

Economic Analysis of the Beijing Green Olympics: Implications on Environmental Protection in China

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Abstract

The rapid economic development and motorization in the last three decades in Beijing has resulted in the deterioration of Beijing's air quality. Since 1998, the Beijing municipal government has made a great effort to improve Beijing's air quality, resulting in significant progress in reducing air pollution in Beijing. However, the air quality is still below the international health standard, especially the particular matter, PM_{10} . This could be a challenge to the Government's promise of clean air during the 2008 Olympics. The objective of this paper is to evaluate, using cost/benefit approach, the measures that Beijing has taken to achieve the goal of a Green Olympics. This paper can have important implications for designing environmental strategies during China's economic transition.

Keywords: Green Olympics, Environmental Protection, Cost/benefit analysis.

1. Introduction

The rapid economic development and modernization experienced by Beijing and its inhabitants during the recent three decades have resulted in a deterioration of Beijing's air quality. One phenomenon or factor that has contributed to this condition is motorization, wherein the number of motorized vehicles used by Beijing's growing population and expanding economy has risen enormously. Since 1998, Beijing's municipal government has made an extensive effort to improve Beijing's air quality, resulting in significant progress in reducing air pollution in Beijing. By hosting the 2008 Olympics, Beijing committed to a "Zero Net Emissions Games," (Note 1) where Beijing would minimize its emissions of air pollution in sulfur dioxide, carbon dioxide, and other pollutants from factories and projects around Beijing. Air pollution over the Olympic Games' host city has been one of the biggest worries for organizers. In fact, the hosting of this international mega event has huge implications in costs and opportunities – environmental as well as political -- as Beijing confronts an emergent environmental problem. To ensure an air quality above the standard of the World Health Organization during the Olympics, several measures have been taken. These measures include: (1) relocating heavy polluting industries (for example, the Shougang Group, one of China's leading steel makers and the capital's major polluter), (2) pulling half of the city's 3.3 million motor vehicles off the roads, (3) temporarily halting most construction projects within the municipal limit of Beijing, (4) constructing more waste treatment facilities, and (5) utilizing geothermal energy resources. The objective of this article is to describe and analyze, using cost-benefit analysis, the measures that Beijing has taken to achieve the goal of a Green Olympics. The result of this paper can have important implications for designing environmental strategies during China's economic transition.

The paper is organized as follows. The next section reviews the literature on pollution control on China. The following sections describe the environmental problem in Beijing and discuss the measures that Beijing officials have taken to achieve the Green Olympics. This is followed by the evaluation of the cost of the measures for the Green Olympics and the examination of the benefits from these measures. Next we propose the measures for sustainability after the 2008 Olympics. We conclude with the implications in the final section.

2. Literature review

There have been various studies on pollution control for China in last decade. Most of them rely on case studies focusing either on transport sector (Deng, 2006 and Jiang et al, 2007) or power plants (Skeer and Wang, (2006)). The current paper may be the first rigorous analysis of the benefits and costs of pollution control on Olympics events. Olsthoorn et al (1999) used simplified air quality models to evaluate the costs and benefits of meeting proposed air quality standards in EU cities for SO_2 , NO_2 and PM_{10} in the year 2010. Taking into account all uncertainties, such as errors and incertitude in various steps of the methodology on estimation of mortality, the study suggests that the benefits of the new standards exceed the costs. Li et al (2004) performs a cost/benefit analysis of air pollution control in Shanghai. They examine two options: integrated gasification combined cycle for power plants and relocation and reduction in coal use by the industrial sector, to control pollution from

stationary sources in Shanghai. The study shows that the benefit-cost ratio is in the range of 1-5 for the power sector and 2-15 for the industrial sector. Hammitt and Zhou (2006) conduct a contingent valuation (CV) study in three locations -- Beijing, Anqing (Anhui province) and the rural areas near Anqing -- in China to estimate the economic value of preventing adverse health effects associated with air pollution. They find that the sample-average median willingness to pay (WTP) to prevent an episode of cold ranges between US\$3 and US\$6, the WTP to prevent a statistical case of chronic bronchitis ranges between US\$500 and US\$1000, and the value per statistical life ranges between US\$4000 and US\$17000. The estimates are between about 10 and 1000 times smaller than estimates for the US and Taiwan.

