Measuring Sustainable Development in China: A "Green" Measure of Net National Product

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To: my daughter, Linlin

Abstract

China, currently one of the world's most booming economies, has achieved great success in its economic growth since the start of economic reforms in the late 1970s. However, little attention has been paid to its environmental problems. Constrained by limited natural resources, China's losses in the environment could offset its economic growth despite the apparently relatively high growth rate.

This research project discusses the theoretical foundations for deriving the "green" Net National Product (gNNP). Empirically it applies the net price approach, the total rent approach and the user cost approach in order to examine how environmental degradation affects sustainable development. The contents of measuring gNNP consist of the following studies:

1. The thesis illustrates the economic reforms and growth in China and points out environmental degradation and natural resource depletion problems there. The procedure for data collection is presented.

2. The research focuses mainly on assessing resource rents in deriving gNNP. The economic valuation of environmental depreciation and degradation in the national accounts is investigated and modelled. And the theoretical exploration relationship between gNNP and economic growth is addressed. A brief overview of models of gNNP is presented with special evaluation of the Hartwick rent. The research sets up the theoretical framework for the thesis by extending and applying the net price approach, the total rent approach and the user cost approach.

3. Assessment of environmental degradation in China. The situation of deforestation is reviewed, and the economic loss resulting from deforestation in China is measured. By using the net price approach and the user cost approach, economic loss from deforestation in China is derived in forest accounts.

4. Measuring energy resource depletion: coal and oil. The status of China's coal and oil situation is discussed. Pricing constraints and subsidies on coal and oil are illustrated. Adjustments to GNP are shown by deriving gNNP by applying the net price approach, the total rent approach and the user cost approach.

5. Major factors leading to air pollution. The status of Air Pollution in China and present pollution control are discussed. Health damage from small particulate matter is derived and economic loss in terms of GNP is computed.

6. Overall evaluation of environmental degradation in China. The overall economic loss from forestry, coal, oil and air pollution is evaluated by adjusting GNP to gNNP. Several aspects of the causes of environmental degradation are studied: population, pricing policies and property rights. Policies and ways to sustainable development are considered.

Finally the thesis summarises the research as a whole and highlights a framework for future research.

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Special Note

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Chapter 1

Introduction

1.1 Purpose of the Thesis

China, currently one of the most booming economies in the world, has achieved great success in its economic growth since it started economic reforms in the late 1970s. However, little attention has been paid to its environmental problems. Under a constraint of limited natural resources, one argument of this thesis is that China's loss in environment could partly offset the benefits of economic growth even if the apparent growth rate is relatively high. Moreover, for the next generation the situation may be even worse if no immediate action is taken to solve the environmental problems. The most serious issues are air, water and land pollution; depletion and degradation of natural forests, grassland and wetland; loss of natural vegetation; soil erosion and desertification. The immediate causes of environmental degradation and natural resource depletion are attributable to industrial pollution, excessive exploitation of natural resources, lack of proper property rights (Pearce and Turner 1990, Bromley 1989), high growth of population (Pearce 1991, Qu and Li 1992, Pearce and Warford 1993) and weak implementation and enforcement of environmental laws and regulations (Smil 1991, Qu and Li 1992, Edmonds 1994, Florig *et al* 1995). The severe consequences of environmental degradation are manifested as serious health damage and other damages due to air, water and land pollution, shortage of water, declines in agricultural yield, frequent drought and flood and loss of ecological balance. A degraded environment can only provide ecological services and natural resources in relatively short and declining supply and in a poor qualitative state. Preservation of ecological functions is therefore essential and urgent for China because it provides a necessary base for the existence of 1.2 billion human beings.

There are some studies on environmental degradation in China (Smil 1983, 1991, Ross 1990

World Bank 1991, Ren and Bao 1992, Qu and Li 1992 and Edmonde 1994). These studies focus on the general description of environmental and natural resource problems. However, little effort has been made in valuation of economic depreciation of the environment and natural resources.

This study estimates the economic value of environmental and natural resource degradation in a national accounting framework. In particular, it focuses on the adjustment of GNP by deriving depreciation for four sectors: forestry, coal, oil, and air pollution. It theoretically reviews and explores different models in 'green' national accounting and it initiates the application of three approaches in valuation of depreciation: the net price approach, the total rent approach and the user cost approach. It also measures the sustainability of the Chinese economy by estimating a 'net saving' level: ie seeing the extent to which actual investment exceeds the sum of all depreciation increases. The reasons for undertaking this study are:

1) since few economic analyses have been come out in this field in China, the research casts light on our understanding of economic development and its impact on the future generations of China;

2) the research is a pioneering work in environmental economics in China. There are few such excercises in existence on China. Economic valuation work is firstly used to assess the extent of environmental degradation and will help to set up a correct valuation in national account and in investment in China;

3) to identify policy implications for maintaining environmental amenity and ecological diversity while having economic growth. The study provides first insights to examine how environmental degradation affects sustainable development and the long-term prospects of economic growth in China in national accounts.

1.2 Background

1.2.1 Economic Reforms in China

China was a centrally planned economy from 1949-1978. The growth rate of Chinese economy was unstable during the period of 1949-1978 due to the some political events. In 1979 China started its economic reforms. With the decentralisation of decision-making, opening policy to the world market and rationalisation of the pricing system, China's economy has grown very fast, at an average annual rate of about 9 percent since 1979. The early 1990s have seen double digit growth, peaking at 13.4 percent in 1993 (*The Statistical Yearbook of China 1993, 1994*). Economic development has substantially raised living standards for the average Chinese, especially in urban areas. Since the economic reforms were launched in 1979, China has lifted several hundred million people out of poverty (The World Bank 1988). The main achievements of the economic reforms have been in the following areas:

1. According to the official statistics (*The Statistical Yearbook of China 1993*) agricultural reform is remarkable and has solved the food problem for most of the rural areas. From 1979 to 1992 the amount of grains increased from 33.2 million tonnes to 44.3 million tonnes. Especially in the early 1980s, the transfer from rigid collective farming to household responsibility farming provided farmers with greater incentives. Farmers then have more freedom in deciding on planting, harvesting and marketing crops than they did previously.

2. Industrial enterprises now have greater authority to determine the size, quantity, type, composition, marketing and pricing of outputs, to decide on the recruitment of employees, to retain profits and other earnings and to make use of these profits.

3. Administrative decentralisation has transferred more of the authority in planning and managing economic activity away from central government and onto provincial and local governments, which are better informed about the local situation and strongly motivated to

promote development. Central control over the economy has been scaled down by reducing the number of commodities and the volume of production subject to mandatory plan targets, and the share of key products distributed through state controlled channels.

4. The government has permitted other forms of ownership, private, cooperative, joint venture and foreign direct investment, etc and supported these with the necessary regulations and constitutional commitments. Resources previously annexed by the state have now been transferred to enterprises and rural producers and this, together with a degree of fiscal decentralisation, has given local authorities more discretion in taxation and expenditures. Product markets have been created, first in rural areas and then extended to urban areas, which allows producers to trade their above plan output at freely determined prices.

5. Financial and banking system reforms have separated the function of the central bank from the commercial and special banks, broken down the old monobanking system and increased the variety of financial institutions, as well as the volume and scope of financial transactions and instruments. The pronounced shift away from budgetary appropriation of investment to repayable loans has reinforced the importance of the financial sector in mobilising and allocating funds (Xie 1995)

6. Foreign trade, now equivalent to over a quarter of GNP (*The Statistical Yearbook of China 1993*), has opened up the economy greatly and there has been greater readiness to seek direct foreign investment in a range of manufacturing and service industries. The creation of economic zones with infrastructure and other facilities has helped to attract a large volume of domestic and foreign capital.

However, there have also been some problems along with the economic reforms. Agricultural reform has produced a dilemma. Growth in the net income of farmers has not kept pace with the increase of production inputs and farmers sometimes cannot get cash payment when they sell products to the government (Harrold and Lall 1993). The farmers normally get so called the 'payment note' instead of real cash. While most state-owned industrial enterprises suffer financial losses, the fundamental issue, property rights or ownership, seems very critical at the point which the government does not intend to change. Income distribution, social justice and social security accompanied by the reforms become crucial problems which need to be solved urgently. Like most fast-growing countries, corruption and rent seeking issue is also significant in China. Above all, the deterioration of the environment and depletion of natural resources are one of the most striking problems since the economic reforms.

1.2.2 The Environmental Situation in China

As Hardin (1968) mentions in his famous paper "The Tragedy of the Commons", population growth would cause environmental problems in the context of open access resources. While China's economy is growing very fast, little attention has been paid to its environmental problems. During the last forty years China has had a centrally planned economy, but at the same time its economy is that of a developing country. During 1949-1979, as a central planned economy, the development process emphasised the output of heavy industries, agricultural yields and manufacturing. Irrationality, waste and inefficiency inherent in these endeavours worsened the country's existing environmental situation, often in immeasurable ways. After 1979, a decentralised and reformed economy paid more attention to economic growth than to sustainable development. As a developing country, with only 10% of its territory covered by arable land, China has to use its limited natural resource base to provide food, housing and clothing for 1.2 billion people and also to meet their energy needs. Therefore, the degradation of land, destruction of natural habitats, air, land and water pollution have become serious issues in China.

China is a continent in itself, and many environmental problems span provincial borders within China. This applies to pollution of rivers and waterways as well as acid rain, a growing regional environmental threat that also causes major concern in countries like Japan. Because of its huge population, coal-based energy structure and rapid economic growth, China is also rapidly becoming a major actor in regional and global environmental issues. China contributes 50 percent of the developing countries' share of emissions of greenhouse gases and ozone-depleting substances, and emissions are set to increase substantially over the coming decades (World Bank 1991). Accordingly, in terms of global environmental problems, the fate of China is the fate of the world.

It is becoming increasingly evident, however, that the rapid economic growth puts severe pressures on the environment. This is happening in spite of an environmental policy infrastructure that is far more advanced than in most developing countries. Notable features of China's environmental problems are the following:

1. Air pollution. Coal is the main energy resource in China. The burning of untreated coal causes air pollution problems. The level of sulphur dioxide (SO_2) and total suspended particulates (TSP) are far beyond the ambient air quality regulated by the National Environmental Protection Agency of China, causing respiratory diseases and other environmental damage. According to the studies (Wang and Zhao 1988, Wang *et al* 1989, Ye 1989, Xu *et al* 1991, Xu *et al* 1994, Florig *et al* 1995), current air pollution patterns in China take a huge toll on the human and natural environment, having an impact on human health, forests, agricultural yields, water quality, visibility and buildings. The country has also become the world's third-largest producer of greenhouse gases (World Bank 1991) and is gaining rapidly on the leaders, the United States and Russia.

2. Water. Water shortage is a problem both for the present and future in China. Rapid growth of population, industrialisation and costless use of water for agricultural irrigation have all contributed to the water shortage. Furthermore, with limited water resources, water has been seriously polluted. The situation is mentioned by the World Bank (1991) which states that "thirteen out of 15 sections of the 7 major rivers that flow past cities are seriously polluted". Discharge levels into water and rivers are alarmingly high. According to studies (World Bank 1991, Edmonds 1994) more than 80 percent of rivers running through cities are seriously

polluted, often well beyond WHO health and safety standards. The World Bank (1991) also observed that only very few rural areas have access to safe drinking water. Water shortage due to excessive groundwater withdrawals further adds to China's water quality problems, forcing the government to invest in huge and highly expensive new water channels.

3. Land. Thousands of tonnes of untreated solid waste, much of it toxic, are scattered on the fringes of cities, along roadsides, on unused land and in ponds, swamps and rivers (World Bank 1991, Edmonds 1994). Solid and hazardous waste pollutes and the land, surface water and underlying aquifers. This has constituted an increasing threat to the already vulnerable ground water table. There is no secure landfill or treatment site for any hazardous industrial waste. Hazardous waste makes living dangerous for millions of people, and was the cause of many serious accidents in 1994 alone (Fridtjof Nansen Institute 1995).

4. Deforestation, loss of biodiversity and soil erosion. The reduction of natural forest and the destruction of grasslands has led to loss of biodiveristy, soil erosion and change of climate, which have also resulted in natural disasters, such as flooding and drought in the country. Soil erosion is becoming more and more serious, increasing the pressure on China's already limited resource base. If present trends continue, China will lose many natural ecosystems within the next few decades. The World Bank (1991) states that "if present trends continue, within the next few decades China will lose almost all wildlands outside its nature reserves---a loss that will be irreversible". Not only will valuable plants and animals be lost, but also many of the various ecosystem 'services', such as the regulation of water discharge and the absorption and breakdown of pollutants, will disappear with them. The diverse gene pool crucial to maintaining or increasing agricultural productivity will be lost or severely diminished.

The quick economic growth that spirals ahead seemingly unaffected by environmental pressures and structural inefficiencies, forms the core of China's current environmental challenge. Growth strategies are vigorously pursued at almost any environmental cost. Town and village enterprises (TVEs) are a crucial driving force in the growth process, but are partly beyond effective pollution control. Even efforts to cool down an overheated economy have a negative environmental impact, with the credit squeeze halting long-awaited environmental investments. Concern for the environment is increasing, but the growing number of environmental organisations and officials still face a tough struggle against a government whose commitment to rapid economic growth seems to outweigh any other concerns.

Constrained by limited natural resources, the economic value of China's loss with respect to the environment could offset its economic growth, even if the growth rate is relatively high. Moreover, for the next generation the situation may be even worse, if no immediate action is taken towards solving environmental problems. When a country degrades its entire ecosystem, the loss is immeasurable.

IUCN (1980) and IUCN-UNEP-WWF (1990) in the World Conservation Strategy both express concern about the irreversible damage that human beings are doing to the biosphere. Many analyses suggest that if human damage continues at recent rates, economic welfare will also be undermined. In China, it is obvious that human beings have a great impact on the environment. It is thus necessary to evaluate environmental damage and natural resource depletion in China. The assessment and analyses on deriving 'green' net national product would reveal the negative impact of environmental degradation to China's sustainable development.

1.3 Data Collection and Adjustment

1.3.1 Data Collection

Since this research is pioneering for China, we met with great difficulties in data collection. Most of the data used in the research were acquired by the field work. Although some of them are the official statistics, it is difficult to get these statistics in public libraries. In order to get these statistics, we visited many institutions repeatedly, used every channel to establish connections with people from these institutions, collected information on how and where we could get these data and spent some costs in obtaining the data. Thus, the field work was divided into four parts: 1) visiting institutions and departments concerned to get some official statistics; 2) visiting some places to get non-statistical data; 3) visiting libraries and information centres to get more references; 4) visiting various publishers and professional book stores to get published statistics.

In the total 6 months data collection period[1], we visited two largest forests in China: Daxinganling forest and Changbaishan forest. We visited City Jinan of Shandong Province for data collection of air pollution. We also visited various government departments for data collection work. The departments we visited were: the Information Centre of the State Statistical Bureau, the Information Institute of the Ministry of Coal Industry, the Information Institute of the Ministry of Oil and Natural Gas Industry, the Information institute of the Ministry of Forestry, the Forest Economic Research Centre, the Beijing Price Bureau, the University of Forestry, the Academy of Oil and Natural Gas Industry, the Mineral Information Centre of the Ministry of Geology, Beijing University, the Environment and Economic Policy Centre of the National Environmental Protection Agency, the Academy of Environmental Sciences, the Beijing Environmental Research Institute, the Natural Resources Survey Committee of the Academy of China and Beijing Library. The local places we visited were: Heilongjiang Province, including Harbin city, Jiagedaqi, Shibazhan and Songling[2] Jinlin Province: Changchun, Longjing, Yanji, Jinlin[3], Jinan City and Beijing Municipality. The data collection was explained as follows:

1) For forestry, field trips were made to the two largest forests in China. They are located in the remote area of the northeast part of China. It was very hard to reach these forests and we had to overcome many difficulties in getting transportation facilities and

[1]The first period of data collection was during June-September 1994 and the second time was during April-May 1995.

