The Problems with Applying Cost-Benefit Analysis to Environmental Policy Decisions

A Case Study of China's Energy Sector and the Three Gorges Dam

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Major Paper

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This paper is dedicated to the memory of

Professeur Marcelle Genné

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In countries' efforts to improve their people's standards of living, as well as their own wealth and power among neighbouring nations, they may grow without concern for their social or environmental impacts. It has been argued that one such country is China. This paper has as a basis to explore the arguments surrounding China's Three Gorges Project and add to the discussion of whether it is socially responsible to build or not to build the dam. The conclusions do not detail the solution to the on-going debate, as the actual detailed analysis for such an assertion is far beyond this paper's scope. Instead, its purpose is to look at why this type of project is proposed, considering the types of costs and benefits that should be evaluated in any analysis to be done within the context of the Chinese economy.

To develop without any concern about pollution is harmful to the environment and therefore, for future economic growth, although it is a common practice in many developing countries. When priorities are set and resources extremely scarce, increasing potential profits is of the utmost importance. However, there are many ways in which increased pollution levels will decrease future profits. Allowing natural resources to be over-exploited, to create a disproportionate amount of carbon emissions or for the air quality to deteriorate to a pitiful state are ways in which the over-use and over-production of coal contribute to environmental degradation.

The question to be answered is: "***Are there more responsible and sustainable ways to grow that will obtain the same rates of growth for approximately the same cost?***" In order to answer this question, we must look at the following factors:
the country: to see what means of growth will be tolerated as acceptable
the economy: to see what typical rates of growth are feasible
the environment: as this project centres on the energy sector, to see what environmental impacts current production and projected future production yield
the project: to see what the proposed costs and associated benefits are anticipated (note – a model detailing the different prices for all benefits and costs is also to be considered)
an alternate project or set of projects: that could replace the proposed project and yield the same approximate benefit, measuring the costs and associated benefits
an analysis: comparing the project and the alternate choice of development

The points listed above have been detailed out into chapters that follow, in an attempt to clarify the question of whether or not it is socially responsible to build the Three Gorges Dam and what factors should be considered prior to asserting any conclusions. The following structure was used in order to answer the above questions.

The first section of the paper looks at the country as a whole, and explores the geography and economic history to help provide a context for the study. In the second section, we begin to study the actual economy and its growth. This section focuses on the growth of the economy, population and the energy sector and begins to delve into associated trends and externalities. This brings us to the third part of the paper, that of a quick study of the environment and ecological impacts due to developmental factors as being experienced in China.

The initial three sections of the paper set a solid context for China's need for a new, large, clean source of energy. The fourth section investigates and describes the actual project chosen to fulfil these needs, the Three Gorges Dam. This is followed by the alternatives China may have to the large dam in satisfying her energy needs.

The basis of the paper is to investigate the premise of the construction of the Three Gorges and compare the results with that of developing a suitable replacement project, or set of projects. The tool employed for such economic studies is usually that of cost-benefit analysis. A theoretical chapter is then outlined that briefly describes the uses and limitations of cost-benefit analysis as well as the many pitfalls and caveats.

The final chapter before the concluding remarks is an actual (very small-scale) cost-benefit analysis, comparing the two projects. Actual numbers and pricing of all elements are far beyond the scope of this paper, however a surface analysis employing the simple technique of comparing negative and positive effects is conducted.

1. The Country

As described above, it is important to understand the country and its cultural evolution prior to investigating options on how to modify its growth and curb it towards more sustainable options. A country's history moulds its people's attitudes towards growth as well as its tolerance for instability.

1.1 Geography

China is approximately 9.6 million square kilometers in size, with an east-west diameter of around 5,000 kilometers, and north-south distance of around 4,050 kilometers. The size of the country ranks it third in the world, after Russia and Canada. China sits on the north coast of Malaysia, and has a plateau of 4,000 meters above sea level and numerous rivers and mountains. For a map, please refer to Appendix A. Although China does not have much agrarian soil, the climate is considered to be in the temperate belt, as it ranges from relatively cold temperatures, found in the north of China, to temperatures in the tropical range which are found in the south. Looking at environmental factors impacting the land, the country has a history of floods, droughts, typhoons as well as earthquakes; additionally, monsoons are common in both summer and winter months.[1]

An important factor about the physical geography of the land is that of the lack of fertile soil throughout the country. Many Chinese people rely on an agrarian way of life but the arable land is at a very high premium.

Culturally, there is great significance to the Chinese people as to their ancestral roots within the confines of individual plots of land and the surrounding landscape. This interesting link between the physical geography and the culture of the people should not be forgotten when compiling the economic models for analysis.

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[1] "China, A Country Study". Edited by Robert L. Warden, Andrea Matles Savada and Ronald E. Dolan. Federal Research Division. Library of Congress: 1987. Section 1.

1.2 Economic History

As we are most concerned with China's more recent history, we will start looking at the country around the time frame of 1949 onwards as that was the year that Mao Zedong proclaimed the founding of the People's Republic of China. This shift to a Soviet-type economy was to help overcome the high inflation and social conflict that the country had been experiencing for decades.

In the decades prior to 1949, there was the war between the Communists and the Guomindang. The Guomindang party was led by Chiang Kai-shek (who succeeded Sun Yat-sen in 1925) was in power and supported by the country's army. Many battles ensued as Chiang attempted to eliminate communism through extermination, and continued to fight the communists even in the face of the Japanese invasion.

Although the communists were far outnumbered and outpowered by the Guomindang faction, the people were tired of the warlords and the landlords imposing burdensome taxes. The Red Army of the communists could travel with little fear of the people turning against them. The battles of Chinese versus Chinese raged on until the Communist Party asked to unite forces against the Japanese invasion. As the soviets, the only Chinese supporters of the time were fearful of the Japanese, they called for a united China as well.

The war was long between the countries and China needed to fund its efforts, but had no trade to bolster its economy. In order to continue funding the battle, China printed money, but had no reserves to back it up. With inflation increasing as well as new taxes emerging, the Guomindang were becoming very unpopular with the people. In fact from 1937 to 1940, the Communist Party's membership grew from 40,000 to 400,000.[2]

World War II provided new allies for China against the Japanese and Allied forces began helping more with both financial and tactical support. After the war was over and the Japanese had surrendered to the Allied forces, both Communist and Guomindang forces scrambled to claim as much land as possible and continued battling one another. The

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[2] Kimball, Charles S. A Concise History of China. http://members.vavo.com/Berosus2/china/ch07.html: December 10, 1997. Chapter 7.

Communists returned to their 'land reform' policy by overthrowing and sometimes killing landlords and redistributing the land to the people. Popularity of the party among the people soared.

As the Guomindang had done before while in financial crisis, the country began printing money in order to fund the war efforts. Once the money depreciated in value to the extent where people were hoarding supplies and it cost huge amounts of dollars to purchase even a loaf of bread, the currency was replaced. Much of the damage had been done, speculation and hoarding continued and riots ensued. In contrast with this development, the communist-controlled areas did not suffer from starvation and inflationary pressures as they had no monetary system and used barter for trade.

Defections from the (Guomindang) Nationalist Army to the People's Liberation Army increased and battles were soon being won by the communists, one by one, cities were soon claimed by the Communist Party. In 1949, Mao Zedong proclaimed the founding of the People's Republic of China.

Throughout the next few years, the economy was restructured and rebuilt to provide jobs and economic growth for the people. The military secured the political direction of change and the government became involved in many facets of its population's regular, daily life. This continued until nearly a decade later, when Mao broke with the Soviet model in August of 1960 (this fracture is commonly named the ***Sino-Soviet Split***).

Within the same time period of reprioritizing China's efforts towards the Chinese people and not the USSR, a new economic restructuring programme, the ***Great Leap Forward*** was created (1958). This programme had as goal to improve diverse aspects of the Chinese economy, industry and technology. The production of steel was to be increased through the implementation of many small factories and agricultural output would be increased through the combination of collective farms into communes. In all, roughly 26,000 communes were created where each commune comprised approximately 5,000 households.[3]

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[3] "Chinese Cultural Studies: Concise Political History of China". Halsall, Paul. Brooklyn College. http://acc6.its.brooklyn.cuny.edu/~phalsall/texts/chinhist.html: September 18, 1998.

The planning of this economic programme focused at the end result and did not scrutinize the means by which it would be obtained as they violated basic economic and ecological principles. After the economy experienced a temporary increase in industrial output (1958-59), there was a downturn in production. The goods produced were unsalable and of inferior-quality. Agricultural production plummeted as well. To worsen the situation, the Soviets were displeased with the new economic model for the country and began withdrawing their support, having open disputes with China in international forums.[4] The failure of the Great Leap Forward in combination with the withdrawal of the Soviet aid and a series of natural disasters resulted in a countrywide famine in the years 1960-62. As of 1962, the economy's output was one-third less than it was three years earlier.[5]

Throughout the 1960s, the political economy was an environment of turmoil and change as it was the time of the ***Cultural Revolution*** (1966). There was a struggle of power for the leadership of the country as the State President, Liu Shaoqi, and the Party General Secretary, Deng Xiaoping, adopted more pragmatic policies to bolster China's economy. The two, distinct visions for the country had the leaders attacking one another and created political and social anarchy.

The cultural revolution surfaced from a political attack on Liu Shaoqi (State President of the day), Deng Xiaoping (Party General Secretary) and other pragmatists who were launching economic policies contrary to Mao's vision. Mao was displeased with his new, diminished role as Party Chairman under the adopted policies and sought popular opposition against the pragmatists. For a communist regime, this was unprecedented.

The radicals led by Mao and backed by the People's Liberation Army (PLA) charged the pragmatists, Liu, Deng and their supporters of leading China back into capitalist ruin. The conflict surrounding the country's leadership continued and peaked in 1971 when a

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[4] "Chinese Politics and Human Rights". Lam, Jason. Index-China.com. http://www.index-china.com/index-english/Politics-s.html: July 16, 2000.

[5] "Humanity and Nature: A Review of Development and Environmental Degradation of Contemporary China". Xie, Jian. Professional Association for China's Environment(PACE). http://chinaenvironment.net/articles/xiejian2.html: October 19, 1999.

coup was staged against Mao by the Party Vice Chairman and Defense Minister, Lin Biao. Lin soon met his fate in Mongolia in a plane crash.

The death of this key pragmatist sparked a reinstatement of several officials to government ranks, including Deng Xiaoping. The continued struggle between pragmatists and radicals surfaced when Mao's wife, Jiang Qing and three other radical visionaries publicly attacked Deng's leadership. This radical group received the title of the "Gang of Four".

Within the same year (1976) two historic deaths would take place. First, Premier Zhou Enlai, a popular political voice, died of cancer in April. Beijing citizens took to Tiananmen Square to mourn the death and support Deng's pragmatic vision. Deng was punished by this outcry by having his official positions removed, although he did maintain his party membership.

Mao died in September of the same year. His position of power was quickly filled by Hua Guofeng, who was named Party Chairman and Premier. Not long after Mao's death, members the Gang of Four were arrested and Deng Xiaoping was reinstated to his posts. The pragmatic leadership encouraged expanding economic reform policies surrounding direct foreign investment, reducing government planning, enterprise autonomy, farming incentives and legal reforms. At this time, a new pragmatic direction of emphasized economic development was created. In the next few years reform policies would be re-examined and be given new life, of specific interest were the reforms known as the Four Modernisations.

1.3 The Four Modernisations

The Four Modernisations were first announced in 1973 at the tenth party congress. The programme involved using capitalist economics to improve production levels in China at a pivotal time when the country was just beginning to recover from the effects of the Cultural Revolution. The modernisations were subsequently implemented by Deng Xiaoping in 1978.

The four modernisations featured agriculture, industry, national defense, and science and technology. In essence, the government was striving to succeed through economic, rather than political means.

Agriculture was the most successful of the reforms as it involved providing incentives for farmers to produce more than the regular quotas required by collectives. It allowed for farmers to work land for profit, once the collective was given an initial amount. This new arrangement provides strong incentives for farmers to minimize production costs, maximize crop output and maintain long-run environmental conditions to continue to prosper from the farmland.

The reform involving industry was much the same model as with the agricultural sector, to provide market incentives to maximize output and minimize costs. This was achieved by taxing the profit of individual enterprises, and letting the company keep the rest. The opening of the Chinese market was also part of this reform and levels of trade continued to rise.

Despite the good results of these reforms, new problems and tensions between party lines had developed and the country was once again experience political turmoil. Due to the financial incentives now available to specific areas of the population, some people were getting rich while others were not. This introduced large income disparities within the economy. Along with this phenomenon came greed, corruption and what some feared, moral degradation of the society.