Other studies that provide possible solution to ensure that the air quality goals for 2008 are met are: Street et al (2007) and Wang et al (2008) assess the contributions of the emission sources outside Beijing to the PM_{10} pollution in Beijing. Based on the US EPA's Models-3/CMAQ model simulation over the Beijing region, they estimate that about 34% of $PM_{2.5}$ on average and 35-60% of ozone during high ozone episodes at the Olympic Stadium can be attributed to sources outside Beijing. Controlling only local sources in Beijing will not be sufficient to attain the air quality goal set for the Beijing Olympics. There is an urgent need for regional air quality management studies and new emission control strategies to ensure that the air quality goals for 2008 are met.

The relationship between air pollution and daily mortality for various cities in China are examined as well. Xu et al (1994) examines the relationship between air pollution and daily mortality in two residential areas in Beijing in 1989. A highly significant association was found between SO_2 and daily mortality and positive association but not significant with TSP. Epidemiologic studies from different locations in China have consistently demonstrated significant positive association of sulphur dioxide, SO_2 , and particulate matter, $PM_{2.5}$ with daily mortality (Xu et al (2000), Venner et al (2003)). Jiang et al (2007) examines the various policy options for promoting of clean and energy efficient technologies in the transport sector that the local government of Beijing faces in order to reach environmental targets of air pollution control measure. A methodology framework using criteria for policy evaluation was used in the assessment. Skeer and Wang (2006) explores how carbon charges on charges and carbon sequestration technology might tip the balance in favor of natural gas use in China. (Note 2) Substitution of natural gas for coal in China's power sector could significantly reduce emissions of carbon dioxide.

3. Air pollution in Beijing

Beijing has undergone rapid economic growth and motorization since 1980s. As shown in Table 1, the rising GDP kept the vehicle growth rate above 10 percent for most years since 1978. The average rate of increase of the motor vehicle population was on average about 15 percent since 1997. In August 2003, the motor vehicle population in Beijing exceeded 2 million. Just before the 24th Olympics in 2008, the motor vehicle number reached 3.3 million. This rapid development and motorization has put heavy pressure on the urban atmosphere of Beijing. In the 1990s, Beijing was listed among the world's top 10 most polluted cities suffering from the mixed-source air pollution caused by coal combustion, vehicle exhaust, fugitive dust, and other sources. Beijing's case reflects the problems that other rapidly developing cities in China are facing. Beijing attracts millions of visitors every year as the political, economic, and cultural center of China; air quality in Beijing is very important for the benefit of its inhabitants and also for the image of the country. China's air pollution has been a high-profile issue to the local and national government and to the people living in the city, especially since Beijing was selected to host the 2008 Olympics. Beijing will face a considerable challenge to improve its air quality while maintaining its substantial economic growth.

Since 1990, air pollution in Beijing has been very severe. In 1998, Beijing began to publish weekly air quality reports according to which air quality for 85 percent of the days exceeded the national Grade II standard. (Note 3) The urban average concentrations of total suspended particulates (TSPs), sulfur dioxide (SO_2), Nitrogen oxides (NO_x), and other carbon monoxide (CO) in the summer were 431, 252, and 201 $\mu g/m^3$, and 4.4 mg/m^3 , respectively, all of which exceed the allowable Grade II standard. NO_x and CO pollutions in traffic areas were severe (see Table 2). Ozone concentration on 101 days in 1998 was beyond the allowable standard. (Note 4)

Since December 1998, the Beijing municipal government has implemented several control measures and emissions standards. The impact of these measures has been to lower the emissions of SO_2 , NO_x , and particulate matter₁₀ (PM_{10}) (PM with an aerodynamic diameter of $\leq 10\mu g/m^3$) by 22.1 percent, 21.4 percent, and 6.3 percent, respectively, and a reduction in the atmospheric concentrations by 36.3 percent, 18.7 percent, and 5.3 percent, respectively, by October, 2000. (Note 5) From 2003 to 2005, the annual PM_{10} concentration remained at a level of around 140 $\mu g/m^3$, which is 1.4 times the standard limit 100 $\mu g/m^3$ on annual average. The effect of a stricter

emission standard (EURO-II implemented in 2003) – which lowers the emissions standard of each vehicle – has been offset by the increase in the number of motor vehicles in operation.

To further improve the air quality for the upcoming 2008 Olympic Games, the EURO-III emission standard was implemented for new vehicles in Beijing in 2005. In the first half of 2008, the major pollutants in Beijing had dropped by 20 percent and small *PM* had fallen by 7 percent. The level of *PM*, still has not met the national standards throughout the year, as only 70 percent of the days passed the blue sky day standard through July 30. The city had 148 ‘blue sky’ days or days with acceptable air quality, for the year through July 30, 2008.