[2]The last three places are located within Daxinganling forest.

[3]The last three places are located within Changbaishan forest.

finding accommodations. We worked very hard under very poor living conditions.

2) Most of the data of coal and oil are from the official statistics, but it is very difficult to get these statistics publicly. We repeatedly visited some departments concerned, tried to establish connections with the people of these departments. The institutions we visited are: the Information Centre of the State Statistical Bureau, the Information Institute of the Ministry of Coal Industry, the Information Institute of the Ministry of Oil and Natural Gas Industry, the Beijing Price Bureau, the Mineral Information Centre of the Ministry of Geology. We also went to libraries and publishers for more references.

3) For air pollution, we specially visited a northern industrial city - Jinan, capital of Shandong Province. There we visited many power stations, industrial factories, restaurants[4] and related institutions, such as Jinan Environmental Protection Bureau. From the visit we understood that most of the emissions of air pollutants are from coal combustion. We also obtained data on air quality standards and the investment. We also visited people from the National Environmental Protection Agency to obtain more comprehensive statistics on air pollution control and ambient air quality standard.

4) For the general data, we obtained from some information institutes and libraries, especially Beijing Library.

1.3.2 Data Adjustments

The official statistics are the basic data used in the research. The use of official statistics as well as those collected from field research raises the question of reliability. It is well known that official statistics are not always reliable in any country, but there is a further problem in the

[4]Most restaurants in China use coal for cooking.

hitherto mainly planned economies. Essentially, output data tend to reflect the planned targets rather than the actual out come. Failure to meet planned targets could result in repercussions for the industry in question. There are three reasons why the official Chinese Statistics have been used. First, as China has liberalised its trade and has sought inward investment from foreign companies and aid from bilateral and multilateral sources, it has been forced to produce more reliable data. Second, planned economies often have in place far better data gathering mechanisms than exist in market economies, simply because the achievement of planned targets has to be monitored at some point, even if the published data do not always reflect those monitored statistics. Allied with the first explanation for improved reliability, this second factor suggests more rather than less accurate collection of data. Third, anyone working on the Chinese economy has in any event to use the official data. No other data exist and rejecting the use of official data is to reject the very idea of carrying out research on China. No one, for example, can 'create' data on coal output for an economy as large as that of China.

It remains the case that some of the data may not be reliable. Where possible, and with the limited means at our disposal, we have tried to make data sets compatible, and in other cases have tried to check published data with field data. Large quantities of data have been collected through field visits, meetings, inquiries to local people, checking up historical data and acquiring data from the departments concerned. However, since there is no systematic data processing mechanism, we spent a great deal of time on data processing and adjustment. The data we acquired are adjusted as follows:

1) Forest resource. The most difficult data to obtain are the unit costs of production. In order to get the unit costs and unit prices, we visited Changbashan Forest and Daxinganling Forest. In our over three months visit, we obtained the most important data, unit cost and price, through our field work to the forests by checking up 10-15 years accounting books from the local management authorities. But these data were in current prices and mixed with other items; we calculated the unit cost by adding wages, machine operating cost, transport and maintenance together. We also adjusted forest

areas, volume, and timber production and consumption by converting them from local measuring units to the international measuring units.

2) Coal and Oil. The most difficult task was to obtain the prices, especially the planned prices. For this we had to have the second time data collection work. Although there are some official statistics, these statistics were not easy to be obtained. By using all the connections and all the ways of getting data, we eventually got some data on unit costs and unit prices of both coal and oil. Because the data came from various sources, They still need to be adjusted in our research. We adjusted all the prices of coal and oil to international level in order to reflect the correct opportunity cost. We also deflated the current prices to get the real value of the prices. We adjusted costs by choosing an average cost level of production for coal and oil.

3) Air pollution. We specially visited some industries, power stations and restaurants in Jinan City for data collection on air pollution. Lack of a series of statistical data is the most difficult problem. According to the statistics from the National Environmental Protection Agency of China (NEPA), China started its environmental statistics in 1981 and the latest statistics was 1990. Thus, we have to use interpolation and extrapolation methods to derive the figures earlier than 1982. The concentration level is difficult to choose. We chose the level from Xu *et al* (1994) since the figures are published internationally.

1.4 Outline of the Research

There is a considerable literature on the valuation of national accounts, including sets of country studies (Repetto *et al* 1989, Solozano *et al* 1991, van Tongeren *et al* 1991, Bartelmus *et al* 1992, Bryant and Cook 1992, Adger 1993 and Young and de Motta 1995). However, there are few studies on national accounts in China to date. Thus it is necessary to carry out a valuation of national accounts in order to see the impact of the degradation of environment and depletion of natural resources on the national income.

Chapter 2 deals with the theoretical model on deriving environmental and natural resources adjusted national accounts. The evolution of developing national accounts is reviewed. The contribution and limitation of the Hartwick rule on deriving 'green' net national accounts are discussed and assessed. The theoretical foundation of the proposed three approaches is presented in this chapter.

Chapter 3 begins with a discussion of the forest situation in China. The decline of the natural forests is discussed and the timber crisis is identified. Chapter 4 handles the valuation of forest adjusted national accounts. Two approaches are applied in deriving forest accounts: the net price approach and the user cost approach. The calculated results show that the forest sector in China is unsustainable.

Chapter 5 reviews the coal situation in China. Coal reserves, production, the pricing problem and subsidies are discussed here. The second part concerns the calculation of coal adjusted forest accounts. Three methods are used in deriving coal-adjusted national accounts: the net price approach, the total rent approach and the user cost approach. It is found that the net price approach is quite erratic in coal accounting. The total rent and the user cost approach by comparison are fairly reliable.

Chapter 6 addresses the oil situation in China. Oil is the second main energy resource in China and accounts for less than 20 percent of energy consumption. Oil production also receives subsidies from the government because the price is set lower than the production costs. Three approaches are used in oil accounting. The oil adjusted accounts show that the industry is not in sustainable development because the net investment is negative.

Chapter 7 estimates energy subsidies in China. Heavy financial subsidies are given to the coal and crude oil sectors due to the low planned prices set by the government, which are below the production cost.

Chapter 8 discusses the air pollution problem in China. Air pollution in terms of total suspended particulate (TSP) and sulphate dioxide (SO_2) is quite high in China. The health damage of air pollution in terms of mortality and morbidity from emissions of TSP and SO_2 is calculated by using the dose-response function. The study finds that SO_2 causes health damage while health damage from emissions of TSP is obvious. A methodology is established to subtract the overlapping part of TSP and SO^2.

Chapter 9 deals with the overall evaluation of environmental damage in the net national accounts in terms of forests, coal, oil and air pollution. The 'green' net national product is derived and the overall environmental damage of the four sectors is shown to be very high compared with GNP by using the total rent approach and the user cost approach. The negative net investment indicates that the development in China was unsustainable from 1976 to 1992. The causes of environmental degradation are analyzed and a framework towards improving the environmental situation is discussed.

Chapter 10 concludes the thesis. A summary is given, and the contribution of this work, as well as proposed research for the future, is discussed.

Chapter 2

Green NNP and Sustainable Development

2.1 Introduction

2.1.1 Flaws in the System of Estimating Present GNP

Since the UN System of National Accounts (SNA) was developed in the late 1940s, it has become a universal approach to using national accounts in the assessment of the economic performance and social welfare of an economy. The present SNA endeavour to measure and summarise transactions for all economic activities of a given year, including income and expenditure from households, various sectors, governments, and other groups. GNP is usually used to measure the "income" of an economy while the rate of change of GNP over time is used to measure economic growth, which is one indicator of how successful the economy has been in increasing welfare. GNP is used inappropriately as an indicator of welfare without consideration of its shortcomings for that purpose. In arriving at a measure of economic performance or net output of all these transactions, the accounts aggregate the final sales made mainly by enterprises to other groups, particularly to households and governments for their consumption, and to enterprises themselves for capital formation. However, although existing accounts do generally estimate the depreciation on man-made capital, such that GNP is equal to NNP plus this depreciation, they fail to account for the depletion of national resources and environmental damage. That is, although all the depreciation of man-made capital are counted in the present SNA, the depreciation of natural resources are not taken into account. This depletion, in fact, endangers sustainable economic development and GNP measures become "deficient in respect of their treatment of environment" (Pearce 1993).

The present method of measuring economic growth is questionable when environmental degradation is a consequence of the prevailing pattern of production growth. Therefore, it has been suggested for more than 20 years that national accounting should be changed in terms of key figures that are the building blocks of macro-economic decision making (Denison 1971, Moss 1973). With the growth of various environmental and natural resource problems, the necessity for amending the national accounts to integrate environmental factors into GNP has been widely discussed. "Green" national accounting has come into practice recently to evaluate the sustainability of the economy. The objective of this practice is to measure and predict more precisely the performance of an economy to ensure sustainable development in the long-term.

Basically, there are three main shortcomings of the present national accounting framework:

1. Environmental assets and natural resources are not included as physical assets in the national accounts and the concept of capital maintenance applies only to man-made assets.

2. The change in the value of stocks of environmental resources, i.e. the depreciation of these resources, is not included in the national accounts.

3. It pays limited attention to the contribution of the environment to economic activity and it fails to take into account the impact of economic activity on the environment.

It is apparent that deficiencies in the SNA stem from the lack of treatment of natural capital in the SNA framework. The existing SNA framework does not recognize natural resources as economic assets. Protective services provided by these assets are not valued. But additional expenditures forced on society by the loss of these services are valued. So there is an asymmetry in the way that the value of natural resources are measured. There are various proposals to modify the SNA to take some account of environment (Ahmad et al 1989, Daly 1989, Harrison 1989, Hueting 1989, El Serafy 1989, Hartwick 1990, Dasgupta 1994, Lutz 1993).

This chapter discusses the overall framework for deriving 'green' net national product (gNNP);

uses of Hartwick's model (1990) to arrive at gNNP; and explores ways of applying some approaches in an empirical study.

2.1.2 The Concept of "Green" National Accounting

"Green" national accounts are designed to incorporate indicators of the stock, value and use of natural resources in the economic sector and of the amounts and type of wastes and pollutants created by individuals, firms and public institutions (UN 1993).

Net national product (NNP) is a measure of net economic performance in the present conceptual framework of national accounts (Ahmad *et al* 1989, Lutz 1993). There are many empirical discussions of the possible ways of calculating "green" NNP which incorporate environmental factors (Adger and Whitby 1993, Daly 1989, Harrison 1989, Hueting 1989, Leipert 1986 and 1989, Peskin 1989, Ward 1982, Weber 1989). The idea of "green" national accounts makes it possible to modify GNP or NNP so as to measure the benefits and costs associated with pollution and its abatement and to measure the depreciation of the stock of natural resources.

The structure of the chapter is as follows. In Section 2.2 we deal with Hartwick's model of "green" national accounts. We also review some other important models of deriving gNNP. In Section 3 procedures of this research are discussed. Three approaches used in the research are illustrated: the net price approach (Repetto et al 1989), the total rent approach (Hotelling 1925, Hartwick and Hageman 1991) and the user cost approach (El Serafy 1989, 1991). An appendix is provided for further discussion on gNNP with air pollution.

2.2 A Generalised Approach to gNNP: An Extended Hartwick Model

2.2.1 Significance of Hartwick's Model

Based on Hotelling's (1925, 1931) model, Hartwick (1978, 1989, 1990, 1991, 1992) extends

Weitzman's model (1976) of gNNP. He proposes that depreciation weighted by marginal rent should be netted out from the conventional NNP. Hartwick's main idea is to subtract from NNP the amount of stock used up over the accounting period weighted by the marginal value of a unit, that is, its price less the marginal cost of producing a unit of the stock (i.e. the marginal rent).

Hartwick (1978, 1990) considers mineral discoveries, durable exhaustible resources, renewable resources, and pollution effects in deriving 'green' NNP. The Hotelling rule is the core of Hartwick's model.

Hartwick applies the current value Hamiltonian in aggregate neo-classical growth theory to reach gNNP. When neoclassical growth models incorporate natural capital, net investment includes the economic depreciation in natural resource capital goods. The Hotelling Rent in Hartwick's model is the difference between price and marginal cost. The dynamic optimization approach yields market or scarcity values for all changes in capital stock including natural capital. In deriving measures of rent, Hartwick sets up each case of natural capital separately. For non-renewable resources the general equation of the dynamic optimization characterises an economy of maximised production and consumption utilities. We write the general equation of the Hartwick model as,

$$gNNP=C+\dot{K}_M-(F_{NR}-f_{NR})\dot{K}_{NR}+(F_{RE}-f_{RE})\dot{K}_{RE}+(F_X-f_X)\dot{X} \quad (1)$$

Where

C	=	consumption
$\dot{K}_M$	=	change of man-made capital
F_{NR}	=	price of nonrenewable resource
f_{NR}	=	marginal cost of extraction or harvest for nonrenewable resource

$\dot{K}_{NR}$	=	change of nonrenewable resource
F_{RE}	=	price of renewable resource
f_{RE}	=	marginal cost of extraction or harvest of renewable resource
$\dot{K}_{RE}$	=	change of renewable resource
F_X	=	price of pollution
f_X	=	marginal cost of pollution
$\dot{X}$	=	change of pollution stock

In the following sections we will discuss each component of the model.

2.2.2 Non-Renewable Resources

In Hartwick's model the measure of depreciation is the value of net change in natural resources, that is, extraction minus discoveries, and

$$gNNP = C + \dot{K}_M - (F_{NR} - f_{NR})\dot{K}_{NR} \tag{2}$$

Note that discoveries are valued at their full rental rates, i.e. they are treated as addition to NNP. Whereas Hartwick values all resource discoveries as unit rents times the amount discovered, Hamilton's expression values D only at the marginal cost of discoveries. The essential difference is that Hamilton sees no rationale for making discovery cost a function of the *remaining* stocks, as in Hartwick's case, but adopts the more likely situation in which discovery costs are a function of past cumulative discoveries. There are in fact arguments for both views: Hartwick's view rests on the idea that resources are discovered along a 'gradient' so that costs rise as more and more 'marginal' source are exploited, whereas Hamilton's view rests on the view that discovery costs will tend to fall as economies of scale and technology are secured.

2.2.3 Renewable Resources

Hartwick (1978, 1992) deals with the analysis of renewable resources. In his 1978 paper, he shows that efficient paths are characterised by constant per capita consumption when population is stationary. In his 1992 paper he further analyzes the relationship between deforestation and national accounting. It is the most relevant paper for our purpose. Hartwick studies a growing economy in which land is being switched continuously from use in forestry to an alternative use. The condition for such an activity to take place is that there must be no net loss to land owners, which implies no deduction in the national accounts for deforestation. With soil erosion on deforested land, Pigovian taxes, referring to corrective taxes leading to efficient resource allocation, must be levied to prevent erosion impairing the productivity of the land to the point where output is non-sustainable. He also sets an optimal tax on households for their implicit use of forests as oxygenation sinks.

The model of gNNP for nonrewable resources can be adapted to the case of renewable resources. Then the depreciation of the resource is:

$$DEP_{RE} = (F_{RE} - f_{RE})(g - h)$$

$$(g - h) = \dot{K}_{RE} \tag{4}$$

and the adjusted net national accounts are:

$$gNNP = C + \dot{K}_M - (F_{RE} - f_{RE})\dot{K}_{RE} \tag{5}$$

2.2.4 Pollution

Hartwick (1990) analyzes environmental pollution. With regard to degradation or stress on environmental capital, pollution is an intrinsic by-product of economic activity. Pollution can impinge negatively on an economy in two ways. It can constrain current production, and additionally, it has a direct negative impact on welfare. To account for pollution, Hartwick proposes that conventional NNP must be reduced by the increase in pollution stock valued at its marginal 'draw-down' of output or the amount of output forgone at the margin. In addition, damages to consumers from the pollution stock must be netted out.