By the 1980s the pragmatic leadership had begun encouraging artists and writers to explore critical (albeit not political criticism) styles. Once the cultural revolution was officially proclaimed a disaster, his protege, Hua Guofeng was replaced by the reformists Zhao Ziyang and Hu Yaobang, as Premier and Party General Secretary, respectively.

Much economic and social good came of the reform policies as the arts and literature bloomed, as did the urban economy. Along with these improvements came a price of inflation, urban migration and prostitution. The country was divided among those who urged on the reforms and the elders who questioned the pace and goals of change.

Demonstrations were once again taken to the streets and government officials shifted positions again. Hu Yaobang resigned from his position, Zhao Ziyang became the General Secretary and Li Peng took on the position of Premier.

Price reforms which had been implemented were now under attack as the country suffered through an inflationary period. A political debate ensued in 1988-1989 as some felt the decision-making had to be re-centralized to protect the economy against Western economies.

The death of Hu and high inflationary pressures in 1989 were contributing factors in the Tiananmen Square protest. The massive movement by students, writers and urban dwellers called for an end of government controls against reform, corruption and for the defense of constitutionally-guaranteed freedoms.

Although the country was encouraging different areas of the economy and reforming in many ways, speaking out against the government was still strictly prohibited. The outcry of the protesting people was coupled with pleas to the government to end corrupt behaviour among the leaders and to uphold the defense of freedoms contained within Chinese Constitution. Martial law was declared and the army diffused the protesting masses using brutal force. Political re-education was required for many people within China, including some of the political leaders in order to stifle future opposition to the government. Although continuing at a slow pace at first, reform pressures continued to re-surge throughout China.

There is now a new generation of leaders in China that governs collectively, with President Jiang Zemin at the center. The government continues to battle along similar faction lines with the pace of reform being the contentious issue. This government has declared economic reforms, specifically reform of state industries and the opening of the Chinese economy to the outside world, as top priorities. The reforms and open-door policy are not new to the Chinese people as the economy has been developing in this direction since the inception of the Four Modernisations. The downsizing of government and privatisation of unprofitable state-owned enterprises encompass some of the strategies currently being put in place.

Along with the privatisation of state-owned enterprises follows the shattering of the ***iron rice bowl***. The iron rice bowl refers to a system where state enterprises guarantee lifetime employment and regular, non-performance related wage increases. This implies that the wages in the state-owned enterprises (SOEs) are artificially elevated and levels of employment are artificially high. When market-oriented firms dominate the market there are consequences to the labour market that will involve many cultural shocks to the labour market. Due to the fact that the SOEs were always the norm, the lifetime employment strategy completed the role of social assistance as well. SOEs supply benefit packages that include disability pensions, hospital service, schooling, food services, retail shops and even housing. In fact, housing is provided for 93 percent of all SOE workers (that is 51 percent of the total urban population).[6] Without a proper social safety net, the Chinese people will experience devastation and absolute poverty when inefficient state-owned enterprises are privatised.

2. The Economy

China's economy is of a dual-nature between agriculture and industry. The two sectors differ greatly in their organisation as agriculture became self-reliant and dependent on market incentives while industry continued to be based on state and collective ownership. This difference in ideological structure combined with the necessary urban-rural split defined by the nature of the two sectors, created an economic-cultural-societal gap which forms a dichotomy in Chinese society.

The major commodities that form the base of the economy are: grain, cotton, edible oils, meat, eggs, textiles, coal, steel, cement, fertilizer, chemical fibres, hydroelectric power, crude oil and natural gas.[7] Due to the limited interaction between differing regions, there is a large base of technology at diverse levels in use throughout the country. The organisational structure, economic activity and wealth of regions vary enormously. Even

[6] Broadman, Harry G. "Meeting the Challenge of Chinese Enterprise Reform," World Bank Discussion Paper No. 283, April 1995, p. 9; World Bank, The Chinese Economy: Fighting Inflation, Deepening Reforms, p. 20.

[7] "China: Country Background". Canadian International Development Agency. http://www.acdi-cida.gc.ca/cidaweb/webcountry.nsf/VLUDocEn/China-CountryBackground: May 25, 2000.

within individual cities, there can be found collectively owned farm or trade units that yield a subsistence level of wealth to members alongside state-owned factories.

This transitioning economy is experiencing growth, as described in the following section.

2.1 Gross Domestic Product and its Growth

From 1949 to 1957, China was recovering from the damage of war, during this time period; the average growth rate of total output (both industrial and agricultural) was 12.7% per year. The emphasis on the development of heavy industry from 1952 until 1957 caused it to grow an enormous 25.4% per year (indicating dips in the production of light industry and agriculture.)[8] During this same period, GDP increased threefold; per capita income was up by 80% and industry's share of the economy rose from 10% to 35%.[9]

After this period of high growth, the economy continued to grow at an impressive 7.9%, however it did so through intense short-term growth fluctuations. Intermittently, between the spurts of growth there existed large downward pressures and periods of great economic decline. The negative economic impacts of the Great Leap Forward and the Cultural Revolution were contributing factors to these negative pressures.

China was having particular difficulty in its growth, as it was isolated from the benefits of innovations from across the globe. From 1980 until 1997, there was a five-fold devaluation of the yuan. This devaluation, or moreover, set of devaluations, increased the volume of exports from the country.

In economic trade, when a country has a currency that has dropped in value in relation to other countries' currencies, exports increase. This is due to the fact that the goods from the country become relatively cheaper to purchase on an international scale.

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[8] "Humanity and Nature: A Review of Development and Environmental Degradation of Contemporary China". Xie, Jian. Professional Association for China's Environment(PACE). http://chinaenvironment.net/articles/xiejian2.html: October 19, 1999.

[9] "China: a world economic leader?". Foy, Colm and Angus Maddison. OECD Observer. http://www.oecd.org/publications/observer/215/e-foy.htm: No. 215 - January 1999.

However, the devaluation of the yuan was not the only factor that triggered an increase in China's trade.

New special economic zones were designed to attract new opportunities and foreign investment. These zones were set up in small coastal areas and enjoyed preferential treatment to international investors in many areas including taxation, fees, exit controls, and ownership. These zones were to foster relationships between China's economy and advanced technologies. These zones were not set up to enable trade, but to encourage investment and relationships with firms enjoying a higher degree of technology, research and development.

Between the devalued yuan and the creation of these special economic zones, the volume of trade increased by 13.5% a year in the 1980s and early 1990s. Within a global context, China's share of world trade increased to 3% (up from 0.8%) and after 1992, a significant current of foreign direct investment flooded the Chinese economy.[10]

During the period from 1978 to 1995 per capita incomes rose by 6% a year, which was far superior to the European Union or United States (averages of 1.5%), outranked the rates of all other Asian countries (excluding Korea) and was six times that of the World average. As of 1995, China's per capita GDP, in international dollars adjusted for PPP, was $2,653 which places it at half of the world average level. This is up from 1990 when the per capita GDP was at one quarter of the world level.[11]

In 1997, many Asian countries were devastated by economic crisis, however China survived the crisis with only a slowdown in economic growth. Currently, the Gross Domestic Product is in excess of $814.33 billion (1990) U.S. dollars.[12]

Looking at how China is planning to continue and bolster its strong growth, there are several possibilities to increase current production levels as well as to delve into new markets, however each scenario has coupled with it an increase in energy requirements. According to Gan Ziyu, Vice Minister of the State Planning Commission, the goal of the

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[10] Ibid.

[11] Ibid.

[12] "Key Energy Indicators in 1997". International Energy Agency. http://www.iea.org/stat.htm: October 27, 1999.

Chinese government to quadruple 1980's GDP by year 2000 will be obtained through the policy of doubling the country's coal production, the nation's largest energy source.[13]

2.2 Population Trends

China's current population is around 1.26 billion people, where only one-quarter of that number live within cities. There are about 56 ethnic groups and many different dialects represented within the country, the largest distinct group being the Han (92% of the total population.)[14]

China is the most populous country in the world, therefore even with a decreasing rate of population increase, the number of births in China dwarfs the numbers typically found in other countries. When China began on its path of economic growth, the standards of living increased significantly enough to induce a population increase. In an effort to curb the over population problem China was facing, the state implemented a family planning policy. The policy itself is arguably a crime against human rights in its enforcement, but this subject is far beyond the scope of this paper.

Since the policy of family planning was established in the 1970s, the birth rate has been on the decline. In 1994, the birth rate was 17.7 per thousand (down from 34.11 per thousand in 1969). Increases in the standard of living have increase longevity as well, however the population growth rate has also decreased since the birth rate reduction has been so great. It has dropped from 26.08 per thousand (1969) to 11.21 thousand as of 1994.[15]

These declines in population are imperative to the economic well-being of the country and will help curb the energy demands as well as the economic growth required in order to maintain the current standard of living in the country. In order to fuel the production required to sustain, and hopefully improve the lives of the Chinese people, the energy sector is key in that development.

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[13] "China's Reform". Steven Schlosstein. Financial Times, 28 February 1993.

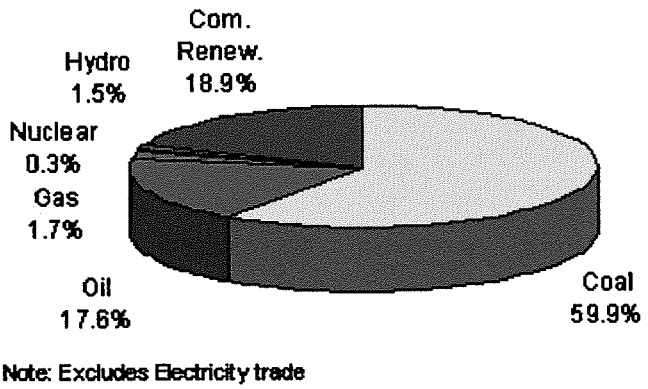
[14] "China: Country Background". Canadian International Development Agency. http://www.acdi-cida.gc.ca/cidaweb/webcountry.nsf/VLUDocEn/China-CountryBackground: May 25, 2000.

[15] "Population and Ethnic Groups". The Consulate-General of People's Republic of China in New York. http://www.nyconsulate.prchina.org/news/PopulationSituation.html.

2.3 The Energy Sector

Although globally there are other high energy consumers, China is distinct in its form of energy consumption. The Chinese economy relies on coal production to fuel its energy needs, in fact, 76 percent of its current commercial energy requirements are filled through the production of coal.[16]

Figure 1 - China's Energy Sources



Note: Excludes Electricity trade

Source: "Key Energy Indicators in 1997". International Energy Agency. http://www.iea.org/stat.htm: October 27, 1999.

Where TPES = Total Primary Energy Supply (indigenous production
+ imports
- exports
- international marine bunkers
+/- stock changes)

One reason for coal's large predominance over alternate energy sources is that rural enterprises must compete with urban ones in the access to energy. By increasing coal production, mines have eased the energy shortage that Chinese firms face. Rural enterprises use over 28% of China's total coal production.[17] The more isolated areas

[16] "Energy pricing for sustainable development in China". Clarke, Rosemary and L. Alan Winters. The Economics of Sustainable Development. Organization for Economic Cooperation and Development: 1994. Page 200.

[17] Fureng, Dong. Rural Reform, Nonfarm Development, and Rural Modernization in China. Economic Development Institute of the World Bank. Washington: 1988. Page 24.

have no access to other forms of energy, particularly, electricity. In fact, over one hundred million people still have no access to electricity in rural China.[18]

The Chinese power sector is now the second largest in the world. Currently, there is a rate of 15-16 gigawatts per year that is being added to the present capacity.[19] When the World Bank developed a baseline scenario to indicate a conservative estimate, they found that coal demand would roughly triple between 1991 and 2020. This tripling in demanded resources occurred even though they factored in declines in the energy intensity of the economy as well as strong, fast growth in the use of alternative sources of fuel.[20]

When looking at the production of coal across the nations, China is the world leader followed by the United States.

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[18] Shiwei, Shao, Lu Zhengyong, Nourreddine Berrah, Bernard Tenenbaum and Zhao Jianping. China : Power Sector Regulation in a Socialist Market Economy. World Bank Discussion Paper No. 361. World Bank, Washington: 1997. Page 2.

[19] Ibid. Page 11.

