 2.0 Beta).

TABLE 1
Carbon Dioxide Emission from Different Usage Sources in China in (MtCO₂e and Percentages)

<i>Energy</i>	<i>Industrial Process</i>	<i>Agriculture</i>	<i>Waste</i>	<i>Bunker Fuels</i>	<i>Land Use and Forest (Net Forest Conversion)</i>
7,222.52 (77%)	969.13 (10%)	698.28 (7%)	194.80 (1.7%)	38.88 (0.3%)	-303.97 (-3%)

Source: World Resource Institute (Climate Analysis Indicator Tool 2.0 Beta).

effect of greenhouse gas is through the natural process of afforestation, which helps in reducing the CO₂ by 3.3% as shown in Figure 2 and Table 1. The effort is commendable but not sufficient considering the magnitude of emissions with respect to other gases. It can be deduced that this process will only reduce the CO₂ emission from energy sources to 77% with a reduction of just 2.2% (see Figure 3).

This work will implore the following model path in identifying and fully proffer mitigating and adaptive methods of sustainable development with respect to alternative energy and administrative know how.

APPROACH/EXPERIMENTAL

The study tends to use logical, scientific understanding and prediction of a sensitivity model (SM) Prof. Vester, which is an integer tool in the assessment of climate change in China. It provides the role for intuition, analysis, and synthesis, and thus links the scientific understanding by taking

advantage of these features. It aids the assessment of future climate change, impacts, vulnerabilities, adaptation, mitigation, and sustainable development.

RESULTS AND DISCUSSION

Introduction: Handling Complexity with the Tool of the Sensitivity Model

The main menu of the sensitivity model shows the recursive structure of the nine steps of the system tool that can be directly activated by clicking the recursive buttons.

Mediation Capacity by Transparent Simulation

One of the main features of the model is its mediation capacity. New ways of visualizing the cybernetic behavior of the system and its parts helps to put different interests in the same model showing their roles are a mutual influence in the complex pattern.

The impact matrix with high numerical values show how critical each variable is to the entire system, i.e., 2035 for Population (Highly Critical), while 1530, 1435, 1332, 1260, 1184, and 1170 represent critical variables for the Total amount of CO₂ emission, Annual GDP growth, Emission per unit energy, Emission intensity, CO₂ per capita emission, and Carbon intensity of energy use, in that order respectively. These are the seven most important variables that accounted for climate change in China. These positions are entered into the systemic role, where each variable cybernetic is evaluated due to its interdependencies. Here, the system is distributed within the four fields of different variables. The model pattern of influence is encompassed at the four corners thus revealing the cybernetic role; these are a lever (Active), a risk factor (Critical), a measuring sensor (Reactive), an inert element (Buffering), and positions in-between. The feedback analysis of the effect system allows recognition of the dominant cycles of the seven critical impacts; these seven critical factors are placed at the center of the effect system and controlling variables are interlinked together in a sustainable manner after serious consideration. The negative feedback in this case is the positive factors that are considered mostly for planning and modeling purposes (Frederic, 2007).

ANALYSIS AND FINDINGS

The model simulated a smooth transition for the next 10 years, and thus does not pose a serious environmental sustainable threat, given the 11 simulated variables for these time periods (see [Figure 4](#)). The positive coefficient for annual GDP growth variable suggests that estimated emissions initially rise with annual GDP growth and eventually fall, as the quadratic term is negative (as shown in [Figure 4](#)). However, the estimated turning point occurs at a very high out-of-sample income level, and this occurs almost critical for all variables on the 7th and 8th year (see [Figure 4](#)). In other words, within the sample data, only a monotonically upward trend in total amount of CO₂ emissions, energy use/consumption, ratio of renewable energy use, and emission per unit with increasing and harmonic income levels is discovered.

To check the robustness of out-of-sample income turning point, the study presents another specification in [Figure 4](#), where the emissions per capita are used as a dependent interconnected variable instead of the total emissions. A model using emissions per capita as a dependent variable also generates an out-of-sample income turning point at the 8th year steadying through the 12th year, although it is far less than the turning point at the upper peak with energy use/consumption hitting its limit of these variables under study in the simulation model. This confirms that



FIGURE 4 The simulation round (year) for 30 years.

substantial economic growth would be required before CO₂ emissions began to decline and the relationship between emissions and economic development is truly a linear one, hence confirming previous work carried out by Ojekunle et al. (2009).