Hartwick (1990) proposes that the increase in pollution stock should be valued at its marginal cost of output. If X is the flow of pollution emission in real terms, F is the shadow price of pollution damage and f is the marginal cost of pollution abatement then the direct negative effect of pollution on household and production utility levels is F_X and the negative effect on production is f_X. The sum of the two impacts i.e. on households and firms, is the pollution damage which should be deducted from the national accounts:

$$DEP_X=(F_X+f_X)\dot{X} \tag{6}$$

Thus, the adjusted net national accounts are:

$$gNNP=C+\dot{K}_M+(F_X+f_X)\dot{X} \tag{7}$$

We consider Hartwick's mode to be the most useful model in deriving green NNP. However, there are some limitations in Hartwick's model. Suppose the utility function is a continuous and increasing function of consumption, and sustainability is defined as being equivalent to constant consumption over time (a minimum requirements). Hartwick's model states that investment should be equal to resource rents so as to have constant consumption. Hartwick assumes the appropriately defined stock to be fixed. Thus, the level of social welfare is also fixed and consumption is the interest on the stock. This is not plausible in the real world. Solow discusses this problem particularly in his 1986 paper. Secondly, for an open economy, Hartwick model is not suitable because trade is not considered in the model. However, since the model deals with all of the resources in the economy, it can be improved by using a generalised Hamiltonian (Dixit, Hammond and Hoel 1980, Hamilton 1993). We can also generalise Hartwick's rule in practice.

Hamilton (1993a) generalises the Hartwick model. It is also helpful to understand Hamilton's (1993c) model with integration of Hartwick model into global stock pollutants in "green" national accounts, which is also one of his six models in gNNP. The treatment of discoveries is his other contribution in this area (see previous discussion). In Hamilton's equation, he derives

$$NNP = C + \dot{K} + g_D D - (F_R - f_R)\dot{R} \tag{8}$$

C = consumption

$\dot{K}$ = change of man-made capital

$g_D D$ = change fo discoveries

$\dot{R}$ = Change of natural resources

Here we could see that in Hamilton's equation, discoveries $g_D D$ are included into the stocks of natural capital instantaneously. This is the difference from Equation (5).

2.3 Three Approaches for Calculating 'Green' NNP

We now discuss how we intend to carry out our empirical study on environmental and natural resources evaluation in China. The procedures of calculating 'green' NNP are as follows:

1. Calculate economic depreciation by using the net price, the total rent and the user cost approaches. These approaches are discussed below.

2. Deduct economic depreciation from GNP.

3. Measure weak sustainable development by calculating the 'genuine' net investment level i.e. gross investment less any net depreciation on capital assets.

It is necessary to illustrate the three approaches that are to be used in our empirical study below.

2.3.1 The Net Price Approach

The net price approach measures the changes of the resources stocks. By defining GNP as Y_t and NNP in the economy at t as

$$NNP = C_t + dK_t/dt + dS_t/dt \qquad (9)$$

where

C_t = consumption at time t

K_t = man-made capital at time t

S_t = natural resources at time t

Using the notion, it follows that NNP = $(1 - \beta)Y_t$. Where β is the annual depreciation rate, so that the annual depletion rate of natural resources is deducted from Y_t. If the value of the annual rate of depletion is not deducted from Y_t, NNP will be over-estimated by $\beta/(1 - \beta)$ percent. Thus,

$$NNP = C_t + dK_t/dt + dS_t/dt = C_t + dK_t/dt - dR_t/dt \quad (10)$$

Where R_t is the consumption of natural resources. In the net price approach the main purpose is to calculate the change of the natural resource, $-dS_t/dt = -dR_t/dt$ over time. Here we write gNNP as:

$$gNNP = NNP - DEP_m - DEP_n \quad (11)$$

Where DEP_m is the depreciation of man-made capital and DEP_n is the depreciation of natural capital. Thus,

$$DEP_n = -dv/dt = (P_{nt+1} - AC_{nt+1})S_{t+1} - (P_{nt} - AC_{nt})S_t \quad (12)$$

where v is the volume of natural capital, so that -dv/dt is the change of volume over time. P_{nt} is the price of the natural capital at the beginning of the period and AC_{nt} is the average cost at the beginning of the period. S_t is the stock of the natural capital at the beginning of the period. P_{nt+1} is the price at the end of the period and AC_{nt+1} is the average cost at the end of the period. S_{t+1} is the stock of the natural capital at the end of the period. Thus the monetary value of the natural resources at the end of the period can be defined as:

$$S_{t+1} P_{nt+1} = S_t P_{nt} + dS_t/dt\, P^* + S_t\, dP_{nt}/dt + dS_t/dt\, (P_{nt+1} - P^*) \quad (13)$$

S_t = opening stock of the resources

S_{t+1} = closing stock of the resource

P_{nt} = net price at the opening of the period

P_{nt+1} = net price at the closing of the period

P^* = average net price during the period

dS_t/dt = changes between S_{t+1} and S_t

dP_t/dt = changes between P_{t+1} and P_t

The following relationship can be derived from the equations:

1. Net variation of stock:

$$S_{t+1} P_{nt+1} - S_t P_{nt} = dS_t/dt\ P^* + S_t\ dP_{nt}/dt + dS_t/dt\ (P_{nt+1} - P^*) \tag{14}$$

2. Current value of net additions during the year:

$$dS_t/dt\ P^* = (Ad - Rd)\ P^* \tag{15}$$

Ad = stock additions

Rd = stock reductions

3. Revaluation:

$$RV = S_t\ dP_{nt}/dt + dS_t/dt\ (P_{nt+1} - P^*) \tag{16}$$

where $S_t\ dP_{nt}/dt$ is the revaluation and $dS_t/dt\ (P_{nt+1} - P^*)$ is an adjustment term. The above equations are given in discrete time. In continuous time the formula would be:

$$N(S)=N((S-R),D)=\int_0^R [S-(P-C)(R)dR]+\int_0^F (P-C)(D)dD \tag{17}$$

Here N(S) is the total value of the resource measured by the net price approach. (P-C)(R) is the net value of extraction, P is the price of the resource, C is the cost of extraction and R is the quantity of extraction. D is the discoveries. Hence, this equation states that the change of the stock is affected by both extraction and discoveries. Here discoveries are treated exogenously. Assuming that the total extraction is given at S_0, the optimal path of the change of the stock is:

Maximise:

$$V=\int_0^{\infty} N((S-R),D)e^{-\rho t}dt \tag{18}$$

subject to

$$\int_0^{\infty} Sdt=(S-S_0)+\int_0^{\infty} Ddt \tag{19}$$

Ddt is the expression for discoveries. The Lagrangian integrand is,

$$L=N((S-R),D)e^{-\rho t}-\lambda(S-R-D) \tag{20}$$

From the Euler-Largrange equation, we get,

$$dR/dt=N'((S-R),D)e^{-\rho t}-\lambda=0 \tag{21}$$

The above equations show the continuous time solution of the net price approach. From our empirical studies we find this methodology is not sound since if the stocks of natural resources are very large depreciation can easily exceed the whole GNP. This approach is suitable for measuring resource changes when there are relatively small stocks. The conditions for using this approach are: 1) the stock of natural resources should not be very large; 2) the extraction of the resource should proceed at a fairly constant rate; 3) there is a small amount of discoveries or growth of the resource. But it is worth applying this approach in empirical work to compare it to others.

2.3.2 The Total Hotelling Rent

In the Hotelling (1925, 1931) model, the notion of the 'social value' of an exhaustible resource is used for measuring the sustainability of any extraction pattern of the resource. The gross value to society of a marginal unit of output or extraction of the resource is measured by the price society is willing to pay to call forth that particular unit of output, and the net value to society is the gross value less cost of extracting that unit.

To find the net social value, the total cost of extraction is subtracted from the gross social value. This net social value is the Hotelling rent, defined as price minus marginal cost. Economic depreciation or total Hotelling rent is defined as rent on the marginal tonne multiplied by quantity extracted over the period.

$$N(q)=\int_0^q P(q)dq-cq \tag{22}$$

Where, N is the depletion of the resource. q is the quantity of extraction. P is the price of the resource and c is the marginal cost of extraction. Assuming that total stock of exhaustible resource is given at S_0, we have to find an extraction path,

$$Max V=\int_0^{\infty} N(q)e^{-\rho t}dt \tag{23}$$

$$S.T. \int_0^{\infty} q\,dt=S_0 \tag{24}$$

By using Lagrangian integrand, the optimal path can be found as,

$$L=N(q)e^{-\rho t}-\lambda q \tag{25}$$

By applying the Euler-Lagrange equation, we get,

$$N'(q)e^{-\rho t}-\lambda=0 \tag{26}$$

According to the differential calculation, we have,

$$[P(q)-C'(q)]e^{-\rho t}-\lambda=0 \tag{27}$$

The implication of this is that along the optimal extraction path, the value of P(q) - C'(q) associated with any point of time must have a uniform present value, λ. We can also say that

$$P(q)-C'(q)=\lambda e^{\rho t} \tag{28}$$

From the equation, it is clear that λ has the connotation of the initial value of P(q) -C'(q). If the P(q) and the C'(q) functions are specific, we can solve the equation for q in terms of λ and t. This approach proves to be empirically plausible for deriving economic depreciation of nonrenewable resources.

2.3.3 The User Cost Approach

We also calculated natural resources-adjusted accounts by using El Serafy's (1989) user cost approach. According to El Serafy, it is necessary to determine the amount of income generating investments one should accumulate, so that at the point at which the natural resources are exhausted, the accumulated man-made assets should be high enough to cover the loss of natural resources.

Here S represents the physical stock of natural resources at a particular point in time, g is the natural growth rate of natural resources or discoveries, Q represents the quantity of extraction in that period and F is the damage to natural resources. Thus we have,

$$S_t = (1 + g)S_{t+1} - Q - F \tag{29}$$

If P is the net price, then the initial flow of income Y can be measured as,

$$Y = p \cdot Q \tag{30}$$

In deriving the user cost for our research, let P(U) be the present value of user cost over some time period (in the empirical sections we use 1976-1992), at a rate of interest equivalent to the opportunity cost of capital (r):

$$P(U)=\sum_{t=o}^{n-1}(U)(1+r)^n=(U)\cdot\frac{(1+r)^n-1}{r} \tag{31}$$

The present value PV(U) of the accumulated capital reinvestment during this time horizon, using r as a discount rate:

$$PV(U)=P(U)\cdot r\cdot\frac{1}{(1+r)^n}=U\cdot\frac{(1+r)^n-1}{(1+r)^n} \tag{32}$$

As Hartwick and Hageman (1991) and da Motta, May and Young (1991) have shown, the last result may then be equated to the present value of the sustainable income Y, or Hicksian income:

$$U=\frac{(1+r)^n-1}{(1+r)^n}=\frac{Y}{(1+r)^n} \tag{33}$$

Simplifying the above equation, we get:

$$U=\frac{Y}{(1+r)^{n}-1}$$

(34)

This is the general equation of user cost, which is equivalent to El Serafy's user cost approach. We have used El Serafy's (1989) user cost approach to estimate the depreciation of forest, coal and oil resources in China. If it is defined so that DF represents El Serafy's formula on user cost or depreciation, then:

$$DF_t=1-\frac{1}{(1+r)^{n_t}}$$

(35)

The most important step is to calculate the user cost at zero percent discount rate. It is very confusing to use the term 'zero discount rate' and it is actually just an approach to calculate economic depreciation. The next step of the calculation is to determine value added from gross output value in the natural resources sectors. Then we derived value added (Y_t). According to El Serafy (1989), Hartwick and Hageman (1991) and Young and da Motta (1995), value added is defined as the difference between gross output value (OV_t) and intermediate cost (IC_t) of production. This difference equals the sum of wages (WA_t), social charges (SC_t) and the gross operating surplus (OS_t). The gross operating surplus can be divided into two parts: the "normal" capital remuneration (CR_t) and user cost (UC_t). Since all the other variables are known, the rent may be obtained residually by:

$$Y_t = OV_t - IC_t \tag{36}$$

$$Y_t = WA_t + SC_t + OS_t \tag{37}$$

And the user cost can be defined as,

$$UC_t = OS_t - CR_t \tag{38}$$

What we have to explain here is that the intermediate cost in output is quite high compared with other countries because in the Chinese accounting system every expense such as social cost, is already included. Therefore, the difference between value added and rent is just wages and capital remuneration. We adjust the equations to:

$$Y_t = WA_t + CR_t + UC_t \tag{39}$$

$$UC_t = Y_t - WA_t - CR_t \tag{40}$$

This is the user cost or economic depreciation at zero percent discount rate.

2.3.4 Summary

Here in brief is the comparison between the net price approach, the total rent approach and the user cost approach:

Net price = price - [marginal (average) cost x Δstocks]

Total rent = price - [marginal (average) cost x amount extracted]

User cost at zero percent discount rate = profit - income = profit$((1/1+r)^{n+1})$

The comparison tells us that when price minus cost equals profit, here we call it net price, user cost of zero discount rate actually also shows the profit level of the year with deduction of income part. From this point of view the net price approach, the total rent approach and the user cost approach at zero discount rate have similarities. This intuitively captures the definition of economic depreciation, that is, the loss in value of a capital good from optimal use.

The user cost method at zero percent discount rate is close to the total rent approach except for the different way of estimating cost. User cost is best used when data on price and cost are not widely available. Many people argue that high positive user cost can be used for the future rent. This argument is not plausible because from our studies, higher discount rates just encourage people to consume more currently with less consideration for future generations.

2.4 Conclusion

In this chapter we have discussed the necessity of having "green" national accounts in calculation of economic growth in respect of environments and natural resources.

We have pointed out the shortcomings of present SNA. In section 2 we have discussed Hartwick's model in terms of treatment of nonrenewable resource, renewable resource and pollution. Then we have given an overview on various models in deriving "green" national accounting. We have also discussed the adjustments in applying this gNNP in the empirical work.

Thus, we have selected three approaches as the approaches in the analysis: the net price approach, the total rent approach and the user cost approach. The application of the three approaches is shown in the following chapters.

Appendix 2.1 Hartwick's Model

A2.1 Significance of Hartwick's Model

Based on Hotelling (1925, 1931) model, Hartwick (1978, 1989, 1990, 1991, 1992) extends Weitzman's model (1976) on gNNP. He proposes that stock of diminution weighted by marginal rent should be netted out from the conventional NNP to account for the economic depreciation of natural stocks. Hartwick's main idea is to depreciate natural resource stocks, i.e. to subtract from NNP the amount of stock used up over the accounting period weighted by the marginal value of a unit, that is, its price less the marginal cost of producing a unit of the stock.

Hartwick (1978, 1990) considers several variations on the theme that stock diminution weighted by marginal rent should be netted from basic NNP. Mineral discoveries, durable exhaustible resources, renewable resources, pollution effects are examined. Hotelling rule is the core of Hartwick's model. In his 1989's paper, Hartwick used Hotelling valuation principle for valuing resource extraction and economic depreciation with exhaustible resources at the level of a firm and of the national income.