4. Environmental Measures of achieving the Green Olympics.

To achieve the Green Olympics, several environmental measures have been taken and investments made. They are: the promotion of renewable energy, the reduction of ozone-depleting refrigerants, the measures taken on transportation, the control of industrial pollution, the increase in green coverage, and the existence of emergency measures.

a.) The Promotion of Renewable Energy

In Beijing, most of the electricity comes from fossil-fueled power plants, such as coal, natural gas, or petroleum. Those fossil-fueled power plants, especially the ones using coal as the source of electricity generation, damage the quality of air. Combustion of coal emits greenhouse gas and toxic substances, like carbon dioxide, nitrogen oxide, sulfur dioxide and particulates, into the air. In addition, the rapid economic growth in Beijing will create a huge demand for electricity in the future.⁶ Promotion of a newer and cleaner source of energy becomes necessary to avoid environmental degradation as a consequence of economic growth.

Hosting the Olympics has provided Beijing with a great opportunity as well as an incentive to encourage the use of renewable energy. During the building of the Olympic venues, energy efficient designs and new technologies have been adopted; renewable energies, such as solar energy, geothermal energy and wind energy, are used instead of fossil fuel energy. The Solar Thermal Hot Water System, for example, has been installed in several Olympic venues, including the Olympic Village, Peking University Gymnasium, Beijing Shooting Range Hall and Beijing Olympic Tower. This system preheats the water using solar radiation, thereby reducing the amount of generated energy required to bring the water to the desired temperature before use by athletes and visitors.

Moreover, Solar Photovoltaic Power Generation Systems have been used in seven Olympic venues, such as The National Stadium, Wukesong Stadium and Olympic Forest Park, so as to reduce the electricity consumption. It is estimated that the system can produce 620,000 kilowatt hours (kWh) annually, and reduce annual coal consumption by 242 tons (metric). The Solar Thermal Hot Water System along with the Solar Photovoltaic Power Generation Systems would reduce carbon dioxide emissions by 630 tons per year.

In order to promote the use of geothermal energy, the Geothermal Heat Pump Air-Conditioning and Heating System, which makes use of the constant year-round temperature from the earth as either a heating or cooling source, has been installed in Shunyi Olympic Rowing and Canoeing Park, Olympic Forest Park and Peking University Gymnasium to provide for the air-conditioning and heating needs for those buildings.

Furthermore, the Guanting Wind Power Station, the first wind power generation station developed in Beijing, has been used to support nearly one-fifth of the Olympic venues’ electricity needs during the Games. This clean wind station can generate 100 million kWh of electricity per year, which is adequate to meet the typical demands of 100,000 families.

Besides these renewable energies, efficient lighting systems have been widely used to cut down the electricity consumption. The National Aquatics Centre (the Water Cube) and other venues have made use of low energy Light Emitting Diode (LED) lighting. It has been estimated that 60-70 percent of electricity consumption has been saved in these venues. In addition, all the contract hotels with the Olympic Games have been encouraged to switch to energy- saving light bulbs. A “Green Lighting Program” has also been implemented in schools to support energy saving. Under this program, seven million old incandescent light bulbs have been changed to energy-saving compact fluorescent light bulbs (CFLs) in all elementary schools and high schools, retirement homes, and across the rest of the city. (Note 7)

b.) The Reduction of Ozone-depleting Refrigerants

To achieve the goal of a Green Olympics, the Beijing municipal government has established a list of policies prohibiting the use of ozone-depleting substances (ODS) in order to protect the earth’s ozone layer. This includes the prohibition of ozone-depleting chlorofluorocarbons (CFCs) which are used in cooling devices, such as air-conditioners and refrigerators in the Olympic venues. (Note 8) Cooperation from enterprises has provided

welfare support to government in its effort to educate and persuade on matters of environmental responsibility. Both Coca-Cola and McDonald's, for example, have stopped using the hydrofluorocarbons (HFCs) as a refrigerant in their cooling machines and freezers. (Note 9)

c.) The Measures taken on Transportation

To ensure a blue sky and clean air, Beijing's municipal government has implemented different measures to improve the traffic congestion. Starting from March 1, 2008, a new EURO-IV standard has been implemented in Beijing, which includes the testing of hydrocarbon (HC), carbon monoxide (CO), and small-sized particulate matter ($PM_{2.5}$) of vehicle emissions. Implementation of the EURO-IV standard is expected to cut the emissions from vehicles by 50 percent and to help with improvement of the air quality.