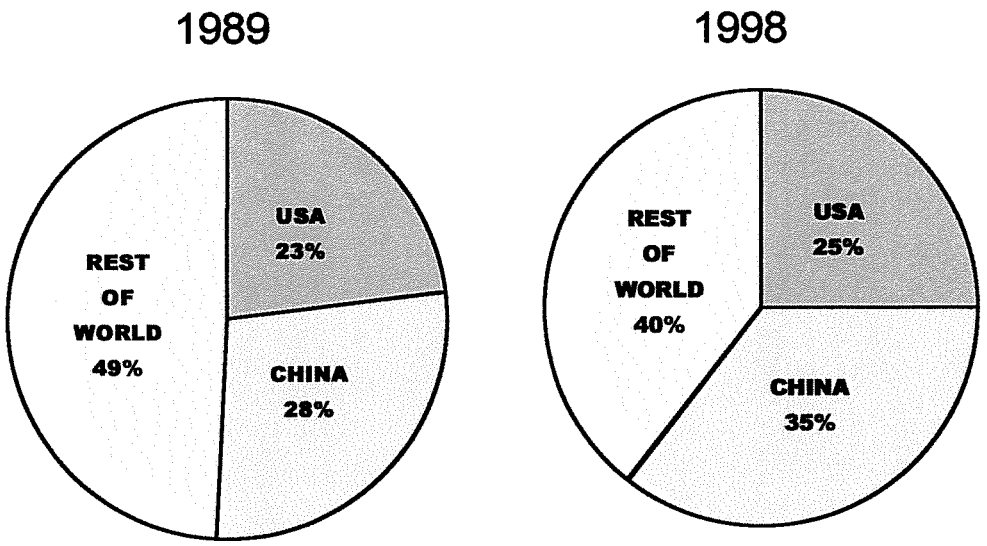
[20] Johnson, Todd M., Junfeng Li, Zhongxiao Jiang and Robert P. Taylor. China : Issues and Options in Greenhouse Gas Emissions Control. World Bank Discussion Paper No. 330. World Bank, Washington: 1996. Page 21.

Table 1. World Production & Trade of Hard Coal 1989-1998 (Mt)

Region/Country	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AMERICAS										
BRAZIL	6.5	6.5	4.1	4.6	4.5	4.5	5.5	5.4	5.4	5.4
CANADA	59.7	58.9	62.2	55.3	59	62.1	74.9	76	78.7	75.4
COLOMBIA	18.9	20.4	22.5	23.3	21.7	22	26.1	28.8	32.3	30.1
MEXICO	10	10	11.8	11.8	11.9	11.9	8.5	8.5	9.1	9.6
USA	809.2	855.8	825.2	823.2	774.2	825	858.1	884.2	904.5	920.8
OTHER LATIN AMERICA	3	5.2	5.7	5.8	5	6	6.6	6	6.3	2.7
TOTAL NORTH & LATIN AMERICA	907.3	956.8	931.5	924	876.3	931.5	979.7	1008.9	1036.3	1044
ASIA & OCEANIA										
AUSTRALIA	154.6	163	167.9	180	180	181.6	194.7	199.8	218	220
CHINA	972.9	998.4	980.4	1008.9	1047	1110	1292.3	1374.6	1387	1303.8
INDIA	184.5	184.9	188	202.2	238	248	266.9	283	300.3	298.5
INDONESIA	8.7	11.2	15.2	23	28.6	32	41.8	51	54.5	60
JAPAN	10.2	8.3	8.1	7.63	7.2	6.9	6.3	6.5	4.3	3.7
NEW ZEALAND	2.4	2.4	2.7	2.9	2.9	3.1	3.2	3.2	3.4	3.3
PAKISTAN	2.8	2.7	2.7	3	2.9	3.1	3.2	3.6	3.6	3.7
SOUTH KOREA	20.8	17.2	15	12	11.1	7.4	5.7	5.1	4.6	4.4
OTHER ASIA	53.7	50.9	48.3	49.2	60	50	35.3	36.6	37.5	35.7
TOTAL ASIA & AUSTRALIA	1410.6	1439	1428.3	1488.8	1577.5	1642.1	1849.4	1963.4	2013.2	1933.1
EASTERN EUROPE										
BULGARIA	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
CZECH REP/SLOVAKIA	25.1	22	19.5	20.7	23.9	19	16.5	17.6	16.5	16.4
EAST GERMANY	0	0	0	0	0	0	0	0	0	0
HUNGARY	2.2	1.7	1.7	1.5	1.5	1.5	0.8	1	1	0.9
POLAND	177.6	147.7	140.1	132	130.6	133.6	137.2	136.2	136	117.8
ROMANIA	8.3	4	4	4.1	4.2	4.3	4.9	5.3	4.3	3.3
USSR (CIS)	576.5	543.3	474.3	460	420.4	269	250.2	242	231.6	222.6
YUGOSLAVIA	0.3	0.3	0.3	0.2	0	0	0	0	0	0
TOTAL EASTERN EUROPE & CIS	790.2	719.1	640	618.6	580.8	527.6	409.8	402.4	389.7	361.3
MIDDLE EAST & AFRICA										
AFRICA	183.8	182.2	179.3	177.8	187.4	203.4	214	214.7	225.9	228.8
MIDDLE EAST	1.2	1.2	1.3	1.4	1.4	1.5	1.7	1.7	1.8	2
TURKEY	5.1	2.7	2.8	2.8	2.7	5	6	5.5	5.8	6
TOTAL MID EAST & AFRICA	190.1	186.1	183.4	182	191.5	209.9	221.7	221.9	233.5	236.8
WESTERN EUROPE										
AUSTRIA	0	0	0	0	0	0	0	0	0	0
BELGIUM	1.9	1	1.7	1.2	0	0	0	0	0	0
FRANCE	12.2	11.3	10.3	10.2	9	7.5	7	7.6	6.2	5.2
GERMANY	0	0	75.2	74.2	64.2	57	53.1	47.9	45.8	42
GREECE	0	0	0	0	0	0	0	0	0	0
ITALY	0	0	0	0	0	0.1	0	0	0	0
SPAIN	19.3	19.6	18.2	18.7	18.2	18	13.9	13.7	13.6	12.8
UK	99.9	91.8	95.7	85.1	67.5	48	52.6	50.5	48.8	41.5
WEST GERMANY	77.5	76.6	0	0	0	0	0	0	0	0
OTHER WESTERN EUROPE	0.9	0.8	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
TOTAL WESTERN EUROPE	211.7	201.1	201.7	190.3	159.5	131.1	127.1	120.2	114.9	102
WORLD										
TOTAL WORLD	3509.9	3502.1	3384.9	3403.7	3385.8	3442.2	3587.7	3716.8	3787.6	3677.2

Source: "World Production and Trade". Jonker, Barlow. coalportal.com: The Interactive World Of Coal. http://www.coalportal.com

Figure 2 – Comparison of United States and China World Coal Production Shares: 1989 and 1998



The above pie charts show an interesting trend in the coal demands of the world. Although it is arguable that coal is not the number one contributor to the environmental degradation currently being suffered by the world (this topic will be covered more in-depth by a future chapter) its use for energy production is one of the contributors. When looking at the comparison between China and the United States, the comparison is not astonishing as China's population is far greater, therefore its coal use per capita would actually be smaller than the U.S. However, when looking at the trend of China's coal use over only a decade, especially once we have seen how China's population rate has decreased over this same period, this is a warning for what rates of coal China may be burning in the near future.

Why should we be concerned with the use of coal as a source of energy? As previously mentioned, it has detrimental effects on the environment.

3. The Environment

The Chinese government is aware of environmental degradation and the effects on the country and its people. In fact, the Environmental Protection Law of the People's Republic of China (PRC) was introduced to legislation as early as 1979. Also, the

Chinese constitution guarantees that the country's people are to be protected from environmental pollution.[21]

Carbon emissions are largely due to the burning of carbon-based fossil fuels and there are many different sources of these emissions, including natural gas, oil and coal. According to the Intergovernmental Panel on Climate Change (IPCC), the ratio of carbon produced per energy unit is approximately 3:4:5 for natural gas:oil:coal. This ratio shows that coal is the least efficient form of energy for eliminating carbon emissions.

In 1992, China was responsible for creating more than 13.5% of the world's carbon emissions, although the economy of China is less than 3% of the world's total GDP.[22] There are many reasons that account for this apparent overproduction of environmentally degrading pollution, including the lack of money and technology to help clean existing production measures, government subsidies to coal producers, not to mention the gargantuan total population size (21.5% of total world). When looking at carbon emissions, the United States is the largest emitter in the world; however, judging by the trends and the rates of economic growth, China will overtake the United States as the largest contributor of carbon emissions as of 2015.[23]

The GDP is well served by the extensive coal opportunities found throughout the land, but environmental costs are taking their toll and a socially optimal energy strategy needs to be found in order to achieve sustainable development. In combination with the excess stock of coal and government subsidies, firms produce beyond normal capacity in order to fulfill government planned targets and quotas of production. The coal use, due to production targets, can be very high.

There are many ways in which the burning of coal effects the environment; these are examples of some of the more common aspects of coal burning that have huge detrimental effects.

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[21] Sinkule, Barbara J. and Leonard Ortolano. Implementing Environmental Policy in China. Praeger Publishers, Westport CT, USA. 1995. Page 4.

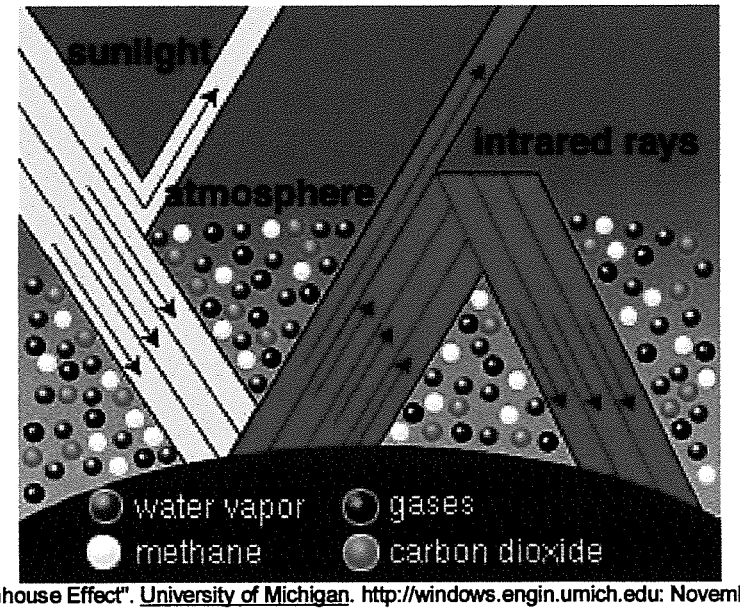
[22] "Is China Taking Actions to Limit Its Greenhouse Gas Emissions?". Weathervane: A Digital Forum on Global Climate Policy. http://www.weathervane.rff.org/features/feature047.html: September 15, 1998.

[23] "Country Energy Profile: China". United States Energy Information Administration. http://www.eia.doe.gov/emeu/cabs/china/part2.html: October, 1997.

First of all, coal burning emits pollutants into the atmosphere, which adversely effect the quality of the air. The excess pollutants in the air will visibly deteriorate air quality as well as cause adverse reactions in animal and human health including breathing difficulties. This can be disruptive to the quality of life in regions of high air pollution. Studies have linked high concentrations of particulates in the air with health risks, such as cancer.

Secondly, coal produces increased levels of carbon dioxide. High rates of economic growth accompanied by the economy's reliance on coal as the main source of energy imply that carbon dioxide emissions will continue to rise. The OECD projects that by 2050, China will be the largest emitter of carbon dioxide in the world, accounting for almost a third of all emissions.[24]

Figure 3 - The Greenhouse Effect



Source: "The Greenhouse Effect". University of Michigan. http://windows.engin.umich.edu: November 1999.

The Greenhouse effect occurs when molecules of water and carbon dioxide are charged with energy in the atmosphere. This makes the molecules reflective of energy and therefore when energy (from our sun) enters our atmosphere; it can get trapped, reflected back onto the earth's surface by these little high-energy molecules. The diagram, above, shows this effect.