Hartwick applies the current value Hamiltonian in aggregate neo-classical growth theory to reach gNNP. When neoclassical growth models incorporate natural capital, net investment includes the economic depreciation in natural resource capital goods. The Hotelling Rent in Hartwick's model is the difference between price and marginal cost. The dynamic optimization approach yields market or scarcity values for all changes in capital stock including natural capitals. In deriving Hartwick rent, Hartwick sets up each case of natural capital separately. For non-renewable resources the general equation of the dynamic optimization characterises an economy of maximised production and consumption utilities. We write the general equation of Hartwick model as,

$$gNNP = C + \dot{K}_{M} (F_{NR} - f_{NR})\dot{K}_{NR} + (F_{RE} - f_{RE})\dot{K}_{RE} + (F_X - f_X)\dot{X} \qquad (1)$$

Where

C	=	consumption
$\dot{K}_M$	=	change of man-made capital
F_{NR}	=	price of nonrenewable resource
f_{NR}	=	marginal cost of nonrenewable resource
$\dot{K}_{NR}$	=	change of nonrenewable resource
F_{RE}	=	price of renewable resource
f_{RE}	=	marginal cost of renewable resource
$\dot{K}_{RE}$	=	change of renewable resource
F_X	=	price of pollution
f_X	=	marginal cost of pollution
$\dot{X}$	=	change of pollution stock

In the following sections we will discuss Hartwick's model in turn.

A2.2 Non-Renewable Resources

Hartwick (1990) mentions that an essential component of formulas for depreciating natural resource stocks in the national accounts is the marginal cost of using the resources over the current period, e.g. marginal extraction costs or extraction costs and discovery costs. We should also give an assumption: population is constant, so labour could be omitted from the model. For non-renewable resources, Hartwick uses the conventional production function at each date.

$$Q = F(K, NR) \qquad (2)$$

Here Q is output level, F is the production function, K is the capital input and NR is input of non-renewable resource. F(K, NR) is a production function for K, man-made capital and NR, the flow of non-renewable resources, thus F(K, NR) is currently produced composite commodity. The stock size S(t) of natural resources declines by an amount equal to current extraction,

$$NR(t) = -\dot{S}(t) \qquad (3)$$

Where S is the stock of non-renewable resource. For the optimal economic growth, it should be,

$$Max\int_0^\infty U(C)e^{-\rho t} \qquad (4)$$

Where U is utility of production function, C is consumption, and ρ is the rate of discount. Then he assumes that f(NR) is the marginal cost of producing NR from the stock S.

$$\dot{K} = F(K, NR) - C - f(NR, S) - g(D,S) \qquad (5)$$

$\dot{K} = F(K, NR) - C - f(NR, S) - g(D, S)$ and $\dot{S} = -NR + D$ are the changes of capital and stock of the natural resource. D is discoveries of natural resources. From the equations we can see:

f(NR, S) = the cost of extracting the non-renewable resource, S is the stock of the non-renewable resource.

g(D, S) = the cost of exploration.

Equation (5) simply says the rate of change in the stock, S is equal to the amount extracted plus the amount discovered. Note that,

$\partial f/\partial NR$ = the marginal cost of extraction $= f_{NR}$

$\partial g/\partial NR$ = the marginal cost of exploration = g_{NR}

Now we set up the current value Hamiltonian as,

$$H(t) = U(C) + \lambda_1(t)K + \lambda_2(t)S \quad (6)$$

Where λ_1 and λ_2 are the co-state variables or the shadow prices corresponding to capital and resource stocks respectively. Using Equation (5), we have the current value of Hamiltonian as,

$$H(t) = U(C) + \lambda_1(t)\{F(K, NR) - C - f(NR,S) - g(D,S)\} + \lambda_2(t)\{-NR + D\} \quad (7)$$

We can see that the Hamiltonian is measured in utilities and is maximised at each point in time under the optimal control. Here we need to establish the maximum principle, portfolio balance and dynamic constraints (Neher 1990) for this problem. These are also the canonical equations for dynamic optimisation.

1/ Maximum Principle (also the equations for control variables)

The control variables are C, NR and D. These conditions are given by:

$$H_C = 0, \text{ or } \partial H/\partial C = \partial U/\partial C - \lambda_1(t) = 0, \text{ i.e. } U_C = \lambda_1(t) \quad (8)$$

$$H_{NR} = 0, \text{ or } \partial H/\partial NR = \lambda_1 F_{NR} - \lambda_1 f_{NR} - \lambda_2 = 0, \text{ i.e } \lambda_1[F_{NR} - f_{NR}] = \lambda_2 \quad (9)$$

$$H_D = 0, \text{ or } \partial H/\partial D = -\lambda_1 g_D + \lambda_2 = 0 \quad (10)$$

They are the corresponding FOCs obtained by the partial derivative. The necessary thing here is that the maximum principle requires that whatever price is, it must enter maximum principle as specified in Equations (8), (9), (10).

2/ Dynamic Constraints (equations for state variables)

The state variables are K and S. They are given by:

$$H_{\lambda 1} = \partial H/\partial\lambda_1 = K = F(K, NR) - C - f(NR,S) - g(D,S) \qquad (11)$$

$$H_{\lambda 2} = \partial H/\partial\lambda_2 = S = -NR + D \qquad (12)$$

3/ Portfolio Balance (equations for costate variables)

As we mentioned before, the costate variables are λ_1 and λ_2. The portfolio balance equations are given by:

$$\lambda_1 = \rho\lambda_1 - H_K = \rho\lambda_1(t) - \partial H/\partial K = \rho\lambda_1(t) - \lambda_1 F_K = \lambda_1(\rho - F_K) \qquad (13)$$

since $\lambda_1 = U_C$, we have,

$$U_C = \lambda_1(\rho - F_K) \qquad (14)$$

$$\text{Also } \lambda_2 = \rho\lambda_2 - \partial H/\partial S = \lambda_2(f_S + g_S) + \rho\lambda_2 \qquad (15)$$

By using a linear approximation, $U(C) = U_C \cdot C$ and dividing the revised Hamiltonian in Equation (7) by U_C ($= \lambda_1(t)$). Hartwick arrives at NNP function:

$$\frac{H(t)}{U_c} = C + \dot{K} - \frac{\lambda_1(t)}{U_C}[NR-D] = C + \dot{K} - [F_{NR} - f_{NR}][NR-D]$$

(16)

In Equation (16), $(F_{NR} - f_{NR})$ is an aggregate rent on the stock of natural resources which is currently used-up or wasted. This rent is to be netted out from C + K to allow for the using-up of natural resource stock over the period. To depreciate natural resource stocks Hartwick proposes that we should deduct the quantity of stock used up weighted by its dynamic rent per unit (NR - D) from Equation (16). Given $U(C) = CU_C$, the new NNP, $H(t)/U_C$ has a price, F_{NR}, minus marginal extraction cost f_{NR}, multiplied by current stock change of the resource (NR - D). $(F_{NR} - f_{NR})$[NR -D] is an aggregate rent on the stock of the exhaustible resource which is currently used up or wasted. Since $F_{NR} - f_{NR}$ is sometimes called dynamic or Hotelling rent, $(F_{NR} - f_{NR})$NR is total Hotelling Rent on the amount currently extracted. This rent should be deducted from C + K to allow for the extraction of nonrenewable resource stock S(t) over the period. We have gNNP here:

$$gNNP = C + \dot{K}_M - (F_{NR} - f_{NR})\dot{K}_{NR} \qquad (17)$$

C	=	consumption
$\dot{K}_M$	=	change of man-made capital
F_{NR}	=	price of nonrenewable resource
f_{NR}	=	marginal cost of nonrenewable resource
$\dot{K}_{NR}$	=	change of nonrenewable resource

A2.3 Treatment of Discoveries

For the treatment of discoveries Hamilton (1994) proposes a different way in deriving gNNP. In Hamilton's treatment he eventually reaches the equation as:

$$NNP = C + \dot{K}_M + g_D D - (F_{NR} - f_{NR})\dot{R} \qquad (18)$$

The differences between Equation (17) and Equation (16) are the inclusion of an explicit depreciation function, d(K), and making resource discoveries g a function of cumulative discoveries D. In both Hartwick and Hamilton derivations, resource depletion appears as a deduction from NNP, it is calculated as the value of current resource rents. But whereas Hartwick values all resource discoveries as unit rents times the amount discovered. Hamilton's expression includes only $g_D D$, the marginal cost of discovering resources times the amount discovered, as an addition to NNP. This term may be considered to be a measure of investment in resource discoveries. Efficiency would impose that the marginal cost of finding a unit of resource should be less than the marginal rent revenue from extracting a unit. Therefore, g_D would be less than $(F_{NR} - f_{NR})$.

A2.4 Renewable Resources

Hartwick (1978, 1992) deals also with the analysis of renewable resources. In his 1978 paper, he shows that efficient paths are characterised by constant per capita consumption when population is stationary. In his 1992 paper he further analyzes the relationship between deforestation and national accounting. It is the most relevant paper to our research project. He studies a growing economy in which land is being switched continuously from use in forestry to an alternative use. The condition for such an activity to take place is that there must be no net loss to land owners, which implies no deduction in the national accounts for deforestation. With soil erosion on deforested land, Pigovian taxes, referring to corrective taxes leading to efficient resource allocation, must be levied to keep the sustainability of the land. He also sets an optimal tax on households for their implicit use of forests as oxygenation sinks.

Comparing Hartwick's model with the general models from Mäler(1991) and Dasgupta (1993), we find that in practice it is easy to use Hartwick's model. In Hartwick's model, he considers an economy with two consumption goods, a composite C and a renewable resource, RE. The utility of current aggregate consumption is U(C, RE) with linear approximation $U_C C + U_{RE} RE$. Let costs of renewable resources, in terms of the produced composite commodity, be f(RE, Z), where Z is the stock of renewable resources and RE is the current harvest. Then $K = F(K) - C - f(RE, Z)$ and $Z = g(Z) - RE$, where $F(\cdot)$ is currently produced composite commodity and g(Z) is now the natural growth in the stock. The current value Hamiltonian is now,

$$H(t)=U(C,RE)+\lambda_1(t)\cdot[F(K)-C-f(RE,Z)]+\lambda_2(t)\cdot[g(Z)-RE]$$

(19)

Equation (19) can be written as,

$$\frac{H(t)}{U_C}=C+\frac{U_{RE}}{U_C}\cdot RE+\frac{\lambda_1(t)}{U_C}\dot{K}+\frac{\lambda_2(t)}{U_C}\dot{Z}$$

(20)

Using the canonical equations, we observe $U_C = \lambda_1(t)$ and $\lambda_2(t)/U_C = (U_{RE}/U_C - f_{RE})$ or that the NNP function is,

$$\frac{H(t)}{U_C}=C+\frac{U_{RE}}{U_C}\cdot RE+\dot{K}+[\frac{U_{RE}}{U_C}-f_{RE}]\dot{Z}$$

(21)

where U_{RE}/U_C is the market price of a unit of natural resources in a competitive world with complete property rights and f_{RE} is the marginal cost of harvesting for RE, and Z is the current net change in the stock of the renewable resource. In a steady state, Z would be zero. In a growing economy, a negative Z is plausible. In recent decades the apparent shrinking of world fish stocks has resulted in shrinking harvests. Thus a negative Z is plausible given world population and income growth. Stocks in per capita terms would be declining more rapidly. The term $(U_{RE}/U_C - f_{RE})\dot{Z}$ is defined as economic depreciation when $Z < 0$. It should be netted-out of GNP to arrive at NNP. Here we derive gNNP as,

$$gNNP = C + \dot{K}_M - (F_{NR} - f_{NR})\dot{K}_{NR} + (F_{RE} - f_{RE})\dot{K}_{RE} \quad (22)$$

Where

F_{RE} = price of renewable resource

f_{RE} = marginal cost of renewable resource

$\dot{K}_{RE}$ = change of renewable resource

A2.5 Pollution

Hartwick (1990) analyzes environmental depreciation in pollution. With regard to degradation or stress on environmental capital, Hartwick views pollution as an intrinsic by-product of otherwise economic activity. Pollution can impinge negatively on an economy in two ways. It can constrain current production, and additionally, it has a direct negative impact on welfare. To account for pollution, Hartwick proposes that conventional NNP must be reduced by the increase in pollution stock valued at its marginal 'draw-down' of output or the amount of output forgone at the margin. In addition, damages to consumers from the pollution stock must be netted out.

The volume of pollution, X is an input of production for given inputs K. More pollution implies less output in F(K, X). Net pollution increments are $X = -bX + \gamma F(K, X)$, where in the absence of production $X = -bX$, or pollution abates at rate b by natural environmental stock regeneration. γ is a parameter linking produced output to increments in pollution. The single control variable here is C, the consumption and K and X are two state variables. The current value Hamiltonian is

$$H(t) = U(C) + \lambda_1(t)[F(K, X) - C] + \lambda_2(t)[-bX + \delta F(K, X)] \qquad (23)$$

Again here $U_C = \lambda_1$, Hartwick then derives,

$$\frac{\lambda_1}{U_C}=[\frac{-\dot{U}_C/U_C+\rho-F_K}{\gamma F_K}]\equiv V$$

(24)

Then the Hamiltonian becomes:

$$\frac{H(t)}{U_C}=C+\dot{K}+V\cdot\dot{X}$$

(25)

Where $V\cdot\dot{X}$ is the economic depreciation of environmental capital evaluated in dollars. Since U(C) is approximated by CU_C, U_C must be zero. δ can be written $(1/\delta F_K)(\rho - F_K)$, where ρ and F_K are dimensionless rates and δF_K is the extra pollution included by employing one extra unit of K in producing the composite good, this latter being priced at i dollar per unit output. Pollution is only controlled indirectly via the output decision of producers. More output caused more pollution of stock size X and more pollution retarded production in the sense that the same amounts of K produces less output for higher levels of X. X was a state variable and there was no control variable in the case. Suppose a pollution abatement control model is introduced, we may introduce abatement costs f(b) as a debit from the produced composite output. a higher value of b implies more rapid cleansing of stock X per unit time. the rate of reduction of X is sped up for larger b. The current value Hamiltonian becomes:

$$H(t) = U(C) + \lambda_1(t)[F(K, X) - C - f(b)] + \lambda_2(t)[-bX + \delta F(K,X)] \quad (26)$$

where C and b are control variables. We have:

$$\partial H/\partial C = 0 \Rightarrow U_C = \lambda_1 \quad (27)$$

$$\partial H/\partial b = 0 \Rightarrow -f'\lambda_1 = \lambda_2 X. \quad (28)$$

To reduce the stock by X(>0) the cost is -(df/db)(1/X) and deducting economic depreciation can be interpreted as deducting the current costs of abating pollution by X. This result provides a capital theoretic rationale for deducting current pollution control expenditures from GNP to arrive at NNP. Hartwick's model in dealing with pollution is also the foundation of Hamilton's model (1993) in treatment of CO_2 in gNNP.

Here we finally get the general model, as Hartwick (1990) proposes, the true net national product is the conventional GNP minus rents for each type of natural capitals or environmental pollution. The equation of national accounts will be:

$$gNNP = C + \dot{K}_{M} - (F_{NR} - f_{NR})\dot{K}_{NR} + (F_{RE} - f_{RE})\dot{K}_{RE} + (F_X - f_X)\dot{X} \qquad (29)$$

where

F_X = Price of stock pollution

f_X = marginal cost of stock pollution

$\dot{X}$ = change of stock pollution[1]

Hartwick's model, which is neatly derived, is considered the most useful model in deriving green NNP. However, there are some limitations in Hartwick's model. Suppose the utility function is a continuous and increasing function of consumption, the minimal sustainability is equivalent to constant consumption over time. It is widely acknowledged that Hartwick's model, which states that investment should equal to resource rents so as to have constant consumption. Hartwick assumes the appropriately defined stock fixed, thus, the social welfare is also fixed and the consumption is the interest on the stock. This is not plausible in the real world. Solow

[1] According to Hartwick that $\dot{X}$ is positive and [p - mc] is negative. The pollution reduction is + [F - f]$\dot{X}$ since X is bad.

discusses this problem particularly in his 1986's paper. Secondly, for an open economy, Hartwick model is not suitable because trade is not considered in the model. However, since Hartwick model deals with all of the resources in the economy, it can be improved by using generalised Hamiltonian (Dixit, Hammond and Hoel 1980, Hamilton 1993). We can also generalise Hartwick's rule in the practice.