Beijing has also introduced a temporary traffic rule, effective from July 20 through September 20, 2008, which requires that vehicles having license plate numbers ending with either an even or an odd number be permitted to operate only on alternative days of the week. (Note 10) In 2008, a new initiative was instituted to encourage the use of public transportation during the Olympics. Since then, four new subway lines and an Olympics Branch Line have been completed. This has increased the total subway capacity from 1.3 million commuters per day in 2000 to 3.9 million commuters per day in 2008. In addition, both the subway fares and public bus fares have been cut. During the games, ticket holders who travelled to the Olympic events could travel free throughout the city, which further encouraged the use of public transportation throughout the Games.

To improve the air quality, the government further encouraged vehicle-owners to use low-emission fuels to replace the use of high-emission gasoline or diesel fuels. To promote the operation of environmentally friendly vehicles, three hydrogen fuel cell buses (FCBs) have been introduced to transport international and national athletes during the Olympic Games, and a hydrogen re-fueling station has been built in the Beijing Hydro Demo Park. The plan has successfully raised the public's awareness about low-emission transportation. (Note 11)

To promote a "zero-emission" means of transportation, a fleet of several hundred bicycles was made available in the Olympic Park and Olympic Village for the visitors to use during the Games.

d.) The Control of Industrial Pollution

One of the major sources of air pollution in Beijing comes from those industrial plants which employ lower levels of technology and coal combustion. In order to improve the air quality during the Games period, the Beijing municipal government has ordered closure, relocation, or upgrading of some heavy polluting, high-energy-consuming and resource-wasting factories. However, the city-based control measures were not very effective on PM_{10} pollution. The high PM_{10} pollution in Beijing is due also to the polluting sources from the neighboring industrial cities such as Tianjin, Tangshan and Shijiazhuang, which have high emission levels. (Note 12) Empirical studies (Streets et al. (2007) and Chen et al (2007)) have indicated that about 34 percent of $PM_{2.5}$ at the urban area of Beijing could be attributed to the emissions outside of Beijing. Thus, there has been a need for a systematic control strategy for PM_{10} pollution in Beijing and the surrounding regions. Cooperation in the interest of pollution control between Beijing and the surrounding regions has been actively pursued by regional authorities to ensure good air quality for the 2008 Olympic Games.

e.) The Increase in the Green Coverage

Based on the scientific literature, trees provide one of the best controls of air pollution. Trees can absorb, bind, intercept and sequester pollutants like PM and NO_x by storing carbon in their roots and trunks and then releasing oxygen into the atmosphere. More importantly, trees can lower local air and building temperatures through transpiration, shading, and buffering winter wind, thus lessening the demand for cooling and heating which contributes to the formation of ozone. In this way, air pollution can be alleviated through the presence of vegetation. Based on the above mentioned reasons, Beijing implemented a plan to increase the green coverage of the urban area with air pollution management in mind.

In 2007, the Beijing municipal government began an initiative to plant a total of 12,000 hectares of trees. This increased the green coverage by 43 percent, and the per capita green area jumped to 48 square meters. In addition, more than 160 green parks were also established and a 23,000-hectare greenbelt was formed by planting trees along the city's five waterways and ten highways. Implementation of these measures has resulted in an increase in the total area of forest coverage by 15.9 percent: from 930,000 hectares in 2000 to 1,078,000 hectares in 2007.

f.) The Existence of Emergency Measures

In the event that the official standard on air quality in Beijing cannot be met, the neighboring city of Tianjin and

the nearby province of Hebei would be required to expand upon their existing emission-reduction regimen correspondent to automobiles and factories (Note 13).

5. The Cost on the Measures of the Green Olympics

According to the Beijing Statistics Bureau (Note 14), Beijing has made a direct investment of 140 billion Renminbi (RMB) in the Olympics, mainly in seven types of industries including electricity, water heating, transportation, information delivery, tourism, accommodation, and food and beverage services. Apart from the capital investment, Beijing has also made a considerable sacrifice in economic growth in order to ensure a successful Olympics under the slogan "Green Olympics." In reality, Beijing shut down more than 105 industrial sites, including those sites for generating electricity, and for manufacturing furniture, building materials, and chemicals; activities at construction sites in Beijing are required to be halted altogether in order to achieve the Green Olympics' goal during the Olympic period. The closing down of these plants had a negative impact on industrial output and development. For example, 27 out of 28 cement factories were shut down during the Olympics, and 40 factories had to be closed in Tianjin, a port city just east of Beijing and a host to Olympic soccer qualifying events. With the closure of the factories, the workers were affected most, as about 60,000 workers employed by the state-owned enterprises were laid off in conjunction with plants relocation to somewhere outside of the city.