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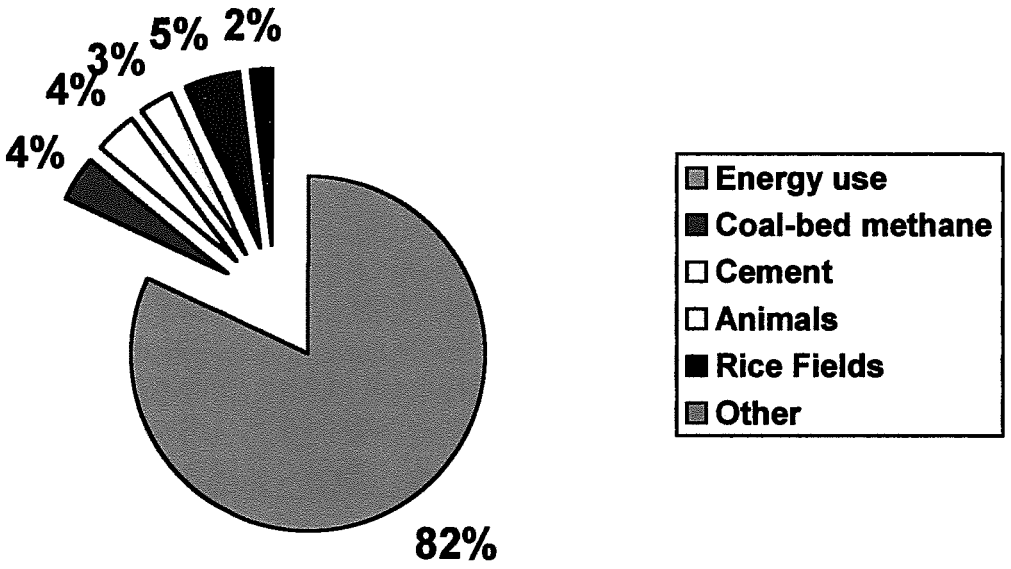
[24] "Energy pricing for sustainable development in China". Clarke, Rosemary and L. Alan Winters. The Economics of Sustainable Development. Organization for Economic Cooperation and Development: 1994. Page 200.

In the case of China, greenhouse gases are mainly produced in direct result from the energy sector. The country's breakdown of greenhouse gas production is depicted in the pie chart below, where an astounding 82% of greenhouse gas emission can be attributed to the energy sector.

Figure 4 - China: Greenhouse Gas Emission, 1990



Source: Johnson, Todd M., Junfeng Li, Zhongxiao Jiang and Robert P. Taylor. China: Issues and Options in Greenhouse Gas Emissions Control. World Bank Discussion Paper No. 330. World Bank, Washington: 1996. Page 13.

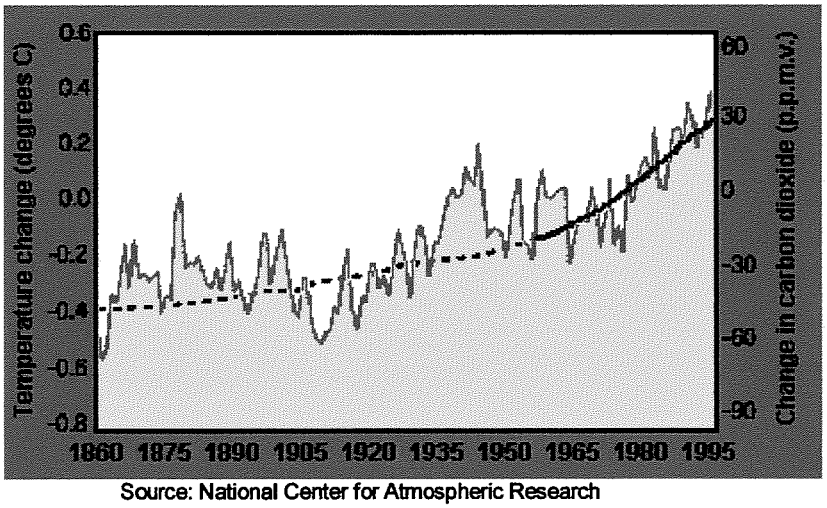
Although the percentage depicted in the graph above is very high, it is still to be kept in context, the energy sector is regularly attributed with the grand majority of carbon emissions and rates in the 80th percentile are not uncommon.

The reason the greenhouse effect is of great interest is this trapped energy causes climatic change. The years from 1987 to 1996 are the warmest ten years on record, and it has been well established that this is due to the increases in carbon dioxide concentrations that have been caused by human activities.[25]

[25]Trenberth, Kevin. The Greenhouse Effect. National Center for Atmospheric Research. Boulder, CO. Dec. 4, 1997.

The result of all of this is termed "global warming". Global warming is the gradual raising of the world's mean temperature. As shown in the figure below, the earth's temperatures have been on the rise for the past 137 years. The temperatures have been compiled from thousands of land and ocean observatories spread over a representative portion of the Earth and controlled for potential biases. The results show that global mean temperatures have risen by about 0.5 degrees Celsius over the past one hundred years. Interestingly, over half of the increase has occurred within the past 30 years.

Figure 5 - Estimated changes in annual global mean temperatures and carbon dioxide concentrations over the past 137 years relative to a 1961-90 base period.



Source: National Center for Atmospheric Research

The blue line represents parts per million carbon dioxide levels that have either been retrieved from ice core samples (dotted line) or air sample (solid line). The red line is temperature data.

Although the temperature increase only seems small, there have been detrimental effects already witnessed by this generation. The glaciers are melting and disappearing from many parts of the world including the Andes, the Himalayas, and New Guinea. This has caused the ocean to expand and the sea level to increase by about 15 cm over the past century.[26] This increase in water levels, is an increase in overall water on the planet and the effects of the increased water are immense. First of all, there are

[26] Ibid.

ecological imbalances, as low altitude land becomes more marsh-like. Also, floods are on the rise. In fact, in the United States and Canada, floods are becoming more common and atmospheric moisture content can be observed to have risen by about 10% over the past twenty years.[27]

To give some indication as to the seriousness of greenhouse gases and their effects on long-run ecological systems, estimates have been made to portray the temperature, carbon dioxide concentrations and water levels in the future. Carbon dioxide concentrations have been estimated to rise to 700 parts per million by the year 2100, this is an 483% increase over the 1996 level of 360 parts per million and 650% over the level experienced 200 years ago. The estimates of global mean temperatures are that of a 1.0 to 3.5 degree (Celsius) increase by the year 2100. The sea's estimated level is another increase by 15 to an immense 95 centimeters by that same date.[28]

As can be seen, greenhouse gases are a serious threat to the earth's delicate ecosystem balance and should be considered when burning large amounts of coal (or any fossil fuel.) When this is considered along with the extraordinarily large percentage of greenhouse gases being produced through energy use, accompanied by the dramatic increases in the amount of emissions as predicted by the forecasts, it is a potential environmental disaster of global proportions.

Yet another environmental concern associated with the burning of coal is that of acid rain. It has been discovered that air pollution from the burning of fossil fuels, including coal, is the major cause of acid rain. Acid rain is formed by emissions of sulfur dioxide and oxides of nitrogen in combination with water and oxygen and oxidants. Once these elements have mixed in clouds, they fall to the earth, commonly as rain.[29] It does not matter which country produces the offending mixture of gases as winds transport the acid rain cloud across national borders. In fact, Japan has lent China money in the form of development loans to help clean up pollutants as the acid rain is causing such damage on the side of the Japanese border.

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[27] Ibid.

[28] Ibid.

[29] "Acid Rain Program". United States, Environmental Protection Agency. http://www.epa.gov/acidrain: April 1999.

Acid rain damages trees and thus would indirectly cause more of the greenhouse effect (this is due to the fact that trees eliminate carbon dioxide from the atmosphere.) As for the actual acid rain itself, it is very detrimental to buildings and equipment; in fact, there are some regions in China where acid rain sets the pace for capital investment due to the rain's extreme acidity. The regions of Chongquing and Guiyang have rainwater acidity of pH 4.14 and pH 4.01 respectively. In fact these Southwestern regions have "...metal structures [that] have to be scraped clean of rust and repainted once every 1-3 years, and bus shells replace every 1-2 years."[30] If firms are making decisions based on maximizing profit and are not considering the pollutant externality production of acid rain, they are not taking all of their profit maximizing factors into considerations. Developing economies have very scarce resources and the amount of money it takes to replace buildings and equipment if ravaged by acid rain would be beyond their budget.

Acid rain also has a devastating effect on water-life. If a body of water's pH balance becomes too acidic, plant life and fish could all die.

These effects are certainly worth consideration when looking at the potential impact of development projects, specifically in a country where direct measures such as rain acidity show that these pollutants pose a serious, real threat within its own borders. The environment impacts should not be the sole determinant of which projects are to be implemented. There are other benefits and costs to be considered, as will be outlined in the following pages. There is also the context of environmental degradation to be considered in order to have a more complete understanding of global impacts and the severity of any particular country's pollutants. The major cause of global carbon emissions is not caused by developing countries, but by developed nations, harnessing the power of industrial production and transportation, such as automobiles. However, not being the worst offender is never a reason to ignore environmental impacts through irresponsible decision-making.

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[30] "Energy pricing for sustainable development in China". Clarke, Rosemary and L. Alan Winters. The Economics of Sustainable Development. Organization for Economic Cooperation and Development : 1994. Page 206.

4. The Project: The Three Gorges

It is certain that China will increase her energy demands as her GDP is rising and population increasing; therefore, the solutions lie with increasing the efficiency of energy use, minimizing damages caused by the current energy source, using alternative energy sources or a combination of all three options.

Many long-term benefits are associated with switching energy sources including environmental health, sustainable growth, reductions in long-run costs, efficiency gains and economies of scale. How can China achieve a switch to a cleaner source of energy? Left to China alone, the country could not possibly allocate the required resources to invoke environmental protection, international assistance is required. As stated by the World Bank:

> 1 percent of primary commercial energy supply in 2020 is equivalent to the baseload output of at least 16,000 megawatts(MW) of electric power plant capacity, requiring an investment in the range of US $15.0 - $30.0 billion. For renewable energy to make an appreciable contribution, it will require a development program of an internationally unprecedented size.[31]

The development programme this paper is scrutinizing is the Three Gorges Project. This project has received much international press due to the continuing controversy of its benefits and costs. As this project is unprecedented in its size and is being proposed by a country that is in crisis, many feel strongly, from both sides of the issue.

The project proposes to build a hydroelectric dam on China's Yangtze River and would be the world's largest hydroelectric project. The Yangtze River rushes into the East China Sea which makes the project have a huge potential as a source of hydroelectric power.

The Three Gorges Reservoir area covers the area from Jiangjin of Chongquing city to Yichange of Hubei. This west to east stretch encompasses 58,000 square kilometers, 29

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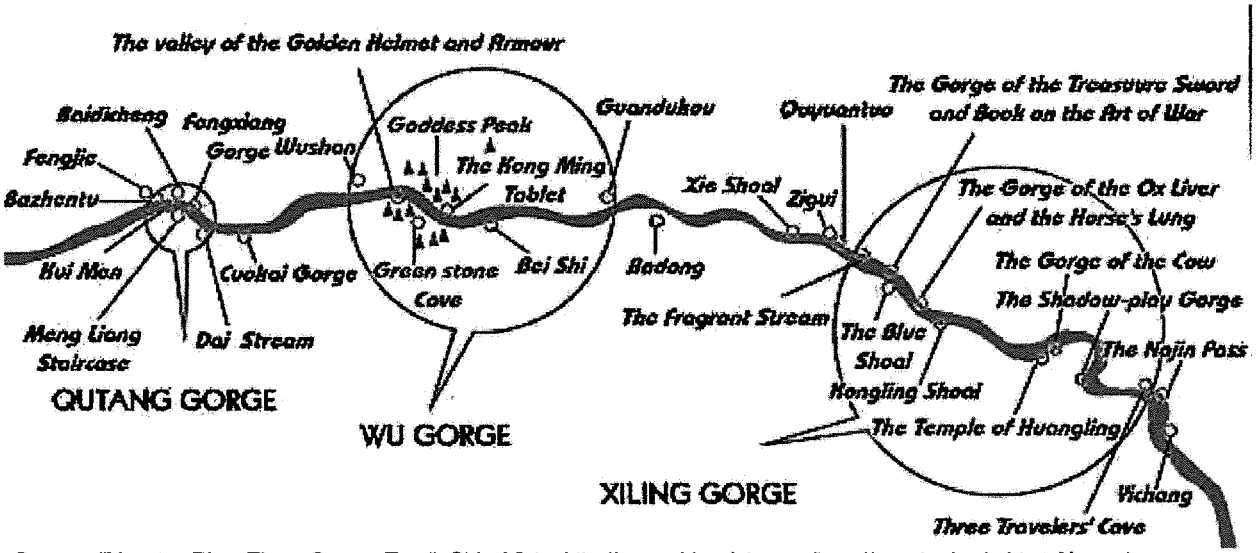
[31] Taylor, Robert P. and V. Susan Bogach. China : A Strategy for International Assistance to Accelerate Renewable Energy Development. World Bank Discussion Paper No. 388. World Bank, Washington: 1998. Page 17.

counties and cities and a population of close to 20 million, over three quarters of which were in agriculture.[32]

The river itself, at 5,989 km, is the third largest river in the world, the first and second largest rivers being the Amazon in South America and the Nile in Africa. The river has three gorges, the Qutang Gorge, Wuxia Gorge and Xiling Gorge, as shown in the diagram below:

Figure 6 – Diagram of the Yangtze River and the Three Gorges



Source: "Yangtze River Three Gorges Tour". ChinaVista. http://www.chinavista.com/travel/yangtze/main.html: November, 1997.