In a recent discussion of national income and sustainability Pemberton and Ulph (1996) point out that measuring national income is not equal to measuring sustainability. They have shown that national income is linked to the notion of wealth along the optimal path. The paper provides a proper derivation for the misleading concept by measuring sustainability by national income accounting after subtracting resource rents. However, to measure sustainability, alternative measures must be used, such as the measurement of strong and weak sustainabilities proposed by Pearce *et al* (1989).

Chapter 3

The Forestry Situation in China

Glossary of Chinese Forestry Terms

land used by forest sector: Land used by forest sector is not necessarily forested land, it can be used for other purposes in China.

forested land: Land which has forest on it.

unforested land: Land which has no forest on it.

timber forest: Forest used mainly for timber production.

natural forest: Forest growing naturally without plantations.

forest stand: Formed forest including both natural forest and planted forest.

timber volume: timber and stand forest measured by volume unit, normally by m^3.

forest area: forest measured by area unit, such as hectare or square kilometre.

forest cover: forested land as a percentage of the territory of the country.

3.1 The Overall Forest Situation in China

This chapter describes the overall forest situation in China. The purpose of this chapter is to explain the situation with respect to forest resources and timber stocks in China; to identify its forest resource crises; and to observe its current timber shortage problem.

The total area of China's territory is about 960 million hectares. According to the forest survey of 1984-1988 made by the Ministry of Forestry of China, the land used by the forestry sector is about 261 million hectares, accounting for 28% of its territory. According to the classification used by the Chinese authorities, the land used by the forestry sector is not necessarily forested land. It can be divided into unforested land or land used for other purposes yet under control of the forestry sector. Within the land in the forestry sector, China has 119 million hectares (45.6 percent) of forested land. The forest cover represents 13 percent of the area in the whole country. About 20 million hectares (7.7 percent) comprise land of sparse woods; 28 million hectares (10.7 percent) comprise bushes; 7.3 million hectares (2.8 percent) comprise reafforestations not yet matured as forests; 0.2 million hectares or less than 0.1 percent comprise nurseries for trees; 86.6 million hectares (33.2 percent) are unforested land (*Statistics of Forest Resources*, 1990).

Of the 119 million hectares of forested land, about 102 million hectares are forested stand; 14 million hectares are forest land for economic purposes, mainly fruit trees and rubber trees other than timber production; and 3.5 million hectares are land of bamboo[1].

Of the 86.6 million hectares of unforested land, 76.6 million hectares consist of barren land and mountains suitable for afforestation; 3 million hectares consist of land after deforestation; 1.3 million hectares consist of land after fires; and 5.6 million hectares consist of sand-soil land suitable for afforestation.

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[1]Bamboo does not belong to the tree family but to the grass family, called *graminaea*.

China ranks low among the countries in the world in terms of forested land, timber stocks and forest cover. The forest stands are even lower. The territory of China accounts for 7% of the world land and its population makes up over 20% of the population of the world. But its forest cover is only 4% of the world forest, and its standing timber volume is less than 3%. Moreover, half of the forests are poorly stocked. Forest density has declined since the early 1980s.

Timber volumes are also sparse, totalling 9.4 billion cubic metres (The Ministry of Forestry (1990)) during 1984-1988, or less than 9 cubic metres per capita. The United States, with only one-fifth of China's population, has about 98 cubic metres per capita. Stock is low in China. Timber densities stood at 84 m^3/ha during 1977-1981 and 79 m^3/ha during 1984-1988. These figures are biased by the remaining virgin forests in remote areas such as Tibet, Xinjiang, Jilin and Heilongjiang. Stocking elsewhere averages only about 30 m^3/ha, far below the standards of the world[2].

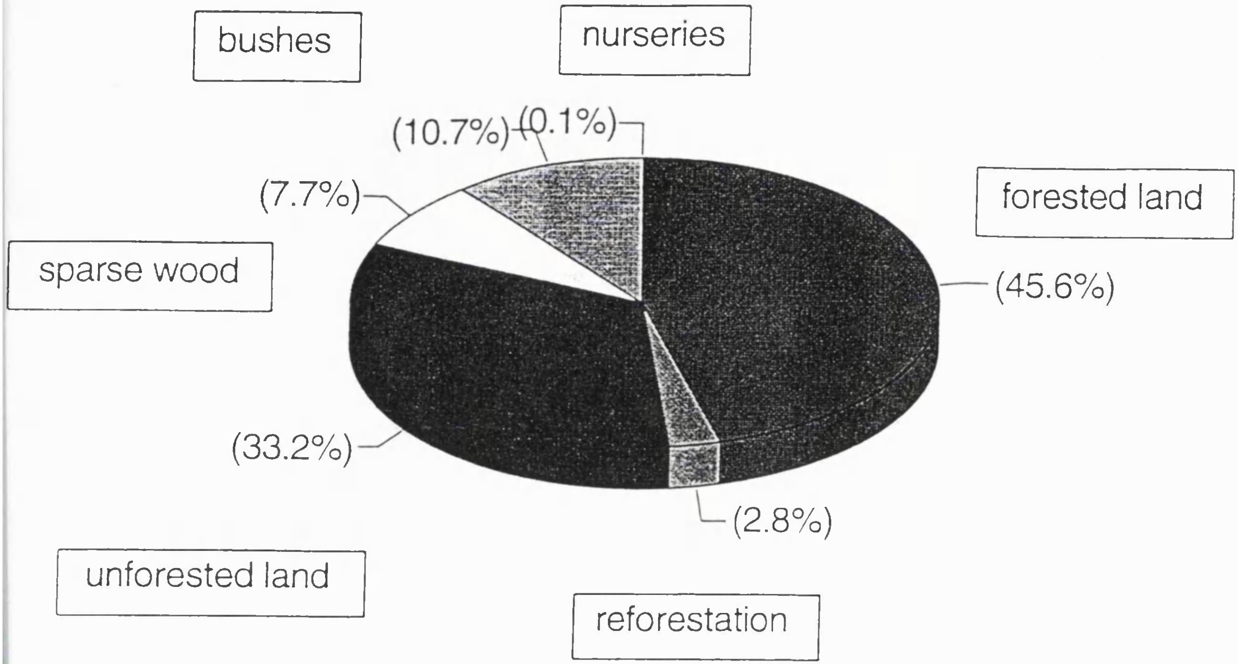
Figure 3.1, 3.2 and Tables 3.1 and 3.2 illustrate the general forest situation in China. It is important to note here that total timber volumes are not necessarily from timber forests. Total timber volumes include volume from e.g. trees around houses and along streets. The following graph shows the forest situation in China.

[2] The forest density in the world is about 100 m3 per hectare. (The World Forest 1990).

Figure 3.1 Forest Distribution in China

Figure 3.2 Land from the Forestry Sector in China

(261 hectares in total)



Land used by Forest Sector: 261 million ha.

Forested Areas: 119 million ha.

Unforested Areas: 86.6 million ha.

Sparse Woods: 20 million ha.

Bushes: 28 million ha.

Reafforestation: 7.3 million ha.

Nurseries: 0.2 million ha

Table 3.1 Change of Forest Resources in China
Unit: million ha & million m^3

year	total timber volume (million m^3)	total forest area (million ha.)	density (m^3/ha.)	of which: timber forest				
				timber volume (million m^3)	area (million ha.)	ratio (in area, timber forest to total forest)	ratio (in volume, timber forest to total forest)	density (m^3/ha.)
1950-1962*	7021	85.5	82					
1973-1976*	9532	121.9	71	7736	98.0	80%	81%	79
1977-1981**	9571	113.6	72	6882	82.4	73%	72%	84
1984-1988**	9418	119.2	79	6173	80.1	67%	66%	77
1989-1993***	11785	133.7	88	5970		51%		

Sources: *The General Commission of Natural Resource Survey of the China Academy of Sciences and the State Planning Commission (1989) *Data Collection of China Land Natural Resources*, Vol.1, Beijing, China, 1989. **The Ministry of Forestry (1990) *Statistics of Forest Resources in China*, page 26, Beijing, China.***The National Environmental Protection Agency (1994) *Annual Report on Environmental Situation in China*, Beijing, China.

Table 3.2 Total Forest Volumes from Different Categories of Forests
Unit: million m^3

category	1973-1976	1977-1981	1984-1988
total volume	9532	9571	9418
timber volume		6882	6173
sparse woods	560	542	546
individual trees	190	545	695
trees along streets and around houses	130	146	191
withered trees			304

Source: as for Table 1.

3.2 Deforestation in China

3.2.1 Deforestation in the Country as A Whole

China has a long history of deforestation. A number of writers, Murphey (1983), Smil (1983, 1992), Pearce and Warford (1993), Liu (1993), Edmonds (1994) and Lughezzani (1995) have discussed the consequences of deforestation in China. Murphey (1983), Qu and Li (1992) and Edmonds (1994) show that the history of deforestation develops with population and economic growth. Reforestation has not kept pace with logging. The Chinese government insisted that the forest cover in 1949 amounted to 8.6 percent of surface area, or about 83 million hectares. Following a decline during the early 1950s, Chinese sources reported that forest cover expanded in an irregular manner to about 13 percent of the surface cover area from the 1984-1988 survey.

Unfortunately, these figures seem to exaggerate the success that had been achieved. This point can be shown by subtracting newly afforested area. From 1949 to 1984, over 131 million hectares were afforested but only about 25 percent were successful. It is reported that during 1984-1988 there were 124 million hectares of forests. It seems that forest land cannot have been less than 91 million hectares, or 9.7 percent of surface in 1949 (Ross 1988).

Forest distribution is geographically unbalanced in China. Most of the forest areas are in the Provinces of Heilongjiang (13.3%), Inner Mongolia (11.9%), Jilin (5.3%), Sichuan (5.9%), Yunnan (8.0%) and Tibet (5.5%). These areas account for nearly 50% of forest lands and 71.9% of timber stocks. However, in the west part of China, where the area is more than one half of the territory, the forest area is less than 1/30 of the total area and the forest cover is below 5%.

Table 3.3 Changes of Forest Volume in 5 Main Forest Provinces

(million hectares, million cubic metres)

province	1973-1976		1977-1981		1984-1988	
	area	volume	area	volume	area	volume
Heilongjiang	16.6	1468	15.3	1437	15.6	1317
Inner Mongolia	10.4	717	13.7	848	11.8	775
Jilin	6.5	684	6.1	657	5.1	590
Yunnan	9.2	911	9.1	1097	6.0	698
Sichuan	7.1	1241	6.8	1049	6.3	713

Sources: the Academy of Sciences of China and the State Planning Commission
Data Volume of Land Resources of China, Vol.1, Beijing, 1989.

3.2.2 Northeast and Inner Mongolia

Since the end of 19th century, the forest cover in Heilongjiang province has dropped from 70 percent to 34 percent. The timber stock has dropped from 4 billion cubic metres to 140 million cubic metres and most of the trees there are small. The forest border has shrunk by 150 kilometres. Upstream of the Songhuajiang River, the forest cover rate has reduced by 10 percent during the last 20 years, which has led to a 25 percent decrease in water level in the river.

Daxinganling is the largest forest area in China, located between the very northern part of Heilongjiang Province and Inner Mongolia, close to Siberia. 30 years ago, Jiagedaqi was still an area of virgin forests and there were only several thousand Evenk and Elunchun people (Minorities in China) living in the forests of the area. Now the area is a city of over 200,000 inhabitants. The General Bureau of Forestry of Daxinganling is located in Jiagedaqi with 293,000 employees in total all over the forest area. There are 9 bureaus under the management of Daxinganling General Bureau of Forestry. Bureaus under management of Jiagedaqi are: Songling, Tahe, Tuqiang, Xilinji, Shibajan, Xinlin, Aermu, Huzhong and Jiagedaqi. As a rough estimation, the total population exceeds 500,000 in the Daxinganling area.

Due to its high latitude, Daxinganling has only a 90 days non-frost period. The tree growth period is short and most of the trees grow very slowly in this area. The soil layer is thin in this area, between 10-20 centimetres, with a mixed layer of yellow soil and stones underneath, the ecosystem in this area is very fragile. Once the original vegetation is destroyed, soil erosion follows easily and it is very hard to restore the original vegetation (see Appendices 1, 2, 3 and 4). Because of the cold climate, there are some places in the area where soil is permanently frozen. On this permanent frozen soil, a hundred years old tree is no thicker than a man's arm and stands shorter than a man. Given the severity and length of the winter, trees are the only fuel for heating in this area. In Daxinganling there is a huge stackpile of wood for heating in every courtyard of each household. In all probability these have been taken from the surrounding forests.

The original conifer and other trees in this area are larch, Zhangzisong (a kind of Chinese fir) forests with a small proportion of oaks and birches. In the past thirty years, almost all virgin forests have either been selectively logged, partially logged or completely logged. There is virtually no virgin forest left except in some remote areas. Most of these areas consist of secondary woods of birch arising after the original conifer trees were logged. There are also young larch in some areas. Forest density is very low and all trees are very young. These trees are rarely thicker than a man's leg. Plantation is not very successful in this area due to the cold weather and poor soil quality. The local people consider that the forest resources in the area can at most last only seven to eight years for logging. As the need for workers has declined, the populace has been forced to rely increasingly on herb gathering and other means of earning a living from the forest[3] (Liang 1994) and this is also the case in the Changbaishan Mountain forest area (the second largest forest area in China), where ginseng plantations are everywhere to be seen.

In the Xiaoxinganling forest area, the virgin forests have all been replaced by large areas of secondary woods and jungle; the forest resources have been greatly deforested over the past forty years. With 6 million hectares of forest areas, the forest cover rate was less than 50 percent and there were no timber resources suitable for logging. In the Yichun forest area, there were 1.4 million hectares of trees suitable for logging in 1949. In 1983 only 765,000 hectares of trees remained, more than half of the area of trees having been cut down. As Zhang (1993) reports, of the remaining trees, less than 10% were of high quality.

In the west area of the Sonhuajiang-Nunjiang plain, because deforestation is greater than reforestation, the forest cover is too low to prevent aggravation by wind and sand damage, and as a result the grassland has degraded. Owing to destruction of the forest, the environment for animals has also changed and deteriorated. Tiger and deer are virtually extinct. Bear and wild pig are rarely sighted in the area. The unbalanced ecosystem here has resulted in the frequent occurrence of droughts and floods. It was recorded that in 1854-1874, forest cover was more than 70 percent in the area, and the probability of there being a drought or flood only 10%. From 1925 to 1974, the forest cover rate fell to 37 percent while the frequency of drought and

[3] Planting ginseng and fostering mushroom and edible fungus are the main means of making a living in these areas.

flood disasters increased to 38 percent, including 5 severe droughts in the period. From 1984 to 1988, the forest cover rate reduced to an all time low of 34 percent. In summer of 1994, Harbin was hit by the Songhuajiang River's most heavy flood.

In the Changbaishan Mountain area, there were 5.2 million hectares of forest area in the 1950s, with the forest cover 63 percent. In the mid-1970s, the forest area was reduced to 34 percent, and the area of trees dropped by more than 16 percent. In the 1980s, the forested area was reduced by more than 18 percent compared with that of the 1950s. The timber trees area dropped by 19 percent (Ren and Bao 1992). Many precious species of tree have vanished. For example, the percentage of Korean pine is less than 3 percent in the natural forest, whereas most artificial plantations are larches, and the timber quality of the latter is comparatively low. The decreased percentage of coniferous trees has led to an increase in insect damage and an enlargement in the scale of soil erosion in these areas.