According to conservative estimates, Beijing's industrial value-added was down by 9.1% because of factory closures. For instance, chemical manufacturing output has decreased by 25.3 percent; the iron and steel industry output has declined by 51.7 percent; and the cement and construction sector output has dropped by 45.3 percent. In addition, according to the Beijing Municipal Bureau of Industrial Development (BMBID), Beijing's infrastructure and public utilities sector, including iron and steel, petro-chemical and cement industries, has lost tens of billions of RMB. Clearly, an economic slip was inevitable in the short term. It has been projected that Beijing's gross domestic product (GDP) growth rate in 2008 will drop by 2 to 3%.

The 'blue sky and through traffic' is not without cost. For some Beijing residents who rely on their vehicle as a daily mode of transportation, convenience, and occupational responsibilities, the policy has intruded upon their human rights. In the past two decades, Beijing's municipal government has encouraged and strongly supported the expansion of the automobile industry to boost economic growth. The implementation of the alternative-day vehicle usage policy conflicts with earlier efforts to promote vehicle ownership and vehicle operation. In addition, the even and odd license plate policy, as mentioned earlier, is just an empty statement: only the underprivileged are hurt. For the privileged individuals, they can easily get more than one car and/or one license plate via *guanxi* (personal connections) or bribery to get an unrestricted license. Clearly, an economic welfare loss is inevitable in the short term for the Beijing residents.

6. The Benefit on the Measures of the Green Olympics

As mentioned in Section 3, after the implementation of these measures, the number of Blue Sky days in Beijing has steadily increased. Compared to the previous year, when Beijing usually scored below 101 days per year, the number of Blue Sky days rose -- to 246 in 2007. (Note 15) In the first half of 2008, the major pollutants in Beijing had dropped by 20 percent and small particulate matter was reduced by 7 percent. The city had 148 'blue sky' days or days with acceptable air quality, for the year through July 30, 2008. (Note 16) Under this circumstance, it is obvious that Beijing has fulfilled the annual 'blue sky' target which has resulted in an improvement in air quality. Data from the Beijing Environmental Bureau shows that the capital's particulate concentration level declined by half during the Games due to the suspension of work at construction sites, vehicle usage restrictions, and other measures.

To assess incremental benefits attributable to environmental policy, such as pollution control during the Games, we must determine how health, ecological and national image change as a result of that policy. These benefits can be classified as direct or indirect, and monetary or non-monetary. Direct benefit arises as a direct consequence of implementing policy, whereas an indirect benefit derives either from direct benefit or from some demand-induced effects. These benefits can be measured in either monetary or non-monetary terms. Some benefits, especially those measures for the Games, are difficult to convert into money terms in the short-run. The benefits from these measures are:

a) International image: Beijing has achieved and even surpassed its original environmental goals – in some cases, far exceeding those goals set and attained by both Sydney and Athens, its two predecessor Olympic hosts. The fulfillment of the 'blue sky' target has made the people in the world believe that China is capable of keeping its promise of providing a "Green Olympics" and fulfilling its obligation in improving the air quality. To a country like China which pays much of the dignity in fulfillment of its promise, this honor can be said to be the

greatest reward. This is one of many examples of direct and non-monetary benefit. According to our estimates, the average willingness to pay per person for such a successful event was 133.5 yuan. Based on this estimate, we project that the total willingness to pay for all Chinese will be 226.9 billion yuan (Note 17).

b) In China, local environmental problems are poorly understood in other heavily polluted cities and required a major effort to identify and convince people to recognize the problem. People generally do not understand how serious the environmental problem is until the environmental consequences translate into direct negative impacts on human health, the quality of life, social and economic productivity, and on the surrounding ecosystem. Hosting the Olympics provides Beijing with an opportunity to further consider the air pollution problem. In addition, Beijing has seized the chance to raise public awareness on this issue. For most of Beijing's residents, they have enjoyed a full two months of blue skies and through traffic -- the convenience and general quality of life benefit scarcely available prior to the initiative of the preparation for the Olympic Games. This gain in welfare is difficult to convert into monetary terms. In addition, this can have a strong demonstration effect for some other cities in China, especially in those cities like Shanghai, Guangzhou, and Shenzhen, where air pollution from vehicles is severe. Environmental degradation has threatened the long-term availability and quality of natural resources critical to economic growth. Local authorities may be reluctant, for example, to enforce pollution control regulations, in fear of driving industry and jobs away from Beijing to other countries. In most cases, in the absence of community awareness and pressure, the simplest political course of action is inaction. This indirect benefit – the environmental awareness from the general public – can hardly be measured in the short run.