The project is not a light one it will take seventeen years to complete it from beginning to end, which have been divided into three stages. Stage one spans from 1993 until 1997, during such time the canal and facilities for continued work are developed; the river will be dammed off at the end of this stage.

Stage two covers the years from 1998 until 2003. The tasks to be complete are the construction of the several portions of the dam, the creation of a hydro-electrical power generator and a ship lock (for ship navigation). The project is due for completion during stage three, from 2004 until 2009.

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[32] "Three Gorges Bulletin". State Environmental Protection Administration of China. http://www.sepaeic.gov.cn/english/quality/3Gorges/index.htm: April, 2000.

In total, the estimates of the dam's total cost vary significantly. Officials originally stated the project was worth 90 billion yuan (10.8 billion U.S. dollars), in 1993 terms. It is now expected that the price of the dam will increase to 240 billion yuan ($28.9 billion U.S.) once interest and inflation have been factored in. Critics suggest the final cost is far greater, in the neighbourhood of 600 billion yuan ($72.3 billion U.S.)[33] The real cost is likely somewhere between these estimates.

4.1 Costs and Benefits of the Three Gorges Dam

The potential benefits of this project are fairly clear. The dam will harness affordable, clean power for China. This affordable, available energy source will help fuel the economic growth of the country and provide energy where it was previously not available. The hydropower station will be capable of an annual production of 84 billion kilowatts an hour[34].

Also, this alternative power source will produce no polluting gases or residue of any kind, a superior environmental choice to coal. The size of the proposed dam is so large that it will produce massive power and once constructed; therefore, it will require minimal input. From this perspective, the project's benefits allow for the decreased use of coal and thus increases in air quality, decreases in acid rain and in air particulates, lower greenhouse gas emissions and harness economies of scale.

River navigation can be an inexpensive, convenient way to transport goods and provide mobility to the population. This project has as goal to improve river navigation which will help fuel the economy and lower overall transportation costs.

Another hopeful benefit is that of flood control. This benefit comes with great debate. It is known that the Yangtze river has incurred many floods over the years, some of them disastrous and killing hundreds of thousands of people over the past century. In 1931, 145,000 people were killed in a Yangtze river flood; another 142,000 fell victim to the

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[33] "Three Gorges Dam". A whitepaper. http://208.2.111.5/special/damkey.php3: 1999.

[34] "Three Gorges Bulletin". State Environmental Protection Administration of China. http://www.sepaeic.gov.cn/english/quality/3Gorges/index.htm: April, 2000.

same fate, four years later.[35] The new, strong dam will help prevent future floods by solidly blocking off the river. There are some other factors to include in the consideration of flood control, however, as the press have reported increases in flooding across China. This is because the older dams are beginning to break. The new proposed dam will not hold the same water as the old ones and so there is a serious risk of major flooding if the money is spent on this one large dam, instead of the smaller ones.

The new body of water that will be created due to the dam will bring a new water supply to towns and cities. This will provide cheaper, clean water to the people. This will basically transfer some of the country's water supply from the South to the North.

However, as with all projects, there are also costs to consider and the potential costs with this project are considerable. First of all, there are economic costs to consider. As described above, there are considerable monetary costs associated with the construction of the dam. Estimates vary greatly, and many have increased as the project costs were underestimated and may continue to be underestimated.

The people of China that are currently living where the new waterlines will be must be displaced. The number that must relocate is not trivial; there are over a million people to be considered in this category.[36] The move is more than an inconvenience to the population. First of all, many villagers have chosen to take residence over fertile soil. Arable soil is not common across China's landscape and to have to move from it to a non-agrarian location will force a necessary change in life for the people. Farmers will no longer be able to support themselves as such when relocated to a city or a non-arable plot of land. The people of China have been offered compensation in order to help with their plight, however it is inadequate to cover the costs of the move, especially the costs that will be incurred to these farmers.

The element of cost which is not taken into consideration by this move is the sheer volume of farmers who will be resettled into urban settings. This change will not only be

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[35] "Three Gorges Dam". A whitepaper. http://208.2.111.5/special/damkey.php3: 1999.

[36] "Three Gorges Bulletin". State Environmental Protection Administration of China. http://www.sepaeic.gov.cn/english/quality/3Gorges/index.htm: April, 2000. Section 3.

an inconvenience or a setting change, but a complete change in lifestyle and in supporting oneself and one's family. To move farmers to these urban settings is not to change their location, but to change their entire existence as they have known it and as it has been known for generations within their family tree.

Also, it should not be forgotten that the people have significant family and historical ties to their land and to leave the ancient family tree and other important cultural artifacts behind is an atrocity to the people. On a more societal level, there are many artifacts that will be submerged by the waters caused by the dam construction, never to be recovered.

The quality of the water itself will deteriorate as the water will not be able to circulate and therefore its ability to restore oxygen in water and to purify itself will decrease. This is a serious pollution hazard that is potentially devastating to plant-life and water creatures. Animal species may be directly killed by the changes in the system, or they may have their reproductive systems or cycles altered and face extinction. The quantity of water, in the form of a flooding of a vast area will undoubtedly affect the agriculture surrounding the Three Gorges.

In addition to the previous discussion about flood control, there will be a potential increase in floods to due the deposition of silt. This change in the silt within the riverbeds will potentially cause farmland to be turned into swamp areas as well as an increased risk of flood.

There is also the local climate to consider. Although there will obviously be a reduction in the volume of carbon emissions in comparison with the alternative energy source of coal, there are other health and climate issues that should not be ignored. One such environmental change is an increase in precipitation and fog in the reservoir area. By building a new, large body of water, this will necessarily change the ecological balance of the area.

There is also considerable soil erosion that will occur due to the construction of the project. Large quantities of rock and dirt are excavated to build the dam, about 5.2

million cubic metres of earth and stone, and 5.4 million cubic metres of concrete will be used this year alone, which is a full million cubic metres more than in 1999.[37]

Another factor to be considered is that of the earthquakes that China faces. If regular patterns persist, within only a few years, China will experience hundreds of small earthquakes, some even fear that the enormous weight of the water could trigger one. This is also compounded by the fact that the dam is located close to seismic fault lines. The shaking caused by these natural disasters will necessarily bring on increased wear and tear on the dam and could cause extensive damage, including its collapse. The chances of a dam collapsing are not negligible; in fact, many dams have collapsed over the years and have shown to be incapable to control floods. The collapses of the Banqiao and Shimantan dams killed more than 230,000 people.[38]

Collapsing due to earthquake is not the only manner in which this dam could be brought down to unleash flood waters on homes, cities and surrounding land. The consequences of a terrorist attack would be disastrous. To fully appreciate the potential of a disaster, there are approximately 400 million people (that is one third of the country's total population), 40% of China's grain, 70% of its rice and 40% of its industrial output in the area of the Yangtze Valley.[39]

How do the costs compare to the benefits? Although we may find that the construction of the dam is of net benefit to the economy, as well as to the rest of the world, it is possible that the alternative, or set of alternative projects, has a greater net benefit. This makes the study of an alternate project or set of projects integral to any cost-benefit analysis.

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[37] "Three Gorges Project Construction Schedule for 2000". People's Daily Online. http://web2.peopledaily.com.cn/english/200001/20/eng20000120N105.html: January 20, 2000.

[38] "The Three Gorges Project". Liu, Qi, Bradley Lai and Ignacio Fernandez. San Francisco State University. http://userwww.sfsu.edu/~ignaciof/3gorges/presentation/presentation.html: May 5, 1999.

[39] "FIVAS Report: Power Conflicts". Hofsvang, Ellen. The Association for International Water and Forest Studies(FIVAS). http://solidaritetshuset.org/fivas/pub/power_c/k6.htm: January, 1996. Section 6.

5. An Alternate Project or Set of Projects

To decide on the alternatives, first a look at what needs the current project is fulfilling should be assessed. The main goals of the dam were to generate an affordable, clean source of energy for the country, provide flood control and provide a navigable waterway.

The energy sector currently has a high reliance on coal to fuel its energy needs. There could be a combination of energy sector projects and policies that could be put in place as a suitable alternative to the Three Gorges Dam. One initial step to finding a good long-run solution is to minimize overall costs would be to eliminate the market distortions, found in the form of government subsidies for coal production. By allowing the price of coal to drop below its marginal cost causes an inefficient over-use of the energy source. This implies that firms will use coal wastefully and maintain older forms of technology, as they are artificially competitive due to the subsidies.

Once the efficient level of coal production is determined, the process of its energy production can be made cleaner through the use of scrubbers. Cleaning existing technologies will curb environmental pollution and improve the overall quality of life for the planet.

To clean the coal technologies will be of lower cost (but maybe not have as many benefits) than eliminating the use of coal as an energy source. It is also likely that the use of coal needs to be reduced, not eliminated, for optimal energy production.

In order to fulfill the gap in the energy demanded versus the energy supplied through coal use, an alternate energy source needs to be harvested to fuel the economy. A dam was chosen to fulfill the flood control and provide navigable waters, so a comparable project would be a group of smaller dams.

It is impossible to define the exact modeling for how the economy would flourish under the different sets of projects, but different aspects can be hypothesized. We will refer to the options as **The Three Gorges Dam** and **Smaller Dams**.

The Three Gorges Dam

Coal production would still continue to be used as a source of energy but perhaps at a lower total level due to the new, abundant source of electricity. Electricity, a much cleaner source of fuel, would be abundant and likely fulfill all current energy requirements for the country, at least as much as any alternative project.

There would be a navigable waterway created but there is some doubt as to the long-run flood control potential of the project. As was described above, there is concern that the dam could collapse, as has happened to many Chinese dams in the past. The fact that this dam lies along a seismic fault line and is of such a size that it will change ecological and environmental balances only exacerbates the circumstances. Part of the problem with having such a large dam is that the level of catastrophe in the case of collapse is extremely high. If the dam should collapse, there would be many lives, homes, villages and industries lost to the flood waters.

Smaller Dams

Coal production would likely still continue under this model that contains several small dams. The rate of coal use would likely be lower than it would be with the Three Gorges Project as coal would be more expensive due to the removal of subsidies as well as due to the increased cost from the installation of scrubbers. Electricity would be abundant from the many smaller dams and could be incrementally added to the economy due to the nature of many small projects in lieu of one large one.

The small dams would create a navigable waterway, however it is unknown whether or not it would be superior to the one large dam. It will be assumed that either project could fulfil the water navigation needs for the country. Flood control would likely be higher with many small dams for several reasons. First of all, there would not be a large basin of water that could trigger an earthquake, nor would there be a large deposit of silt that would build up and cause flood waters. There is also that fact that smaller dams would be less likely to suffer a terrorist attack. Secondly, and perhaps most importantly, regardless of the chance of dam collapse, the destruction caused by a collapse would be astronomically higher with a dam as large as the Three Gorges in comparison with a regular dam. Understanding that there is a risk of collapse with any dam, this

catastrophic event should be considered regardless how many precautions are taken to avoid it.

Looking at the two descriptions, it seems that they could be comparable as different means to achieve a relatively similar end. Looking at the descriptions alone, we may form an opinion as to which method to follow to fulfil China's energy demands, however to have a more complete understanding, we can set the two models up for a cost-benefit analysis.