3.2.3 Central China

Most of the forests in the central part of China were logged in the past several thousand years and there is a very low forest cover in the area. A few remnants of natural forests exit either in the high mountain areas or in remote places. However, even these forests have not escaped deforestation or reclamation for agricultural production.

The following are illustrations of deforestation in the central part of China. In the Qinling-Banshan mountain area of Shaanxi Province, 22 out of 30 counties have a timber consumption which is higher than the rate of growth of trees. Consumption is 87% higher than the annual growth rate of trees. The forest border has shrunk 10-20 kilometres compared with that in the 1950s. Denudation of forest, clear felling trees for agricultural cultivation, and planting crops on the steep slopes of mountains have all led to large areas of soil erosion. In Ankang of Shaanxi Province, 23% of the cultivated land was on a slope greater than 35 degrees. In Zhenba County in Hangzhong Prefecture 60% of cultivated land was on a slope greater than 25 degrees, and 41.3% land was on a slope greater than 30 degrees. In the low mountain areas of Zhenba County, the annual soil erosion quantity has reportedly reached 6000 tons per square kilometre. (Ren and Bao 1992).

3.2.4 South and Southwest China

Deforestation was serious in the south part of China. In Hainan Province historically there used to be a vast area of tropical forest. The area was 867,000 hectares in the 1950s and forest cover was 25.7 percent. Because of denudation and reclamation for agricultural land, the forest area is now less than 400,000 hectares and forest cover is only 10%. Destruction of forest vegetation led to an increase in frequency of droughts and floods, and sedimentation of river and port areas. Sand content in the water flow of Nandujiang River, Changhuajiang River and Wanquan River has increased owing to the reduction of forest areas. In the 1960s the sand content of the three rivers was on average 0.10 kilograms per cubic metre; in the 1970s, the sand content was 0.15 kilograms per cubic metre, an increase of 39 percent.

In Xishuangbanna Prefecture of Yunnan Province, a large tropical rainforest maintained a good natural environment in the past. The change of forest cover over the years is shown below (Ren and Bao 1992):

year	forest cover
1950s	55%
1959	44.7%
1963	36.1%
1973	33.9%
1980	29.8%

In the past several decades, the forest area has reduced at a rate of about 17,000 hectares per year. This has caused deterioration of the environment and has threatened the existence of many varieties of plants. It is recorded that since 1957, 500-800 species and varieties have become extinct or close to extinction (Ren and Bao, 1991). The situation has also endangered the existence of some animals in the forest. For instance, rhinoceros in Xishuangbanna have become extinct. The stock levels of the gibbon, the tiger, the elephant, the wild bull, and some species of bird have decreased rapidly. Xishuangbanna was called 'the home of the peacock', but now they are very rare. Some insects which can pass on pollens have also reduced in number, marketing it necessary to provide some plants with artificial pollen.

In the southwest area of Sichuan Province and the north area of Yunnan Province, trees are cut down for firewood. Forest has been extensively destroyed with the result that forest cover is now just 19.5 percent. In the southeast area, forest cover is only 15.4 percent. In the northeast part of Yunnan Province the forest cover is only 18.8 percent. In Xuanwei County, forest cover was 64 percent in the 1950s, but has now fallen to only 4.6 percent. In Simao of Yunnan Province forest fires and conversion into agricultural land have reduced the forest area by 20 percent. In Honghe Prefecture, forest cover in 1958 was 48 percent, in 1962 it was 43 percent while in 1973 the rate dropped to 18 percent. Barren mountains and land have become common spectacles. Deforestation has led to an unbalanced ecosystem, an increase in the frequency of natural disasters, soil erosion, mud-rock collapse and landslides. In Yangliuxiang of Guangxi Autonomous Region, large scale denudation and reclamation has caused soil erosion, and sand and soil have inundated 300 hectares of farmlands.

Deforestation in the southwest part (Yunnan, Sichuan and Guizhou Provinces) of China is very high and has continued for some time. According to the survey in 1980-83, using the primitive slash-and-burn cultivation method, burning forest for cattle grazing and hunting led to a 700,000 m^3 loss of timber on average per annum; furthermore, denudation induced a reduction in timber of 10 million cubic metres on average per annum; and forest fires caused loss of forest of about 1.3 million cubic metres on average per annum. Consequently, large amounts of timber cutting and daily consumption have also led to a high reduction of forest area. Because of the reasons mentioned above, the net reduction of forest resources in Yunnan Province during that period was 10 million cubic metres on average per annum.

3.3 The Forest Crises in China

3.3.1 Decline of Natural Forests

In the previous section, the trends within the process of deforestation in China have been compiled. In this section some specific points and implications of deforestation are highlighted. There has been a striking reduction in major natural forest areas, that is, the forests without plantation. During 1984-1988 the main forest resources in the northeast part of China and Inner Mongolia decreased by 277,000 hectares compared with the figure during 1977-1981. While the area of overall forests increased slightly during 1984-1988, the volume and area of timber forests decreased. During 1984-1988 the biggest reduction was 5.2 million hectares in the northeast part and Inner Mongolia. The next was Yunnan and Sichuan Provinces at 1.2 million hectares. Ten provinces in the south part of China decreased by 0.9 million hectares and other provinces decreased by 0.06 million hectares.

Table 3.2 shows the overall decline in forest resources in China over the past two decades. The decline in the timber stock is indisputable. The total timber stock from forests was 9571 million cubic metres over the period 1977-1981 and 9418 million cubic metres over the period 1984-1988, of which, the stock from timber forest was 6882 million cubic metres during 1977-1981 and the volume was 6173 million cubic metres during 1984-1988, the total reduction was 709 million cubic metres. On the other hand, the stock from sparse woods was 542 million cubic metres during 1977-1981 and 546 million cubic metres during 1984-1988; the stock from individual trees was 545 cubic metres during 1977-1981 and 695 million cubic metres during 1984-1988; the stock from trees along streets and around houses was 146 million cubic metres during 1977-1981 and 191 million cubic metres during 1984-1988. In China, as we mentioned before, timber volume and forest cover include individual trees along streets and around houses.

The volume of mature forests declined considerably from 3846 million cubic metres in 1976-1981 to 2622 million cubic metres in 1984-1988, a total reduction of 1224 million cubic metres. Within only seven or eight years, one third of mature forests was depleted, the net reduction rate being 4.4% per annum. As mentioned above, in Tibet there are 500 million cubic metres of mature forests which are still difficult to reach with present technology. The remainder includes a large proportion of diseased, wind-broken and withered trees. In addition to these, there are substantial forests located along the upstream of rivers that cannot be logged because of their important function in soil conservation and ecosystem protection. Another large proportion of forests is located in high mountains and deep valleys. Transportation cannot not be extended to such places, rendering these forests very inaccessible for felling. The percentage suitable for timber felling, over all mature forests, is estimated to be only 79 percent. According to recently published figures timber stock from mature forests decreased by 200 million cubic metres during 1989-1993.

Between the period 1977-1981 and the period 1984-1988, total timber volumes decreased by 153 million cubic metres, the net reduction rate was 1.6%; the annual reduction was 27 million hectares and annual reduction was 0.3%. In all provinces, ten provinces in the south showed a reduction of 186 million cubic metres; Sichuan and Yunan provinces showed a reduction of 86 million cubic metres and the northeast part and Inner Mongolia showed a reduction of 83 million cubic metres. There was in fact an increase in 'Other Provinces', the total increase was 128.8 million hectares. But the decrease was greater than the increase of timber volume.

There was a sharp decline in timber volume throughout the whole country. The mature forests reduced most quickly; in the northeast part and Inner Mongolia the annual reduction was 109 million cubic metres by our calculations; Yunnan and Sichuan provinces had an annual average reduction of 31 million cubic metres; 'Ten Provinces' in the south had an annual average reduction of 22 million cubic metres and other provinces had an annual reduction of 8.6 million cubic metres.

The shortage of forest resources has had severe consequences for industrial production and living standards (Wang 1994). Timber distributed through state channels totals over 60 million cubic metres per year[4]. Besides trees used as timber, there are other timber consumptions[5] as well and the total consumption of timber was 344 million cubic metres per year (the Ministry of Forestry 1990). The shortage has affected the entire economy, and along with only two other goods steel and cement, timer has been subject to strict pricing and distribution quota controls by the Ministry of Materials before 1992.

Table 3.4 Different Categories of Forest Areas

unit:million hectares

category	1973-1976	1977-1981	1984-1988
total area	257.6	261.0	261.0
forested area	105.0	113.6	119
sparse woods	15.6	17.2+5.6**	19.6+7.3+0.2**
bushes	29.6	26.8	28.1
unforested area	107.4	97.8	86.6
individual trees	n.a	n.a.	n.a.
trees along streets and around houses	n.a.	n.a.	n.a.

** These were areas of young trees before forming into forests.

[4]Data from the Statistics of Forestry in China 1992.

[5]It is unclear for the composition of other consumptions. According to the statistics, timber output was 60 million cubic metres in 1992 and the total timber consumption was 344 million cubic metres.

Table 3.5 Comparison of Two Forest Surveys in China

area	time period	total timber volume (million m^3)	forest area (million ha.)	timber forest (million m^3)	unforested land (million ha.)	forest density per m^3/ha.
total	77-81	9571	113.6	6882	101.9	84.3
	84-88	9418	119.2	6173	86.6	79.0
	changes	-153	+5.4	-709	-15.3	-5.3
	year av.	-19.1	+0.7	-88.6	-1.9	
northeast and Inner Mongolia	77-81	3209.1	35.1	2709.2	30.6	86
	84-88	3210.2	34.8	2568.7	19.9	83.9
	changes	+1.1	-0.3	-140.5	-10.7	-2.7
	year av.	+0.13	-0.04	-17.6	-1.3	
Yunnan & Sichuan	77-81	2856.6	19.4	1798.2	14.7	141
	84-88	2759.3	20.1	1411.1	13.3	127.8
	changes	-97.3	+0.8	-387.1	-1.4	-13.2
	year av.	-12.2	+1	-48.4	-0.18	
ten south provinces	77-81	1871	39.4	1336.7	30.2	49.6
	84-88	1685.4	40.7	1138.8	27.2	43.7
	changes	-185.6	+1.3	-197.9	-3	-5.9
	year av.	-23.2	+0.2	-24.7	-0.4	
other provinces	77-81	1021	16.6	592.2	25	62.3
	84-88	1149.8	18.6	535.6	23.9	59.8
	changes	+128.8	+2	-56.6	-1.1	-2.5
	year av.	+16.1	+0.3	-7	-0.14	
no-survey provinces	77-81	613.5	3.1	503.2	1.4	185.4
	84-88					
	changes					
	year av.					

Source: The Minstry of Forestry, *Statistics of Forest Resources in China*, Forest Press, Beijing, 1990.

3.3.2 Further Discussions

When the total timber volume declined from 9571.2 million cubic metres during 1977-1981 to 9418.2 million cubic metres during 1984-1988, the net reduction was 153 million cubic metres and the percentage of decline was 1.6 percent, although there was an increase in forested area from 113.6 million hectares to 119.2 million hectares. More serious is the decline of timber forests from 6882 million cubic metres to 6173 million cubic metres in the two periods. A remarkable decline in timber forest volume of 10.3 percent during the two periods further exacerbated the timber shortage. This reduction was caused by human activities, logging trees of higher economic value, reclamation for agricultural production and natural decrease. Timber forests indicate a trend of reduction. From the report by the Ministry of Forestry (1990) and other data, the reduction was linked with following effects:

1. during the two periods only 2.7 million hectares of forests were shifted from forests for environmental protection, fuel, special purpose and economic use to timber forests, but 7.7 million timber forests were changed to forests for other purposes.

2. 8 million hectares of timber forests became sparse woods and bushes because of timber logging; only 6.8 million hectares of sparse woods and bushes grew into timber forests.

3. In the meantime, the net growth of timber forests was 223 million cubic metres per annum; the average consumption of timber was 344 million cubic metres per annum. Consumption was 121 million cubic metres greater than growth of forests. Compared with other countries in the world, the volume of consumption of timber in China was only less than the USA and the Former Soviet Union. The consumption of timber per 10,000 US dollars of GNP in China was 9.83 cubic metres, much higher than any other country in the world. The following table shows the low utilisation rate of timber in China, the serious waste:

Table 3.6 Timber Consumption in Some Countries

country	year	GNP(billion USD)	Timber Consumption (million cubic metres)	timber consumption per 10,000 USD GNP (cubic metre)
Japan	1982	1156.3	33	0.29
USA	1982	3500.0	397	1.13
Germany	1982	654.0	31	0.47
Philippines	1982	39.2	34	8.67
Canada	1982	289.0	130	4.50
China	1985	350.0	344	9.83

Sources: Academy of Social Sciences of China (1986) *1983-1984 Annual Statistics of World Economy*. FAO (1988) *1975-1986 Annual Statistics of Total Timber Output.*

4. Of timber forests in China, the mature forests were 27.4 million hectares or only one fourth in area of timber forests, and were 3846 million cubic metres or one third in timber volumes during 1977-1981. These limited timber stocks decreased further during 1984-1988. During the latter period the area of mature forests reduced to 18.2 million hectares while the timber volumes reduced to 2622 million cubic metres.

5. From the figures published by the Ministry of Forest Industry, during the two periods, only 2622 million cubic metres of mature timber forests remained, with a deduction of 500 million cubic metres from Tibet, and a 30 percent reduction in forest resources from the Jinsha River, Yalong River, the west part of Tianshan Mountain, Qinling Mountain and forest resources in the upstream of rivers. China at that time had 1400-1500 million cubic metres of forest resources available at the best estimate. If the consumption level of timber remained at 170 million cubic metres per annum, all mature timber trees would be logged within about eight

years. However, a 200 million cubic metre reduction in timber volume occurred during 1989-1993.

The northeast part of China and Inner Mongolia had mature timber forests of 950 million cubic metres during 1984-1988. According to the survey from 1984-1988, annual consumption was 110 million cubic metres greater than growth of forests. In other words, if consumption kept up at this rate, in eight or nine years there would be no mature forest resources left in these areas. In 'ten provinces in the south' timber forests accounted for only 1.7% of forest resources, with 180 million cubic metres of timber volume on high mountains and in remote areas. In fact most of the forests logged in these provinces were middle age forests.

7. Unsuccessful control of logging also contributes to the decrease of timber stocks. Starting from 1990 due to the situation of reduction in timber stocks, the Ministry of Forestry implemented a policy of "allowing limits for annual logging" (equivalent to 'annual allowable cut' in other countries). However, it appears that this regulation had little effect on restricting timber consumption, which still remained higher than the limits. The following is a comparison of the limits and the actual consumption of timber in 1991.

Table 3.7 Timber Limits and Actual Consumption in 1991*

Unit: million m^3

area	limits	consumption	area	limit	consumption
total	248.1	276.9	Henan	7.5	7.4
Beijing	0.15	0.16	Hubei	6.7	7.7
Tianjin	0.02	0.02	Hunan	9.9	12.5
Hebei	2.16	2.14	Guang-dong	8.0	6.4
Shanxi	1.4	0.9			
In. Mon.	13.8	15.5	Guangxi	13.0	13.8
Liaoning	2.9	2.9	Hainan	1.5	2.3
Jilin	15.8	15.3	Sichuan	25.0	28.1
Heilong-jiang	30.2	39.1	Guizhou	9.0	10.2
			Yunnan	37.4	38.9
Jiangsu	0.7	2.2	Shaanxi	7.0	7.9
Zhejiang	6.0	7.3	Gansu	2.3	2.2
Anhui	6.0	6.9	Qinghai	19.9	20.0
Fujian	23.0	26.5	Ningxia	8.5	18.7
Jiangxi	12.6	14.7	Xinjiang	2.4	2.1
Shandong	4.1	3.7			

*The figures in this table only include central planned figures, consumption out of the plan is not included.
Source: The Ministry of Forestry (1992) *Annual Statistics of Forestry in China*, Forestry Press, Beijing.