c) Environmental pollutants such as polycyclic aromatic hydrocarbons (PAHs), lead, and mercury are released by the combustion of fossil fuels such as coal, diesel, and gasoline. There is growing evidence (Tang, 2008) that prenatal exposures to air pollutants from combustion of coal and other fossil fuels have adverse effects on fetal growth and early neurodevelopment. PAHs are toxic, mutagenic, and carcinogenic air pollutants that are generated by the incomplete combustion of fossil fuels. PAHs are also present in tobacco smoke and grilled or broiled foods, as well as in ambient air. The closing down of heavy-pollution-causing plants or relocating the plants outside of the city would help in reducing the level of damage that might cause impaired lung function and genetic defects in children, spontaneous abortions, reduced life expectancy, and other health impacts. This indirect benefit can hardly be realized or measured in the short run.

7. Measures for Sustainability after the 2008 Olympics

Despite the high cost of tackling the air pollution for the 2008 Olympics, Beijing's municipal government continues to focus on the long-run goals of energy conservation and emission reduction despite the threat of a global recession. According to one estimate, two million more cars are expected to take to Beijing's roads by 2012, bringing the number to 5.4 million, an increase of 20 percent per year, or 300,000 new cars a year. The new cars will need another 60 square kilometers of parking space, which equals the total area within the Second Ring Road. The new vehicles will also burn at least 1.3 billion liters of gasoline fuel each year.

Beijing is already plagued by traffic congestion and poor air quality caused by emissions from a growing number of cars. New administrative and legislative measures are needed to restrict the growing number of new cars. First, Beijing must introduce more bus-only lanes to encourage more people to use public transportation during traffic rush hours. Bus-only lanes should also be introduced in areas where there is a heavy flow of commuters to improve the efficiency of public transport. Besides, more subway lines should also be built to meet the increase in demand for commuting infrastructure (Note 18). Second, the even-odd license plate number policy adopted during the Beijing Olympics to ease road traffic and pollution should be reintroduced in central Beijing. Third, the introduction of tolls for the use of certain roads during peak hours must be looked at. Fourth, Beijing plans to ban a total of 357,000 "yellow plate" vehicles from entering the Fifth Ring Road starting Jan 1, 2009, to improve the city's air quality. By October, 2009, all yellow license plate vehicles (Note 19), mostly tippers and heavy-duty trucks, will be banned in Beijing. Lastly, tax exemption policies will be introduced in 2009 to encourage the development of electric vehicles, those using mixed energy, and those with low emissions.

Some local governments are still holding the age-long mindset that higher economic growth is a priority (Note 20) despite the fact that a nationwide campaign to promote sustainable development and environmental/economic harmony has been ongoing for years. Those local governments' poor environmental awareness may be a major threat to the sustainability of economic progress. Rushing to pump up GDP without adequate consideration of environment would only compound an already serious situation. (Note 21) The central government should strengthen inspections to prevent local governments from acting in such a way that risks stabilizing economic growth at the expense of environmental protection. Of the 4-trillion-yuan economic

stimulus plan, 34 percent of the first 100 billion yuan pledged for the first quarter of 2009 will be spent on rural infrastructure. Waste water treatment in rural areas would be one priority focus for investment consistent with the State council's target of increasing such treatment by 10 percent by 2010.

As part of the economic stimulus plan and according to the energy conservation measures from the Beijing Olympics, if every rural household were given two 60-watt compact fluorescent light bulbs, this would result in CO₂ savings over incandescent bulbs equal to the emissions from 4 gigawatts of coal-fired electric power which is equivalent to 6 percent of the nation's power generation increase in 2007. If we add an additional 30 million solar water heaters for rural households, the nation would save the green house gas emissions equivalent of another 7 gigawatts. Taking the two measures together, we can cancel out more than 16 percent of 2007's emission increase from power generation. At the same time, these investments would create many jobs.

Another measure is to promote the use of household biogas digesters which transform agricultural wastes into clean energy. According to one estimate, each household biogas digester can avoid more than a ton of carbon dioxide equivalent emissions for each year of its operation. With more than 20 million household digesters currently in operation, this is a saving of more than 20 million tons of carbon dioxide equivalent per year. This is roughly equivalent to the annual emissions from more than 5.5 million new cars or 4 modern coal-fired electric generating stations.