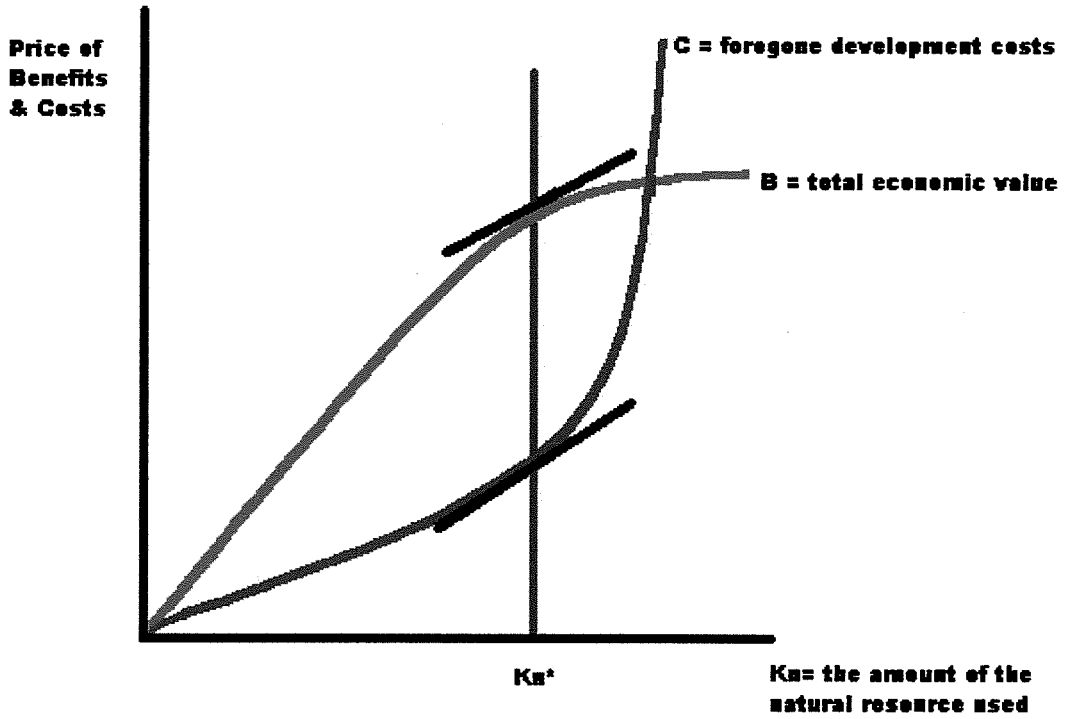
6. Cost-Benefit Analysis: A Synopsis

As it has been explained, pollution can not go unnoticed. Environmental and social concerns are an important part of development, for any country, regardless of income constraints. Therefore, especially if a country has tight income constraints, there needs to be a method to allow for choices among development strategies that will yield the most benefits possible with a least-cost strategy. There are many different ways in which the desirability of programmes can be determined. One such method is that of cost-benefit analysis.

A cost-benefit analysis is one where the perceived positive attributes of development are compared against the perceived negative ones. If the net present value, the difference between the discounting flows of benefits and discounting flows of costs is positive (i.e. $B\text{-}C \geq 0$) then it is beneficial for the development to occur.

A cost-benefit analysis is not a tool for the justification of massive environmental degradation, such as clearing tropical rainforests for agricultural purposes. When measuring costs and benefits, more than the GDP valuation of each possibility should be regarded, the economic and environmental benefits of conservation must be weighed against the economic and environmental costs of forgone development value.

Figure 7 - Cost-Benefit Analysis Curve



Source: D. Pearce

Looking at the options above it is clear that China has some decisions to make on her path to sustainable development. For the purpose of this paper, sustainable development will be defined to be where a system of desirable attributes such income per capita, the health of a population, education levels and resource levels within the economy are non-decreasing. If this occurs over the span of a period of time, it is a definition of weak sustainability and if it does so over every distinct time frame, it is strong sustainability.

The question must be asked: Is sustainable development in agreement with cost-benefit analysis? It appears that cost-benefit analysis implies there is a constant level of natural resource degradation that is optimal whereas in the definition used for sustainable development, above, it called for the non-decline in resource levels. These two goals appear to be contrary in approaches.

For many developing countries, this point is irrelevant as the point of environmental degradation is far to the right of the optimal point. This implies that the goal of equating marginal cost to marginal benefit will yield an identical result as deciding to maintain resources at non-declining levels. That result would be one of environmental and societal rights protection.

Unfortunately, there are some shortcomings that follow suit with a cost-benefit analysis as this type of study only covers the scope of economic efficiency and not the non-efficiency benefits of natural capital stocks. Distributional goals and future generation considerations fall under this non-covered category.

Another possible difficulty with this type of analysis is that costs and benefits can be too easily measured in terms of economic price and contribution to GDP. Efforts to put economic values on these non-marketed functions, and even to trace through otherwise disguised market functions of natural systems, demonstrate that the "true" rate of return to investment in K_N is significantly higher than concentration of market outputs would suggest.[40]

Cost-benefit analysis rules tend to ignore considerations of equity and can be regressive in nature. The poor end up paying proportionally more of their income due to this regressivity and the benefits are enjoyed by all as most environmental and social programmes are in the form of a public good, being non-exclusive and non-divisible.

These shortcomings impede the credibility of the cost-benefit analysis tool but there are several ways in which the analysis redeems its name. First of all, developing countries need to achieve the most benefit at the least cost since the financial resources at their disposal are so scarce. Knowing this is the case, a method of cost-benefit analysis is intuitively appealing. Also, with any case in resource economics, the scarcity of resources prevails in all decision making for choices in environmental and social programmes.

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[40] Pearce, David, Edward Barbier and Anil Markandya. Sustainable Development : Economics and Environment in the

Cost-benefit analysis provides a useful tool that can be used to measure which programme would benefit the environment to the greatest degree possible and allows for the government to efficiently allocate resources accordingly. Cost-benefit analysis attempts to reconcile the concepts of welfare economics with those of project appraisal terminology and valuations.

Also, cost-benefit analysis uses a criterion called the ***potential pareto superiority criterion***. This criterion asserts that a project is superior if the losers have the potential reimbursement from the winners and no one is worse off in the end.[41] Unfortunately, for programmes to have the potential to reimburse the losers and for this to actually occur is not always the same outcome.

If the analyst considers these potential problems, cost-benefit analysis can prove to be a very useful tool in quantifying these qualitative issues.

6.1 Different Methods of Cost-Benefit Analysis

In order to understand some of the difficulties associated with cost-benefit analysis, it is important to understand that there is no one method used by all analysts. A theoretical section in the paper covering a quick survey of some of the more accepted methodologies follows:

Net Present Value (NPV)

The first method to be reviewed is the generally accepted standard for cost-benefit analyses and is that of Net Present Value. The reason that this method is so desirable is that it has the ability to portray the potential benefits and costs of a project throughout the life of the project down to a single number. Unfortunately, there are difficulties encountered with this method that involve the determination of the discount rate.

Third World. Earthscan Publications Ltd., England: 1990. Pages 18-19.

[41] Sassone, Peter G. and William A. Schaffer. Cost-Benefit Analysis : A Handbook. Academic Press Inc. New York: 1978. Page 9.

The Net Present Value Equation is:

$$NPV = \frac{B_0-C_0}{(1+d)^0} + \frac{B_1-C_1}{(1+d)} + \frac{B_2-C_2}{(1+d)^2} + \ldots + \frac{B_t-C_t}{(1+d)^t} + \frac{B_n-C_n}{(1+d)^n}$$

where,

C_t is the dollar value of costs incurred at time t,

B_t is the dollar value of benefits incurred at time t,

d the discount rate, and

n the life of the project in years.

The number that this method yields as a result is that of the value of development in terms of what its worth would be in dollars (today) less the environmental, social and Gross Domestic Product costs. Unfortunately, the method is not as clear and simple as it seems. There are several difficulties associated with the accounting of the costs, specifically those that lack a generally agreed-upon price, but this matter is dealt with later in the paper. There is also a question as to what the discount rate should be, again, this topic due to the numerous calculations that can be used to derive the number, is reviewed in its own section.

Internal Rate of Return

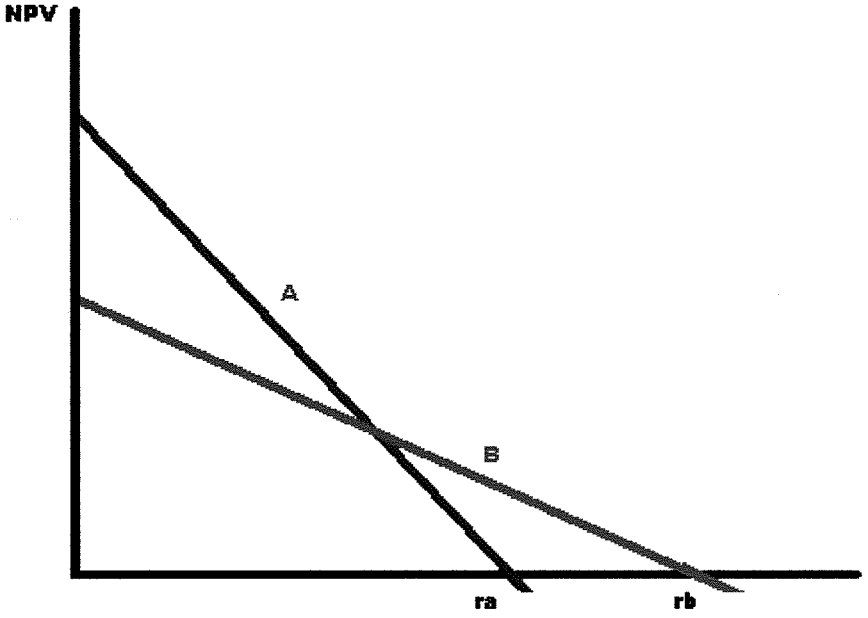
The Internal Rate of Return method of valuation, made popular by Keynes, is defined to be the rate of discounting that equates future benefits with the initial costs. Solving for this rate would of course, make the net present value of the project equal to zero.

The equation for the Internal Rate of Return Equation is:

$$C_0 = \frac{B_1-C_1}{(1+r)^1} + \ldots + \frac{B_t-C_t}{(1+r)^t} + \ldots + \frac{B_n-C_n}{(1+r)^n}$$

Although this method used to be the standard for cost-benefit measurements, there are some key problems with using the Internal Rate of Return (IRR) method. First of all, the IRR method does not necessarily yield a unique solution nor does the rate of social discount give a conclusion if it falls between the two solutions deemed appropriate by a cost-benefit analyst. Also, there are some discrepancies when results are compared from this method with the currently generally accepted Net Present Value (NPV) method. For example:

Figure 8 - Comparing IRR and NPV



Source: D. Pearce

Looking at the NPVs of both projects, it can be seen that project A would be preferred to project B (as it is a higher value) but using the IRR criterion, the analyst looks where NPV equals zero (where the values of the project cross the horizontal axis.) At this point, the analyst is looking at ra and rb. rb is greater than ra and thus project B would be the chosen one. These opposing results are due to the choice in rates used. As mentioned above, the paper dedicates a section to the analysis as to the decision of discount rates later in the paper.

Benefit-Cost Ratio

Historically, a very popular method is the Benefit-Cost Ratio. This method, normally uses discounted values of benefits and costs and follows the formula:

$$\frac{B}{C} = \sum_{T=0}^{n} \frac{B_t}{(1+d)^t} \Big/ \sum_{T=0}^{n} \frac{C_t}{(1+d)^t}.$$

Although this method has been very popular in the past, it possesses a flaw of great magnitude. The ratio of the benefits to the costs says nothing of the general size of

either. Therefore, smaller total benefits can be rated much higher than their larger counterparts. Although it is important to understand proportionately how much a proposed project will cost (i.e. what the derived social rate of return on the investment on the project will be.) To lose sight of the total benefit or cost is unrealistic, not only because total benefits of a much greater magnitude are more beneficial to the economy but total costs may exceed the budget of a developing economy. This is of particular importance to a developing country as it has very scarce resources, and therefore should never be overlooked.

Another difficulty lies in the definition of benefits and costs. If a positive outcome occurs is it necessarily a benefit or is it a reduction in future costs? The position in numerator versus denominator has a large impact on the results of the equation. This concern with the definition is not an issue when dealing with the standard difference between costs and benefits, as it is trivial to make the distinction between a cost reduction and an enhancement of benefits.

In a more positive light, this method is not completely useless with current knowledge of modern methodologies, such as the NPV. If a government wishes to implement several projects concurrently, a common desire among developing economies receiving aid for economic and environmental development, this method is preferred over others. This is because it has the ability to choose many smaller projects and yield a higher overall NPV of the benefits. This is because its point of focus is with the overall rate of return and not the individual totals.

6.2 Identification of Costs and Benefits

It is difficult to identify which costs and benefits should be included in an analysis. An example of this would be if a developing nation that has severe soil erosion due to the overexploitation of the soil through the use of heavy fertilizers to feed a large population. If swamps are drained in order to provide more fertile soils, the benefits of the new source of crop-producing land is weighed against the costs of the destruction of the swamp.

If the swamp was farther away from the village where the crops initially were, are transportation and commuting time periods taken into consideration with the costs? The

benefit that may also accrue from the programme is the employment of those who must drain the swamp. Should this be included in the analysis? These are all questions that require the analyst to make judgement calls regarding the usefulness of the project, and each decision has an impact on the results that will be obtained by the final analysis.