3.3.3 Quality Decrease in Forest Resources

Based on our analysis of the data published by the Ministry of Forestry (1990-1992), the quality of forest resources decreased in the following aspects:

Density

Between 1977-1981 and 1984-1988, sparse woods increased by roughly 10%, which was 15% of forest land in the country. The growth rate of trees per hectare was only 2.4 cubic metres per annum, much lower than the world level. Average density per hectare dropped from 84.3 cubic metres during 1977-1981 to 79 cubic metres during 1984-1988, an average decline of 5.5 percent per hectare. The density of timber forests dropped from 84 cubic metres per hectare to 77 cubic metres, an average decline of 8.3 percent. The density of timber forests is only 70% of the accepted world level[6]. Intensively selective felling for the best quality woods was the main reason for quality decrease of timber density per hectare.

Decline of proportion of mature trees to young trees

The proportion of young to mature trees has increased. The country had standing forests of 102 million hectares during 1984-1988, of which young growth trees constituted 33 million hectares, middle age trees 35 million hectares and mature forests, 31 million hectares. But the majority of the mature forests are in the remote areas. In the south part of China most forest consists of young growing trees. Within timber forests, the proportion of available mature timber forests has decreased. During 1977-1981 the area of mature forests was 27 percent of timber forests and timber volume was 57 percent. However, during 1984-1988 the area of mature forests fell to 18 percent, while timber volume fell to 42 percent. Low productivity is attributed to inefficient use of land for forestry, many secondary and incomplete forests of low unit timber

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[6]As mentioned before, the world density level is above 100 m3/hectare.

density and the slow growth rate of trees. Forested lands make up only 45.6 percent of the land used by the forest sector, so the utility is very low. Except in very distant areas, all the natural forests have been logged or deforested to varying extents, leaving secondary forests with low timber density and poor quality of woods.

During 1977-1981 the ratio of young and middle aged trees to mature trees was 71:29 while the ratio of timber volume was 42:58. During 1984-1988 the ratios were 80:20 in area and 54:46 in timber volume. The situation showed that the quality of forest resources in China had dropped, and the timber shortage was further intensified.

Table 3.8 Forest Stand Resources from Different Ages of Trees

Unit: million hectare

year	1973-1976	1977-1981	1984-1988
young growth	42.2	33.5	39.6
middle age tree	28.5	34.7	32.6+9.1* = 41.7
mature tree	35.3	27.4	12.6+5.6** = 18.2
non-classified	4.2	n.a.	n.a.
total	110.2	95.6	102.2

*9.1 is the figure of middle age forest which is close to mature.
** 5.6 is the figure of over-mature forest.

Decline of coniferous trees

The proportion of coniferous trees dropped and the density of main species of timber trees declined sharply. There was a 3 percent drop in area and density of coniferous trees. Of the main species of timber trees, the volume of Korean pine mature forests decreased from 90 million cubic metres to 45 million cubic metres; Chinese fir decreased from 74 million cubic metres to 39 million cubic metres; Yunnan pine decreased from 193 million cubic metres to 91 million cubic metres. Some precious species, such as the northeast China ash, walnut catalpa and others also reduced from 54 million cubic metres to 33 million cubic metres.

In the Daxinganling area, because of poor coordination in logging and planting trees, the area of plantation has been only 40 percent of the area of logging trees. Conifers of good timber quality have greatly decreased in this area and original conifer forests have all undergone logging. The percentage of conifers has dropped from 14 percent to 4.8 percent in the Yihuli mountain area. Natural conifer trees in the Jiagedaqi area have all been logged. The Jiagedaqi Bureau is responsible mainly for reforestation since it has nothing to log.

Fire and insect damage

Quality decrease is also reflected in insect and fire damage. Fire and insect damage have also destroyed large areas of high quality forest. Because of fewer species of trees and poor management, insect damage has increased year by year. Fire damage has also been very frequent. During 1984-1988 about 2.3 million hectares of forest were subject to fire (The Ministry of Forestry 1949-1988). The major forest fire in Tahe, Tuqiang and Xilinji Bureaus destroyed 700,000 hectares of trees in 1987.

3.4 Conclusion

China is a forest deficit nation in ecological, economic and social terms and currently has a serious timber shortage. Main natural forests have been greatly decreased, timber stocks have dropped, the quality of forests has declined and forest stocks cannot last another ten years of consumption. While the economic loss is clearly very great, the environmental damage may be still greater. Thus, it is necessary to conduct an economic valuation on forest accounting to discover its effect on the national economy.

The causes of deforestation are generally similar to the situation mentioned by Brown and Pearce (1994), such as agricultural conversion. Another reason is the demand for timber consumption. Although people and industry in China may cope with shortages of wood by making do with less consumption or relying more on concrete, bagasse and other substitutes, the long term environmental consequences are severe. Some ecological losses cannot be retrieved: deforestation increases water run off and aggravates soil erosion, loss of natural vegetation means that soil erosion and natural disasters such as flood and drought take place more frequently, the changed climate and soil erosion also make agriculture unproductive and the timber shortage will force people to log even younger trees and thus make the situation worse.

China has officially reported a rise in timber production over years to just 60 million cubic metres. However, its annual timber consumption reached 344 million cubic metres. Considering the intergenerational issue of property heritage including natural resources, the misuse of forest resources in China is not only the cause of the current timber shortage crises, but will also bring considerable problem for future generations. It is therefore crucial for China to determine a long-term strategy for conservation of its forest resources and proper consumption of its very limited timber reserves.

Summing up what we have discussed regarding the forest situation, it is clear that a forest crisis is taking place in China. That is why forest resources are selected for estimation of 'green' national accounts. The necessary economic and social analysis should be carried out in order to prevent further deforestation. If no action is taken, China will lose all its timber stocks in the near future and the consequences of this will lead to a series of social, economic and ecological problems.

Appendix 3.1 Secondary Woods in Daxinganling (Photograph)

Appendix 3.2 The Author (second from the left) in the Forest (Photograph)

Appendix 3.3 Soil Erosion after deforestation (Daxinganling)

Appendix 3.4 The author (first right) and local people in the deforested land (Daxinganling)

Chapter 4

Adjusted Forest Accounts for China

4.1. Data Limitations and the Scope of Accounting

4.1.1 Data Limitations

In order to determine the scale of economic rent in China's forest sector, the official statistics are used as the base for calculation, with some adjustments. We consider forest areas, forest cover and standing timber volumes disregarding ages, diameters and species. Owing to data limitations, the prices used in the analysis are the average prices for all kinds of timber. There is no logging cycle in China, and a timber harvest is conducted every year in the winter according to the state timber planning targets.

China has carried out four forest resources surveys throughout the periods 1973-1976, 1977-1981, 1984-1988 and 1989-1993. The most difficult task is to determine the reliability of the official statistics. From the official statistics we learn that forest areas, forest volume and forest cover are increasing every year. In contrast to this situation of apparent increase, there is observed depreciation of natural forests as discussed in the previous chapter. Since data from the fourth survey were not fully available, our analysis is confined to the four periods 1973-1976, 1977-1981, 1984-1988 and 1989-1992. The latest estimate was a general figure published in *China Environmental Report 1993*. Consumption of timber and forest resource reduction has been estimated and these estimates are used to calculate net measures of investment and national product from 1976 to 1992.

Careful analysis of the statistics suggests that, while officially there were increases in all areas, if we trace only timber resources, especially mature trees in natural forests, there is in fact a continuous decrease of forest volume over time. By subtracting the items "individual trees" and "trees along streets and around houses", we find that the volume of timber stock reduces to about 90 percent of the total timber stock. If we further subtract items of "sparse woods" and "withered trees", the total timber volume reduces to 8004 million cubic metres or 85 percent of total reported volume. In fact the volume from timber forest was only 76 percent of the total timber volume or 6173 million cubic metres in 1984-1988 (the Academy of China and the State Planning Commission 1989). We discovered that although the reported total timber volume increased, the volume of timber forests actually decreased over time because of timber logging. This is the reality of the forest resources and timber situation in China. In such a case we have to select the volume of timber forests as our basis of calculation. Repetto *et al* (1989) suggest that both timber volumes and areas can be used for forest accounts. Here we choose to use timber volume only, because areas of forests could have various densities and these statistics are not available.

4.1.2 Data Adjustment

We thus selected natural forests, mainly timber forests in China, as our research domain. China's natural forests have actually declined. At present the loss is not reflected in the national accounts. On the contrary, the net revenues from overexploiting forests have been treated as factor income, not as capital consumption. Tables 4.1 and Table 4.2 indicate the procedures of estimation for variations of timber stocks. Table 4.3 shows the adjusted timber volume. Growth and consumption are assumed to be constant in the calculation because we could not obtain data for each year's change. Prior to 1981, the official statistics did not make any mention of withered part of forests. For 'withered' timber, it would be preferable to derive a trend but it seemed difficult to extrapolate for ten years, and, we thus assumed that the volume of withered trees remained constant for each year. Thus when calculating the withered part starting from 1976, we based this on the average withered figure 35.5 million m^3. In addition, the four surveys excluded the period 1982-1983. We include this period in the 1984-1988 period for continuity of analysis. Fire damage and insect damage are calculated by using the official statistics. Fire damage is calculated by actual areas times average density of forests, 79.05 cubic metres/hectare, then divided by two since we assume that only half of fire areas would be accounted for damages. The volume of insect damage is also calculated by actual insect areas minus treated areas times the average density, then times 10 percent as we assumed that only 10 percent of insect area would be subject to insect damage or timber loss. Having finished all the loss calculations, there is still a gap between the published figures and our calculated figures: the calculated figures are smaller than the official figures. The reason is that we could not get the figures for logging damages, fuelwood use and illegal logging. We use an "adjustment" item to fill in the gap.

Table 4.1 illustrates the importance of factors other than harvest in explaining the reductions in timber stocks that occurred. It shows the ratio of timber reduction to net depletion. In all forest areas in China, fire and insect damage accounted for a large percentage of reductions in standing volume. While fire damage decreased gradually, insect damage steadily kept constant or increased year by year. Withered stock also accounted for part of the reduction.

Table 4.1 Variations of Timber Stocks (million m^3)

year	consumption (1)	withered (2)	fire damage (3)	insect damage (4)	reduction (5)=(1+2+3 +4)	growth (6)	net reduction (7)=(5)-(6)
1976	294.1	**	76.8	19.5	390.4	275.3	115.1
1977	294.1	**	101.9	17.1	413.1	275.3	137.8
1978	294.1	* *	19.5	17.0	330.6	275.3	55.3
1979	294.1	* *	39.5	24.4	358.0	275.3	82.7
1980	294.1	* *	13.9	34.4	342.4	275.3	67.1
1981	294.1	* *	16.2	37.7	347.9	275.3	72.6
1982	344.8	35.5	13.3	38.8	432.5	329.5	103.0
1983	344.8	35.5	6.9	36.6	423.8	329.5	94.3
1984	344.8	35.5	5.6	35.7	421.6	329.5	92.2
1985	344.8	35.5	5.5	38.9	424.7	329.5	95.2
1986	344.8	35.5	11.0	48.2	439.5	329.5	110.1
1987	344.8	35.5	63.7	40.2	484.3	329.5	154.8
1988	344.8	35.5	2.5	38.6	421.4	329.5	50.9
1989	344.8	35.5	1.2	51.7	433.2	329.5	103.7
1990	344.8	35.5	0.5	36.3	417.2	329.5	87.7
1991	344.8	35.5	0.8	27.4	408.5	329.5	79.0
1992	344.8	35.5	1.3	24.0	405.6	329.5	76.1

Sources: Adapted by the author from data in the Ministry of Forestry: *Statistics of Forestry 1987-1992,* Beijing.
*Fire and insect damage are calculated by fire area times forest density (79.05 M^3).
**Data are not available.

Table 4.2 Loss of Timber through Fires and Insects

year	fire area** (10000 ha) (1)	stock at risk from fire (million m^3) (2)	fire damage (million m^3) (3)= (2)/2	insect area* (10000 ha) (4)	stock at risk from insect (million m^3) (5)	insect damage (million m^3) (6)=(5)x0.1
1976	194.3	153.6	76.8	247.2	195.4	19.5
1977	257.9	203.9	101.9	216.3	171.0	17.1
1978	49.3	39.0	19.5	215.3	170.2	17.0
1979	99.8	78.9	39.5	308.9	244.2	24.4
1980	39.7	27.8	13.9	435.3	344.1	34.4
1981	41.0	32.4	16.2	476.4	376.6	37.7
1982	33.7	26.6	13.3	491.0	388.2	38.8
1983	17.4	13.8	6.9	462.5	365.6	36.6
1984	14.2	11.2	5.6	451.4	356.8	35.7
1985	14.0	11.0	5.5	491.5	388.5	38.9
1986	28.0	22.1	11.0	609.3	481.6	48.2
1987	115.2	91.1	63.7	508.4	401.9	40.2
1988	6.3	5.0	2.5	487.9	385.7	38.6
1989	2.9	2.3	1.2	653.7	516.8	51.7
1990	1.4	1.1	0.5	459.3	363.1	36.3
1991	1.9	1.5	0.8	346.1	273.6	27.4
1992	3.2	2.5	1.3	303.7	240.1	24.0

Sources: Adapted by the author from data in the Ministry of Forestry: *Statistics of Forestry 1984-1992,* Beijing.
*Insect area is the total damage area minus areas treated with insecticide. Insect damage is calculated at 10% of the areas.
** Area affected by fires. Fire damage is calculated at 50% of fire areas.

The stock of timber in logged-over forests increased for two reasons: residual timber in newly logged virgin forests that are classified as logged-over, and timber growth that occurred in existing logged-over forests. Here we only consider growth because this figure represents the growth from both logged-over forests and reforestation. As in natural forests, timber stocks decreased during logging due to harvest, defect, and damage, and they also decreased when

The stock of timber in logged-over forests increased for two reasons: residual timber in newly logged virgin forests that are classified as logged-over, and timber growth that occurred in existing logged-over forests. Here we only consider growth because this figure represents the growth from both logged-over forests and reforestation. As in natural forests, timber stocks decreased during logging due to harvest, defect, and damage, and they also decreased when forests were converted. Timber stocks also decreased as fires and insects rose yearly. Table 4.3 shows changes of forest volume in the whole country; these timber stocks were actually used in the present research.