To further examine the relationship between population growth and emissions intensity, the model further introduces two more control variables, GDP per capita and frequency of natural hazard, which are declining all the way until they reach their lowest limit at the 11th year (see Figure 4). The variation of emissions across the trend could be affected by government tax for CO₂ reduction (Declining) and renewable energy use (Rising). Of course, it is better to use government tax for CO₂ reduction (Declining) and renewable energy use (Rising) in the model, but the study will lose a lot of variables in the sensitivity model as some of them have no cybernetic connections. Thus, the increase as percentage of GDP is used as a proxy to capture the possible linkage. The variation emissions across variables could also be affected by the structural changes in the economy. The GDP per capital variable probably could not fully capture the variation in structural changes, and thus the study further introduces a variable, environmental quality (which is an indicator for good health and sustainability) as a percentage of GDP, which intercepts on the 13th year. The sensitivity model further confirms a positive and significant association between changes in population and changes in emissions intensity. Specifically, 1% increase in population will reduce the emissions intensity by 1.18%, which is slightly lower than that of the baseline model. Thus, the impact of population growth on emissions is found to be robust.

To test the hypothesis that population pressure has exhibited a different impact on emissions across China with different levels of affluence, the study creates an interaction term, which is shown in Figure 4. This model is hierarchical to the baseline model and these models are nested. The model fit the data well, which is indicated by a further significant reduction in the Akaike Information Criterion (AIC) statistics as compared with the baseline model (-856 versus -826), relative to a change of one degree of freedom (($n - 1$) which is +26.0%). The negative coefficient of the interaction term suggests that the marginal effect of population diminishes as income level stabilizes. In other words, the impact of population on emission has been more pronounced in lower income than in the higher income range contradicting the popular EKC.



FIGURE 5 The simulation round (year) for 30 years with intervention.

The other appealing finding is the differentiating effects of energy efficiency on emissions in China of various affluence levels. The role of energy efficiency on emissions has been the greatest when the total amount of CO₂ emission is at its peak. A 1% increase in energy efficiency could decrease the CO₂ emissions by almost 1.5%, which is in sharp contrast to the 5th year when a 1% increase in energy efficiency could increase the CO₂ emissions almost the same 1% (see Figure 4). Also, at the lower middle income range where a 1% increase in energy efficiency decreases the emissions by only about 0.5%. For upper-middle and high income ranges, energy efficiency could reduce the emissions by a little over 0.20%. Furthermore, affluence has exercised the greatest impact on emissions in the low-income region; a 1% growth in GDP per capita could bring about a 2.43% increase in emissions. It is the least in the upper-middle income range where a 1% growth in real GDP per capita increases the emissions by 0.51%.

As results of the first intervention simulation showed (see Figure 5), while short-term intervention for total amount of CO₂ emission (8th year), energy use/consumption, annual GDP growth, and ratio of renewable energy use (all the 11th year) would mean a long-term gain for the emission per unit energy and environmental quality; in the long term, it would constitute a sustainable development to the 20th year given the various interventions as seen in Figure 5, while all other factors remains constant. Other 'if-then' simulations with alternative possibilities then showed that things would develop differently if China sensitivity model variables did in fact start with higher population and total amount of CO₂ emission, but in return for an additional guarantee of continue existence imposes certain controls to caution the effects.

SUMMARY AND CONCLUSIONS

The empirical study confirms that Chinese economic growth leading to rising average incomes (income per GDP) and population is by far the most important driver of energy trends and emission. China's overall environment sustainability is very poor. Although its economy is big, due to its large population, its per capita GDP though increasing is still relatively low. From a per

capita perspective, CO₂ emission is not high in China but is high in absolute terms. These empirical systems show that China has a long way to go in improving the country's environmental quality, and as such, in the course of its development, improving environmental sustainability will be a big challenge. The challenges will focus on population, CO₂ emissions, annual GDP growth, energy consumptions, climate condition, emission intensity, and effective technology for CO₂ reductions.

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