Another issue that creates difficulties in associating costs and benefits to a project is that not all elements associated with a given project have a price. Examples of this would be costs like pollution costs, deterioration in air quality, increased risk of human deaths and decreases in levels of education or health services. There can also be benefits that have this lacking of a specific generally accepted price, such as, the improvement in life expectancy rates of the population, improvements in the clarity of the drinking water and the redistribution of wealth, to name but a few.

The problem is that if these measures are not taken into consideration, the analysis will be incorrect in its measurements, however, it is impossible to accurately measure these effects as they lack an appropriate price.

This is a regular distortion of all cost-benefit analyses. The necessary inclusion of these non-price elements induces value judgements of normative economics into a traditionally positive field of accurate data and empirical analysis. One way to confront this obstacle is to create a set of prices associated with non-price elements. This is a practice known as shadow pricing.

6.3 Shadow Prices

Shadow prices may be assigned in several manners: the value of similar goods or services that have prices in the market; resulting prices assessed in surveys of the general public; shadow prices previously chosen in decisions by the government; or, many other types of precedent or equivalent-type values.

In essence, a shadow price is when an economist "consider[s] a general equilibrium model of the economy in which the national goal is embodied in an acceptable objective function... the shadow price of a given scarce economic resource represents the change

in value of the objective function, caused by a marginal change in the availability of that resource."[42]

The reasoning behind the need of shadow pricing is quite simple. In order for decisions to be made, there must be some value assigned to all elements that are valued in society, regardless of whether or not they have a market valuation. By assigning a dollar value to all elements of the project in consideration, it will be possible to measure the costs and benefits, even though there will be some judgement and bias included in the analysis.

Shadow prices are particularly useful in the valuation of a public good. In the case of China, one of the elements to the environmental analysis is the cost of the deterioration of the atmosphere. The atmosphere is a global public good, but there is no price associated to it. It needs to have a shadow price in order to be able to include it in a quantitative analysis. To evaluate the costs associated with the burning of coal, to not include the deterioration of the atmosphere would be to distort the model and give it a strong bias towards producing above optimal levels.

One common method of shadow pricing is to include the restoration costs of the damages done. By including the externality costs in the price of the element, no damage is created that can't be repaired. With this method of shadow pricing, future generations are protected from the current generation's activities.

Another method of shadow pricing is contingent valuation. The concept of this type of shadow pricing is equal to the society answering the question of how much they value a particular element. When looking at costs and benefits, there are many different aspects of the environmental resource to be considered. For example, there are both use and non-use benefits in the total economic value of resources.

The use benefits might include things such as its enjoyment by naturalists or the beneficial impact it exerts on air quality. A non-use benefit would include the mere

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[42] Munasinghe, M. Committee of International Development Institutions on the Environment (CIDIE). World Bank, Washington: 1993. Page 23.

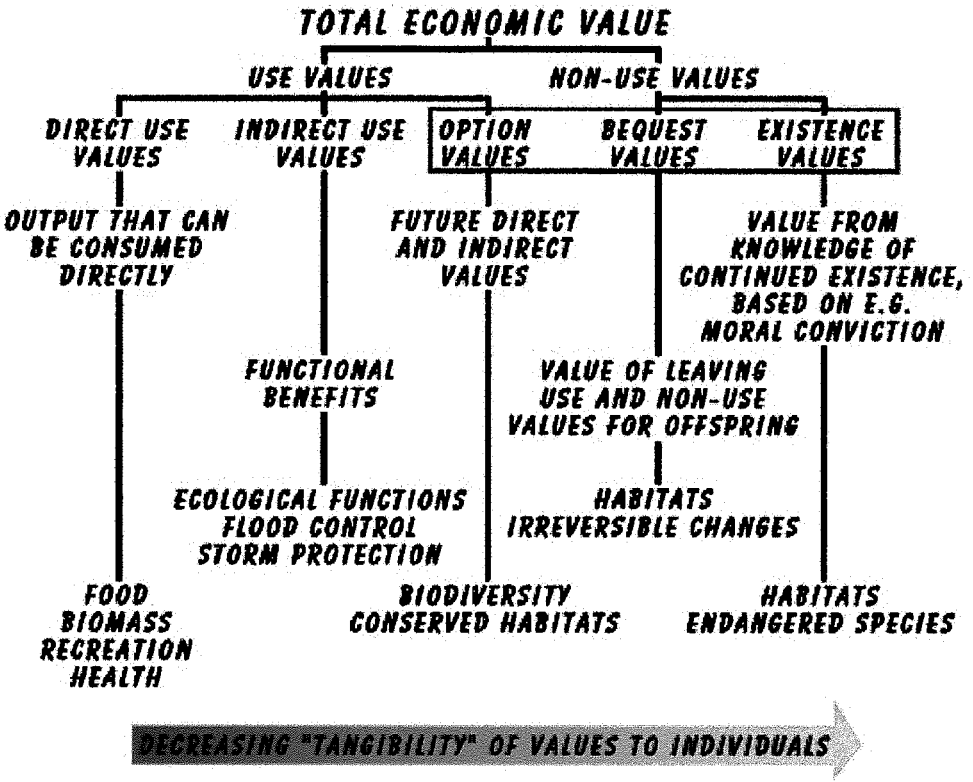
existence of the resource for peace of mind or the world's sake. It is the sum of both of these uses that acquire the total economic value of any resource in the world.

The element has use and non-use elements that can be subdivided to cover what the society would pay:

- to derive a benefit from the element (both directly and indirectly)
- to have the option to derive that benefit at a later date
- to be able to leave the element to future generations (their children)
- to have the piece of mind that the element exists.

This previous list can be visualized as in the chart below:

Figure 9 – Total Economic Value



Source: Munasinghe, M. Committee of International Development Institutions on the Environment (CIDIE). World Bank, Washington: 1993.

6.4 The Discount Rate

One of the more difficult tasks to maneuver when attempting a cost-benefit analysis is that of the determination of the discount rate. This rate can make even the most carefully thought out plan, complete with shadow prices and indirect costs and benefits, resemble the banal. Environmental projects occur over the course of several years and are not the product of a one-time, overnight process. Since there is an element of time involved with the projects, Net Present Value is used. As was viewed in section **6.1 Different Methods of Cost-Benefit Analysis**, when calculating present values, a discount factor is required.

The discount rate is the combination of a subjective rate of time preference in addition to the rate of productivity of capital. More formally, it can be described as "... [where] the rate at which individuals are willing to trade present for future values is just equivalent

[to] the margin to the rate at which they are able to transform present goods (in the form of foregone consumption), into future goods (through capital investment)".[43]

This implies that for developing countries, such as China, where there is a scarcity of capital, the discount rate will be inflated. However, high discount rates discriminate against future generations. It is arguable that in the case of developing countries, where rates are high, they should be lowered to reflect environmental, intergeneration equity and social concerns. Not all economists feel that this is a prudent course of action.

Norgaard argues that lowering rates has negative environmental consequences, as capital costs decrease and production costs decrease along with the discount rates and so consumption will be artificially elevated. The manipulation of discount rates yields inefficient use of capital. He suggests that instead of focusing on the discount rate, government planners should consider direct income transfers to compensate for environmental degradation. It is the concept of future generations being paid by the current generation for the right to pollute (similar to the shadow price where clean up costs are included). The constraint used in Norgaard's models is to not let tomorrow have less than today.

The discount rate is crucial in decision making as it will be the deciding factor of whether the Net Present Value of a project is greater than zero or not. Also, if several projects are being considered for implementation, the discount rate will determine the ranking of the decision. This is due to the fact that benefits need not be constant over time for projects to be successful and miscalculated discount rates produce biased results in favour of longer or shorter run projects.

There are several rationales behind discount rates. Firstly, there is the one of pure time preference. Individuals are impatient. There is a necessity to have a discount factor because there is an inter-temporal substitution that an individual will always prefer a dollar today than a dollar tomorrow. However, this argument of impatience is fairly weak when dealing with environmental issues as preferences of individuals may not be the best indicators as to what is best for the country in question.

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[43] Ibid. Page 35.

When uncertainty exists concerning a choice, the preference for that choice will diminish. In the case of inter-temporal choices, there is uncertainty regarding the existence of the individual in the future (death), the existence of the same preferences of that individual and the existence of the same cost and benefit structure from the potential project. Since all of these factors are unknown, there is an element of risk with the future dates of the project and so those dates will yield lower values to the individual as the risk becomes greater, in this case, in farther and farther time periods.

There are several reasons that there exists diminishing marginal utility of consumption. The first has been mentioned and that is the time preference or impatience factor of the individual. The second factor involves the speed at which the utility from consumption falls as consumption grows. This is described well by Pearce, Barbier and Markandya as they described "... the reason for this is that the more one has in the future, the less one is willing to sacrifice today to obtain even more in the future."[44]

This is especially interesting when looking at the case of developing countries. It has been shown the per capita consumption has been on the decline and therefore there should be a decrease in the rate of discount. Also, the rates typically used in project appraisal are typically in the range of 10-15 percent.[45]

The opportunity cost of capital is a useful notion when explaining the typically high rates of discount that are used as capital tends to be scarce in developing countries and would have a high opportunity cost. The discount would be the rate of return of the project that could not be implemented due to the use of the capital in the chosen project.

There are, of course, critiques of all of these elements of discounting, but when looking at all of the arguments, it is still preferable to use a discount rate when tabulating present value. There is also another concern, specific to environmental matters, and that is the discounting of natural resources.

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[44] Pearce, David, Edward Barbier and Anil Markandya. Sustainable Development : Economics and Environment in the Third World. Earthscan Publications Ltd., England: 1990. Page 30.

[45] Ibid. Page 31.

Having a discount rate that is too high would induce the overexploitation and subsequent depletion of natural resource stocks. It can be ascertained that when natural resources are involved, either renewable or non-renewable, that an element of sustainability should be included when solving for the rate of discount. Several factors should also be considered when solving for a discount rate. These factors include environmental risk, irreversibility of decision-making and future generation concerns.

There are many more factors that can be involved in the determination of a discount rate; they can encompass many different economic and social factors. For every factor that is considered, the discount rate may become more accurate, but if the effect of these rates in incorrectly estimated, the number chosen may become increasingly arbitrary.

6.5 Problems with Applying Quantitative Analysis to Qualitative Issues

Once the discount rate has been decided upon, the model is then set up. As was shown in section **6.1 Different Methods of Cost-Benefit Analysis**, there are many different ways to set up the model. No matter how the policy setter chooses to set up the model, there is a quantifying of the environmental, social and economic situation that is necessary.

As was shown in the previous sections, it is very difficult to put environmental and social concerns in terms of numbers. Knowing what to include (indirect effects) and how to include non-price elements through shadow pricing or other means is not a simple task.

Many biases get introduced into the model, all of which are due to the perceived value of the issues by the individual setting the quantitative values to the qualitative elements. This is the downfall of cost-benefit analysis.

In order to get a sensible answer, the different aspects of the model should be quantified with distinct reasoning prior to any of the experimentation. By placing different quantities into the equation, any result could be attained; therefore, the analyst is at a severe risk for inadvertently biasing his or her own results by their prejudices. By modeling the state

of the world and discovering values for each element individually, these risks can be minimized.

Once the different elements have been estimated, they are positioned in the model and the most efficient project or group of projects yielding the greatest benefits at a least cost is then chosen.

6.6 How This Type of Analysis Can Be Useful

After stating how many biases the analysis could entail along with the difficulties of conducting a quantitative model to qualitative issues, why would anyone choose to embark on this type of analysis?

In countries that are trying to achieve a better standard of living (that would notably be all countries) and to do so at a least cost solution, a quantitative analysis is necessary. There are an infinite number of ways that an economy can develop, the question remains with which path to take. Cost-benefit analysis allows planners to measure the different paths against one another, without such a tool it would be nearly impossible to look at two different plans and state which one would yield the highest benefit at a least cost when there are so many non-priced goods involved. It is very complex and there can be many similar options, yet a tool that lends itself to black and white results is a very powerful tool when environmental and social issues are usually surrounded in an infinite sea of gray.

Understanding the concepts of what needs to be measured, applying a consistent ordinal ranking of importance to non-priced goods and using several models while testing would help any analyst.

7. The Evaluation of the Three Gorges Dam versus Smaller Dams

Using cost-benefit analysis to choose whether or not to implement these projects is not an easy task. First of all, the different benefits and costs for each project need to be established. As the scope of this paper is not to actually complete the cost-benefit analysis but rather to set up the constraints and the main issues surrounding it, the main benefits and costs of the projects as described earlier in the paper, will be employed as

the complete model. All methodologies used focused around the net benefits of a project, regardless of the type of analysis used, if net benefits are negative (costs outweigh benefits), the project should not be implemented. If net benefits are positive, the project may be implemented, depending on how much greater and budgetary constraints.