As we know, the bicycle is the most thermodynamic and efficient transportation vehicle in the world. The bicycle lets you travel three times as far as you could walk on a plateful of calories and it is 53 times more energy efficient than the typical automobile. Most importantly, bicycles never pollute the air. So far, China has both the largest stock of bicycles and the largest number of bicycles per capita in the world. Moreover, China may also be the world's largest manufacturer of bicycles. In fact, bicycle is the main transportation vehicle in the countryside. Because of motorization, the bicycle is no longer a main transportation vehicle in the cities, like Beijing, Shanghai and Guangzhou. Promotion and encouragement of the use of bicycles in most of the heavily polluted cities seems necessary. The local government can build more bicycle lanes and bicycle parking spaces. This would not only solve the congestion problem, but also reduce the dependence upon pollution-causing forms of energy.

8. Conclusion

From our rough estimate, the cost/benefit ratio of the Beijing Green Olympics might be greater than 1.0 in the short run. We strongly believe that in the long run, taking all the benefits into consideration (Note 22), this ratio will be less than 1.0. In environmental context, "one world, one dream" is all we want to achieve. Tackling air pollution is not just a short-term job. Temporary measures are not enough to improve the current situation in Beijing. Those measures should be sustained over a long period of time and improved consistently. Hosting the Olympics is an opportunity not only for Beijing but also for the Chinese government to begin considering the problem of air pollution and understanding it. Beijing has seized the chance, achieving and even surpassing the original environmental goals. These goals may be attained at a high cost, but the realization of the ideal, 'green' environment is invaluable for all residents of China.

With the passing of the Olympics, the Chinese government should continue its environmental measures in other cities, for example, the temporary closing of high-pollution industrial plants, especially on those days that are high in humidity. In the long term, Beijing may consider a subsidy that encourages the development and adoption of new, cleaner technology by industries in hopes of further reducing emissions. In addition, laws should be established to strengthen the implementation of those measures instead of just using the non-binding nature of the guidelines. Besides, the lack of transparency and the lack of third party auditing would be hindrances to the improvement and development of those measures. Transparency of the policies and public participation are essential for an environmental regimen that supports the decision-making process and advocates the need and general welfare of all of Beijing (human and enterprise constituencies). (Note 23)

As mentioned in the previous section, Beijing's air quality would be affected not only by internal air quality impact factors, but also by air quality impact factors imposed by its neighboring cities. That implies that controlling the air pollution is not just one city's problem, but also a regional problem. Regulations and rules should be established in all provinces in an effort to collectively control and improve the air quality.

Last but not least, education is a major means of dealing with the environmental problem in China. No matter how many rules or guidelines are set up, education of those who are required to follow such rules and guidelines must be seen as synonymous with educating those who are expected to benefit from them—the people of Beijing naturally extended to include the people of China.

The Olympics in Beijing has provided China with a golden opportunity to raise awareness among all Chinese citizens with regard to the problem of air pollution. The Chinese government should make use of this opportunity to educate China's citizens about the issue and cause of environmental protection. Moreover, more funds should be put into the research development and acquisition of technology which is environmentally friendly. Despite the huge cost that Beijing incurred during the Green Olympics, the long-term benefit of these measures will not only reward the Beijing residents but also all the people in the Mainland.

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Notes

Note 1: The Beijing government's determination in improving the air pollution can be found from their commitment when Beijing bid for the host of the game. "While air quality during the period of the Games in 2008 will be of a high quality, and meet Chinese and World Health Organization (WHO) standards." "Beijing's Post-Olympic Blues", Available: http://www.eeo.com.cn/ens/finance_investment/2008/10/15/116324.html.

Note 2: This would have a large impact upon China's energy consumption portfolio as well as policy, behavior, economic and market spillover effects onto the world.

Note 3: The Grade I standard is for national reserves, national parks, and other protected areas. The Grade II standard is for urban residential, commerce-traffic-resident mixed, common industrial, and rural areas. The Grade III standard is for special industrial areas.

Note 4: 1998 Report on the State of Environment in Beijing; Beijing Environmental Protection Bureau. <http://www.bjepb.gov.cn/>

Note 5: Yuan, J., et al. Environmental Effect Analysis for Four Stage measures of Short-Term Air Pollution Control in Beijing: China Enviro, 2000, 34, 353-465.