The following listing is in reference to section **4.1 Costs and Benefits of the Three Gorges Dam** as well as section **5 An Alternate Project or Set of Projects**. The **net benefits** would yield a function that resembles the following for the Three Gorges Dam:

Hydroelectric power
Plus: country's economic growth bolstered by project and newly available energy source
Plus: reduction in carbon emissions
Plus: reduction in the concentration of particulates in the air
Plus: potential flood control
Plus: navigable waterways (and associated growth due to lower transportation costs)
Less: costs of construction
Less: displacement costs** (economic moving costs as well as happiness of population)
Less: cultural loss** (national treasures all buried forever)
Less: arable land loss
Less: flora and fauna loss
Less: potential collapse (cost of dam reconstruction plus lost lives, homes, cities, etc...)

A set of small dams would likely have many of the same types of benefits (but perhaps in different quantities) and would likely not have much of the cost, other than the actual costs of construction.

Once the benefits and costs have been established, then a method for quantifying them for the analysis needs to be prepared. Standard economic values or shadow prices can determine the necessary quantifying values for the analysis. Having the required valued elements, we must choose a discount rate as well as a methodology, or set of methodologies, for our cost-benefit analysis. All of these important factors would be combined to build a proper model.

Part of the difficulty with assessing this project in particular is that both chosen projects involve very large shadow prices that will influence the final results of the analysis. The shadow price for the cost of relocation alone could make the Three Gorges Dam project unfeasible. This is interesting as we have complete control over the results by subjectively deciding on those values. If a bias or a pre-determination of the solution has been made, the costs of relocation (or any other cost that has a shadow price) may be portrayed as minimal or could be over-emphasized. The quantitative model needs to be carefully designed to avoid this kind of data mining.

Another concern that influences a proper analysis is the methodology of cost-benefit analysis. The methodology chosen could have an impact on which project will appear as the most beneficial at least cost to the economy. The two projects have one very large difference that makes their comparison a difficult one. The Three Gorges Project is a long term solution to China's energy crisis, the construction of many small dams can span from short term solution to long term solution and could solve China's energy crisis must faster with minimal upset to the country.

If we were to choose the method of Internal Rate of Return, the discount rate alone could be the factor deciding which project should be implemented. The discount rate would also effect the other methodologies as it is an important element in itself.

This difference between long-run and short-run time horizons in conjunction with the extraordinarily large proportion of the shadow-priced elements makes this a very difficult analysis to undertake.

Above we looked at the elements contained within a simplified version of the net benefits for the Three Gorges Dam. In order to compare the two projects, we take the net benefits of the dam and compare them with the net benefits of building the smaller dams. In fact, our equation will reflect the choice to not build the smaller dams as an opportunity cost of building the Three Gorges. Therefore, we subtract the net benefits of the small dam construction from the Three Gorges Dam net benefit equation. If the final result is positive, the analysis recommends the construction of the large dam over the combination of smaller ones.

The final equation resembles the following:

Hydroelectric power generated by the Three Gorges Dam

Plus: country's economic growth bolstered by the Three Gorges Project and energy

Plus: reduction in carbon emissions due to the Three Gorges

Plus: reduction in the concentration of particulates in the air due to the Three Gorges

Plus: potential flood control from the Three Gorges

Plus: navigable waterways (and associated growth due to lower transportation costs) created by the Three Gorges

Less: costs of the Three Gorges Dam construction

Less: displacement costs (economic moving costs as well as happiness of population)

Less: cultural loss

Less: arable land loss

Less: flora and fauna loss

Less: potential collapse of the Three Gorges (cost of dam reconstruction plus lost lives, homes, cities, etc...)

Less:

(

Hydroelectric power generated from the smaller dams

Plus: country's growth bolstered by the construction and energy from small dams

Plus: reduction in carbon emissions due to small dams and scrubbers

Plus: r□□eduction in the conc. of particulates in the air due to small dams and scrubbers

Plus: potential flood control from small dams

Plus: navigable waterways (and associated growth due to lower transportation costs) due to the small dams

Less: costs of small dam construction

Less: potential small dam collapse (cost of dam reconstruction plus lost lives, homes, cities, etc...)

)

The elements that are mainly costs due to the Three Gorges are not included in the net benefits of the construction of small dams. Further manipulation of the elements in the equation yields:

(Hydroelectric power generated by the Three Gorges Dam – Hydroelectric power generated by the small dams)
+ (country's economic growth bolstered by the Three Gorges Project – country's growth bolstered by the construction of small dams)
+ (reduction in carbon emissions due to the Three Gorges - reduction in carbon emissions due to small dams and scrubbers)
+ (reduction in the concentration of particulates in the air due to the Three Gorges - reduction in the conc. of particulates in the air due to small dams and scrubbers)
+ (potential flood control from the Three Gorges - potential flood control from small dams)
+ (navigable waterways created by the Three Gorges – navigable waterways due to the small dams)
- (costs of the Three Gorges Dam construction – costs of small dam construction)
- (displacement costs (economic moving costs as well as happiness of population))
- (cultural loss)
- (arable land loss)
- (flora and fauna loss)
- (potential collapse of the Three Gorges - potential small dam collapse)

Going through the process of shadow pricing each of these items goes far beyond the scope of this paper; however, we can postulate which element may be positive or negative depending on assumptions and previous descriptions. The initial state of the two projects is that they generate identical amounts of hydroelectric power. The other elements will be determined based on this assumption of output. This yields the following values:

Plus: Hydroelectric power generated (assumed to be zero difference)
Plus: Country's economic growth (unknown, but likely close to zero)
Plus: Reduction in carbon emissions (likely negative, as described above with decreased use of coal and the employ of scrubbers)
Plus: Reduction in the concentration of particulates in the air (likely negative, as described above with decreased use of coal and the employ of scrubbers)
Plus: Potential flood control (likely negative, as the Three Gorges would have increased silt deposit, a large reservoir of water to sustain, lies along a seismic fault line, is more of a target for terrorist attack and would require many small dam floods to reconcile costs)
Plus: Navigable waterways (assumed to be zero difference, as previously stated)
Less: Costs of construction (unknown, dependent on quantity of small dams required)
Less: Displacement costs (positive)
Less: Cultural loss (positive)
Less: Arable land loss (positive)
Less: Flora and fauna loss (positive)
Less: Loss incurred due to potential dam collapse (positive)

What the above function shows us is that the costs of construction will determine which project is the more beneficial. If the construction costs are positive (meaning that the cost of the Three Gorges is greater than the cost of building the smaller dams), then it would be beneficial to build the smaller dams in lieu of the Three Gorges. If there is minimal or no difference between the two costs, it would still be most beneficial to build the smaller dams.

In fact, the only way a result to build the Three Gorges Dam would occur involves the cost of building the smaller dams being **much** larger than that of building the Three Gorges. To define "much larger", the construction cost of the smaller dams would have to be greater than the cost of the Three Gorges plus the costs associated with displacement, cultural loss, arable land loss, loss of flora and fauna and the costs of a potential dam collapse. These are astronomical in size and likely dwarf the construction costs of the smaller dams.

There are many elements left out of the analysis such as maintenance costs, costs of reconstruction, tourism revenues, etc... but it was decided to streamline the model to the

costs and benefits that were deemed largest in order to keep the equation as simple as possible. The inclusion of all elements could yield a different result, but due to the magnitude of the elements used, it is unlikely that they could reverse the decision found by the analysis.

Conclusions

China has a pollution problem stemming from its energy production. The great majority of its energy is derived from a non-clean burning source, coal, and there are many environmental repercussions for this. A few of the problems associated with the burning of coal involve deterioration in human health due to poor air quality, acid rain and the greenhouse effect. Although China may not be a huge offender by today's standards when looking at the population of the country, forecasts show that she will overtake the world's leader in pollution levels and will continue to increase exponentially. This is especially concerning since China's rate of population growth is decreasing over this same time period.

Pollution, global warming due to greenhouse gases and acid rain are all evolving in the same direction due to human interactions and this is causing the effects to accumulate over time. Without intervention, the results are clear, the pollution will eventually reach high enough levels to be of serious harm to the Earth and all of its inhabitants. Agriculture, fisheries, water resources, animals, humans, in fact, all elements to ecosystems will find themselves in unpredictable situations.

Without changing the current levels of development, the Earth is on a path of self-destruction. In order to develop economies and produce energy or whatever other required resource for an economy, it must be done with the consideration for tomorrow.

In addition to the environmental concerns of the globe, there are also the social considerations of the rights of China's people. To develop without considering the standard of living, happiness or past of a people is socially unjust and would not be tolerated in Western societies. These important factors must also be considered when conducting a proper analysis.

Knowing that there are these environmental and social externalities with the production of energy, analysts have devised a way to measure the effects of different strategies to help combat the negative environmental impacts. This strategy is cost-benefit analysis. A few of the many different methodologies of cost-benefit analysis were outlined in the paper to show how they can differ.

Prior to conducting a cost-benefit analysis, a quantifying of the model is required. The difficulties associated with attaching numerical values to qualitative issues were summarized. Pricing non-priced goods, deciding which effects to include of the non-direct effects, and choosing a discount rate are all problematic issues.

Economists can not only depend on cost-benefit analysis to determine the worth of development programmes since numbers do not portray the complete picture. Intuition and economic theory along with political and social analysis should be included in the multi-disciplinary matter. Once the economist looks at the qualitative aspects of the programme as well as the qualitative ones that do not translate well, the analysis becomes much more robust.

If there are no completely right or wrong ways in which to perform cost-benefit analysis and decide which programmes to implement, why should anyone bother? Is the environment really that important to developing countries?

Clearly, addressing these questions involves much more than scientific judgments, these are moral questions that involve values as well as considerations for future generations. Pollution lasts a long time and will surpass the lifetimes of those that produce it. Excess carbon dioxide will survive in the atmosphere for hundreds of years and the oceans take centuries to change their levels, implying that the effects of today's pollution have not fully been realized by the Earth, yet. Social ramifications such as the health of a nation, happiness of its inhabitants and the honouring of cultural traditions are all to be considered. These elements are comprised in our daily lives and if they are destroyed in the name of development, we must question for what we are developing.

It has been stated that China, through her four modernisations, has promised to build on economic principles and not base large projects on politics. Is this truly the case for the Three Gorges Dam?

What did this quick analysis portray of the projects? It is likely that the Three Gorges project is not the most beneficial way for China to achieve her goals of hydroelectric power generation, flood control and navigable waterways. The only way this project could have been considered beneficial over other alternatives was if the cost of building a set of smaller dams that generated the same quantity of hydroelectric power would be greater than the combination of the following costs: construction of the Three Gorges Dam, displacement, cultural loss, arable land loss, loss of flora and fauna and the costs of a potential dam collapse. A highly unlikely scenario.

The building of the Three Gorges Dam would involve a huge volume of individuals being displaced from their homes and ways of life. It involves the burying of national treasures and historical artifacts so that they are never recoverable again. There is the potential destruction of firms, homes and entire cities due to flood disasters. More importantly, the dam will cause the loss of life, both plant and animal and it could result in a death toll that will be the largest due to a human-made disaster, ever. ***Due to these facts alone, it is asserted that regardless of the economic costs of development, the social and environmental costs are too high to contemplate its construction as an efficient economic choice.***

Why would the project then be supported by the government? There are many possibilities as to why the development of the Three Gorges is currently underway, even at a large cost to the people of China. As we saw in the historical snapshot, the government does not have a good track record of listening to the popular outcry. As was shown by the experience at Tiananmen Square, the government will silence the people at all costs and does not accept criticism. Once the project was announced, it would be very unlikely for it to be terminated.

China's history of the Great Leap Forward and the Cultural Revolution shows that she has little patience for small steps. There is also the prestige in building the largest dam ever created. China has a history of large projects, such as the Great Wall of China, that

draw awe and attention from the rest of the globe. There could be multiple political, ideological or even competitive reasons in favour of the Three Gorges Dam, but not economic ones.

It is possible that in the coming years the Three Gorges Dam will be considered an economic and social catastrophe, costing millions more in construction costs, a climate of unhappiness among the people and bury priceless historical artifacts forever. However, even if this is the case, it will likely take a dam collapse, which would constitute the largest man-made catastrophe ever, for the Chinese government to publicly acknowledge the development project a mistake.

Appendix A – Map of China

Source: Map ©1999 NGS Cartographic Division. Developed in association with GeoSystems Global Corp.

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