Note 6: As rising incomes lead to more electricity consumption resulted in chronic widespread electricity shortages. *Thus China plans to build more than a hundreds new power stations over the next decade, adding 18,000 mega-watts of capacity every year.* By 2020, its coal consumption will have doubled, if not tripled. All this will not only worsen the country's acid-rain and air-pollution problems; it will endanger the entire planet by accelerating the global warming.

Note 7: "Environmental Report on Beijing Olympic (Go beyond Beijing, Go beyond 2008)" <http://www.greenpeace.org/china/ch/news/green-beijing-olympics-report/full-report>.

Note 8: The Beijing Organizing Committee for the Games of the XXIX Olympiad (BOCOG) has made some guidelines, such as "Environmental Protection Guidelines for Olympic Projects", states that all the materials in the constructions shall not contain any ozone-depleting substances.

Note 9: *ibid*

Note 10: The Olympic games run from August 8 through 24, while the Paralympics run from September 6 through 17.

Note 11: *ibid*

Note 12: In the Chen et al. study, it was found, on the basis of the annual average, that 34.7 percent of PM_{10} in Beijing came from outside areas.

Note 13: At the time of Olympic games, the committee does not have to implement this emergency issue.

Note 14: *ibid*

Note 15: There were just 100 blue sky days in 1998 when the city launched the blue sky campaign.

Note 16: "China Determined to Stage Blue Sky Olympics", Available: <http://www.ens-newswire.com/ens/jul2008/2008-07-31-01.asp>

Note 17: A contingent valuation survey was conducted in Lingnan campus on November 26, 2008 to elicit willingness to pay (WTP) from 206 students for having such a successful event in Beijing. We found that the average willingness to pay from each respondent was 133.5 yuan. If we project this to all Chinese people in the world (the residence in mainland plus all overseas Chinese), it is estimated that the total willingness to pay will

be 226.94 billion yuan. Of course the accuracy of this estimate depends on the respondent's characteristics (such as place of residence, education, income, etc.) For example, the relative income of Hong Kong people is higher than those in mainland China. Thus, the use of average willingness to pay from Hong Kong survey will overestimate the total willingness to pay.

Note 18: By the end of 2009, three additional lines will be opened in Beijing.

Note 19: Trucks in Beijing are issued with green or yellow plates according to their emission levels. Those yellow plates are banned from entering the city of center during the day.

Note 20: The strategy of "Develop first, environment later" was deeply rooted in most of local governments.

Note 21: Daniel Dudek, "Stimulus projects must meet green standard," China Daily, 12 Dec., 2008.

Note 22: *ibid*

Note 23: A contingent valuation survey or a dose responses method can be used to estimate the long term benefit of reducing of mortality from respiratory diseases due to reduction in air pollution and cleaner air.

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Table 1. Growth rate of Real GDP, Per Capita GDP, Motor vehicles, and Electricity Consumption (%).

	Real GDP	Per Capita GDP	Motor Vehicles	Electricity consumption per household
1991	9.91	18.53	25.67	16.67
1992	11.28	17.55	-29.42	13.99
1993	12.31	23.97	65.30	14.88
1994	13.69	27.90	17.86	14.32
1995	12.00	23.93	21.05	9.19
1996	8.99	12.32	-0.73	20.18
1997	10.10	16.52	27.64	21.65
1998	9.49	15.11	14.16	11.10
1999	10.91	11.92	6.74	21.27
2000	11.80	12.74	9.91	33.63
2001	11.69	11.92	14.71	13.19
2002	11.51	14.23	12.77	16.08
2003	10.99	13.14	12.79	12.28
2004	14.10	17.79	8.84	14.10
2005	11.80	10.57	13.56	10.87
2006	12.80	10.92	11.90	7.82
2007	13.30	15.47	11.56	11.27

Source: Beijing Statistical Yearbook, 2008.

Table 2. Atmosphere Environment and Planted Areas (2000-2007)

	Air pollution index better than G2 (days)	COD discharge volume (10000ton)	SO ₂ discharge volume (10000ton)	Daily mean of SO ₂ in the year (mg/m ³)	Daily mean of Nitrogen dioxide in the year (mg/m ³)
2000	177	---	---	0.071	0.071
2001	185	---	---	0.064	0.071
2002	203	---	---	0.067	0.076
2003	224	---	---	0.061	0.072
2004	229	---	---	0.055	0.071
2005	234	11.6	19.06	0.05	0.066
2006	241	10.99	17.55	0.053	0.066
2007	246	10.65	15.17	0.047	0.066

Source: Beijing Statistical Yearbook, 2008.