Table 4.3 Stocks of Forest in China
(million cubic metres)

year	stocks (a)	growth (b)	consumption (c)	withered (d)	fire damage (e)	insect damage (f)	reduction (g)=(c+d+e+f)	net reduction (h)=(g)-(b)
1976	6881.9	275.3	294.1	*	76.8	19.5	390.4	115.1
1977	6766.8	275.3	294.1	*	101.9	17.1	413.1	137.8
1978	6629.0	275.3	294.1	*	19.5	17.0	330.6	55.3
1979	6573.7	275.3	294.1	*	39.5	24.4	358.0	82.7
1980	6491.1	275.3	294.1	*	13.9	34.4	342.4	67.1
1981	6424.0	275.3	294.1	*	16.2	37.7	347.9	72.6
1982	6351.4	329.5	344.8	35.5	13.3	38.8	432.5	103.0
1983	6248.4	329.5	344.8	35.5	6.9	36.6	423.8	94.3
1984	6154.1	329.5	344.8	35.5	5.6	35.7	421.6	92.2
1985	6061.9	329.5	344.8	35.5	5.5	38.9	424.7	95.2
1986	5966.7	329.5	344.8	35.5	11.0	48.2	439.5	110.1
1987	5856.6	329.5	344.8	35.5	63.7	40.2	484.3	154.8
1988	5701.8	329.5	344.8	35.5	2.5	38.6	421.4	50.9
1989	5650.9	329.5	344.8	35.5	1.2	51.7	433.2	103.7
1990	5547.2	329.5	344.8	35.5	0.5	36.3	417.2	87.7
1991	5459.5	329.5	344.8	35.5	0.8	27.4	408.5	79.0
1992	5380.5	329.5	344.8	35.5	1.3	24.0	405.6	76.1

Sources: Calculated from *Statistics of Forestry 1987-1992. Data Collection for Natural Resources of China, 1990.*
*Data are not availalbe.

Figure 4.1 Net Reduction of Forest Resources in China

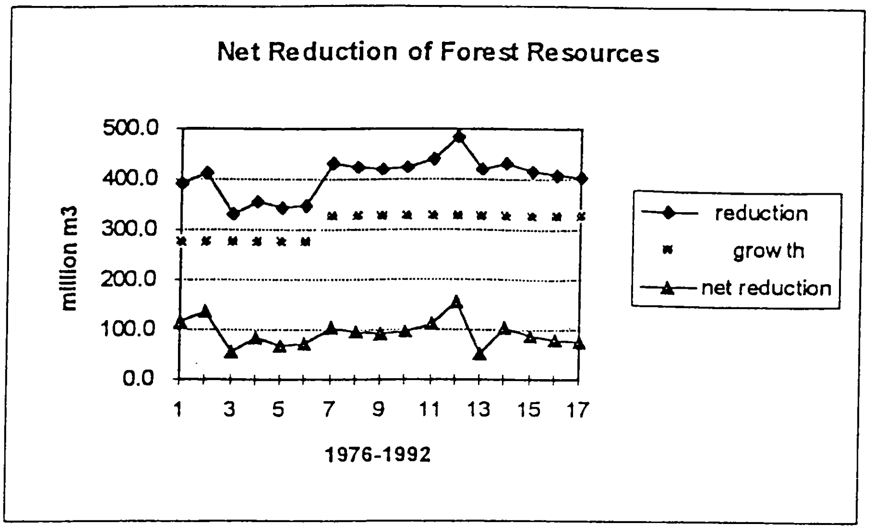


Table 4.4 shows the output of timber from 1976 to 1992. In light of differences in forest areas, forest cover and timber stocks in China, we divided the whole country into four parts: the northeast part and Inner Mongolia, which accounts for the largest area of forest in China; Sichuan and Yunnan Provinces, which is considered the second largest area of natural forests in China; ten south provinces including the provinces of: Guangdong (Hainan is also included.), Guangxi, Fujian, Zhejiang, Guizhou, Hunan, Hubei, Jiangxi and Anhui. Other Provinces include 14 municipalities and provinces of: Beijing, Tianjin, Shanghai, Hebei, Liaoning, Shandong, Henan, Shanxi, Shaanxi, Jiangsu, Ningxia, Qinghai, Gansu and Xinjiang, where virtually no natural forests exist. The natural forests in Tibet are normally inaccessible, but we present the data here in order to give a clear picture of China's total timber outputs. Another effect that should be mentioned is that the output of timber is lower than the reduction of forest volume. This implies that there is a large quantity of reduction due to consumption other than timber production (e.g. timber that is used as fuelwood, raw material for pulp, synthetic fibre and other purposes), illegal logging, fire and insect damage, plus other damages.

Table 4.4 Output of Each Region (1976-1992)
unit: million m^3

year	NE & IM	Sic & Yun	10 SProv	Tibet	others	total
1976	25.2	4.6	13.9	0.2	1.8	45.7
1977	25.2	5.2	16.8	0.2	2.3	49.7
1978	25.7	5.9	17.1	0.2	2.8	51.6
1979	26.6	6.6	18.0	0.2	3.0	54.4
1980	26.7	6.6	17.2	0.2	2.8	53.6
1981	25.8	5.4	15.8	0.2	2.2	49.4
1982	26.7	5.4	15.7	0.2	2.4	50.4
1983	27.3	5.6	16.8	0.2	2.4	52.3
1984	27.8	7.6	25.4	0.2	2.8	63.8
1985	28.0	7.5	24.0	0.3	3.3	63.2
1986	30.9	7.7	22.7	0.3	3.5	65.0
1987	31.3	7.9	21.3	0.2	3.4	64.1
1988	31.6	7.8	19.6	0.3	2.7	62.1
1989	29.6	6.8	17.5	0.2	3.6	57.7
1990	26.2	6.2	17.9	0.2	5.1	55.6
1991	24.0	6.9	19.5	0.2	7.4	58.0
1992	22.8	7.4	24.0	0.2	7.3	61.7

NE & IM = Northeast China and Inner Mongolia
SIC & Yun = Sichuan and Yunnan Provinces
10SProv = 10 southern provinces in China
Sources: The Ministry of Forestry: *Statistics of Forestry 1984-1992*, Beijing.

4.2 Estimating Stumpage Value

4.2.1 Unit Cost and Unit Price

As is well-known, marginal cost is a crucial element in calculating Hartwick's rent. However, there is little empirical work which has attempted to derive numerical values for marginal cost to estimate economic rent. Daly (1989), Devarajan and Weiner (1990), Bartelmus (1992), Adger and Whilby (1993) and Pearce *et al* (1993) discuss the treatment of average cost statistics in calculating environment-adjusted national accounts. In practice, average cost is commonly substituted when deriving economic rent, as in the case studies of Indonesia (Repetto *et al* 1991), Mexico (van Tongeren *et al* 1991), Costa Rica (Solorzano *et al* 1991), Papua New Guinea (Bartelmus *et al* 1992) and Malaysia (Vincent and Ali 1994). Average cost is used in this analysis since data deficiencies prevent us from estimating marginal cost. Estimates of natural resource depreciation using average cost can be biased upwards or downwards.

In practice, China's forest resources are *de facto* not tradeable. But we choose to the use of International prices, in order to correct price distortions. We do not have in hand the data of costs for 1977-1981. However, we do have timber prices of 1980 and 1981, and from these data we know that the costs are just one half of prices, then we can get the rough costs in 1980 and 1981. These two estimates are used as the average costs in our analyses.

4.2.2 Stumpage Value

The stumpage value represents the value of timber stocks valued at timber sale proceeds, less the costs of logging, transportation, and processing. Better quality and more accessible timber stands will command a higher stumpage value theoretically. We thus use the average market prices to reach an average stumpage value. The relevant measure of monetary value to be applied to these changes in the physical resource base is the value of the standing timber prior to any value added by processing. In a market economy with full knowledge of the resource and competitive bidding, this is the maximum amount a concessionaire would pay for harvesting rights. However, in China to date all logging work is done by governmental-run forest bureaus with no competitive bidding, and thus the cheap logging costs have contributed to the decline of forest resources. In calculating the stumpage value of timber, we adjust all the values by national income deflators. Stumpage value is given by:

$$S_V = P_S - (1 + r)(C_M + C_T + C_H) = P_S - AC \qquad (1)$$

Where:

S_V = stumpage value

P_S = price of marketable products

r = standard profit margin or return on capital, equal to the prevailing interest rate

C_M = cost of management

C_T = cost of transport

C_H = harvesting costs

AC = average costs

Here timber stocks refer to all the standing trees with no classification of age, height and diameters, as these indicators cannot be found in the official statistics. Volumes are estimated based on volume of standing trees as opposed to volume of usable timber. The accounts were based on the following general assumptions about changes in areas and stocks. There was basically no virgin forest left in China (except 5 million m^3 of inaccessible virgin forests in Tibet). All the forests are logged-over forests, mostly secondary forests with fewer species and lower density. When a hectare of virgin forest was logged, only a portion of the timber stock on it was harvested. Some of the timber could not be harvested because it was defective, and some was lost due to logging damage. What remains was added to the stock of logged-over forests if the hectare was not converted for other purposes. If the hectare was converted, it was a loss. However, this kind of logging damage could not be found in any of the statistics. Furthermore, we know that every year a certain volume of timber stock is logged for use as fuelwood, but here it was also hard to determine the figure from statistics. The only estimation we could use was the adjustment of reduction of timber stock after estimating all losses. This figure was used to represent both logging damage and fuel usage.

Unit costs and unit prices were obtained from field work in Daxinganling forest. Based on the cost and price data from Daxinganling, we applied these data to all areas in China. We assumed costs and prices are applicable to all areas in China since the unified costs and prices are also the fact in the centrally-planned economy. We use the international timber price (FAO 1995) for our calculations. We adjusted the unit price and the average cost with deflators (1980 = 1). Figures shown in Table 4.5 are inflation-adjusted real values. To derive the cost of 1980 and 1981 we divided the price by two, so that the costs of 1980 and 1981 should be 34 yuan/m^3 and 45.8 yuan/m^3. This procedure is only approximate, but data limitations prevent a more sophisticated analysis.

Table 4.5 Stumpage Value (1980 price) unit: yuan/m^3

year	real price	real cost	stumpage value
1976	86.3	37.6	48.7
1977	96.8	37.2	59.6
1978	101.9	36.7	65.3
1979	133.2	35.9	97.3
1980	137.7	34.0	103.7
1981	139.1	45.8	93.3
1982	136.3	49.8	86.5
1983	120.1	49.3	70.7
1984	161.2	47.6	113.6
1985	162.3	44.7	117.6
1986	193.3	48.0	145.3
1987	205.3	54.0	151.3
1988	225.5	61.1	164.3
1989	219.2	65.9	153.4

1990	289.7	65.0	224.7
1991	284.1	65.5	218.6
1992	332.1	69.3	262.8

Sources: 1) Data obtained from the Forest Management Bureau of Daxinganling, Jiagedaqi, July-August 1994. 2) *The Statistical Yearbook of China 1993*, Beijing.

4.3 Estimating Depreciation

4.3.1 Economic Depreciation by the Net Price Approach

Theoretically, physical depreciation of forest resources can be expressed as the difference between the final area and the initial area of forests. Differences in surface area are produced by changes in the extent of logged-over lands, secondary forests, and newly reforested areas. In this sense, the appreciation or depreciation of the forest resource equals the final volume of timber in a given period less the volume at the beginning of the period. The volume at the end of a period equals the initial volume plus the increases due to growth and new forests minus the changes due to deforestation, exploitation, damage, and fires.

The monetary depreciation of the forest asset is the difference between the stumpage value of the forest at the beginning and the end of the year. Depreciation is equal to the decline in the present value of a forest's future profits due to harvesting, fire damage, insect damage and other loss. The capital value of a forest does not depreciate if these reductions do not surpass growth in the same period. But reduction in excess of growth reduces the total value of the asset and depreciates the resource. When reduction exceeds growth, the part of production that exceeds growth and diminishes the potential usage of forests, in conventional GNP, is regarded as part of the national income instead of capital consumption.

We calculated the change of timber stocks in the previous section. The reduction of timber volume times the stumpage value equals economic depreciation. Table 4.6 shows depreciation by the net price approach. From 1976 to 1992 economic depreciation was from 2.02 billion yuan to 8.31 billion yuan. The comparison between depreciation, GNP and the gross product of the forestry sector (GOP) was made. We found that the depreciation accounts for from 0.4 percent to 1.8 percent of GNP and accounts for from 24 percent to 55 percent of GOP.

Table 4.6 Depreciation of Forest Resources and Ratios to GNP and GOP
(billion yuan)

year	depreciation	GNP	ratio GNP/ depreciation	GOP	ratio GOP/ depreciation
1976	4.33	269.5	0.016	8.3	0.52
1977	5.13	291.6	0.018	10.0	0.53
1978	2.02	390.3	0.005	11.6	0.17
1979	2.98	430.3	0.007	16.6	0.18
1980	2.28	455.9	0.005	17.5	0.13
1981	3.33	473.7	0.007	15.6	0.21
1982	5.18	509.1	0.010	14.9	0.35
1983	4.98	561.1	0.009	13.1	0.38
1984	4.64	643.9	0.007	19.1	0.24
1985	4.76	719.2	0.007	18.9	0.25
1986	5.27	786.6	0.007	22.8	0.23
1987	9.57	850.8	0.011	18.6	0.51
1988	5.02	973.6	0.005	16.1	0.31
1989	8.31	1016.0	0.008	15.1	0.55
1990	5.84	1063.5	0.005	22.1	0.26
1991	6.07	1147.1	0.005	19.3	0.31
1992	5.70	1299.5	0.004	24.0	0.24

Sources: calculated by the author.

4.4 The User Cost Approach versus the Net Price Approach

4.4.1 Adjustment for Calculating User Cost

We also calculated forest-adjusted accounts by using El Serafy's (1989) user cost approach to reach forest-adjusted income account in China. According to El Serafy's user cost approach, it is necessary to determine the amount that would be crucial to keep income generating investments, so that at the point at which the natural resources are exhausted, the accumulated man-made assets should be high enough to cover the loss of natural resources.

We followed the concept of El Serafy's user cost approach and modified the procedures developed by da Motta, May and Young (1991) to derive forest-adjusted income accounts for China. Since El Serafy's user cost is for nonrenewables, it is necessary to adjust the stocks of forest resources. For the treatment of the change of forest stocks, we calculate the net depletion by taking growth, consumption, fire and insect damage of forests into account. Here K represents the physical stock of forest resource at a particular point in time, g is the natural growth rate of forest resource, Q represents the quantity of timber logging in that period and D denotes the damage to forests. Thus we have,

$$K_{t+1} = K_t(1 + g) - Q - D \tag{9}$$

If P_t is the net price, then the initial flow of income Y_t can be measured as

$$Y_t = P_t \cdot Q_t \tag{10}$$

The following step of the calculation was to determine value added from gross output value in the forestry sector. Then we derived the value added (Y_t). The value added is defined as the difference between gross output value (OV_t) and intermediate cost (IC_t) of production. This difference equals the sum of wages (WA_t), social charges (SC_t) and the gross operating surplus

(OS_t). The gross operating surplus can be divided into two parts: the "normal" capital remuneration (CR_t) and the total rent (TR_t). Since all the other variables are known, the rent may be obtained residually by:

$$Y_t = OV_t - IC_t \tag{11}$$

$$Y_t = WA_t + SC_t + OS_t \tag{12}$$

The user cost can be defined as:

$$UC_t = OS_t - CR_t \tag{13}$$

In Table 4.7 the total product of the forest sector from 1976 to 1992 was presented as published in the official statistics. It is important to explain here that the intermediate cost in output is quite high compared with other countries, because in the Chinese accounting system, expenses such as capital remuneration and social cost, are already included. Therefore, between the value added and the rent is solely wages; we adjusted the equations to:

$$Y_t = WA_t + CR_t + UC_t \tag{14}$$

$$UC_t = Y_t - WA_t - CR_t \tag{15}$$

As for calculation of the user cost, we listed the changes of stocks to derive the periods of timber consumption. According to the stocks from each year, we derived the period for timber consumption. The consumption period we derived varied from less than 50 years to over 100 years, according to the net depletion of the year. Based on these calculations we derive the value added, and the user cost. Depreciation is a measure of the past investment level that would have to be set aside to maintain the productive capacity in the forestry sector. The value added is defined as gross output minus intermediate cost and social cost. The user cost is derived from the value added minus wages. This was the procedure to calculate the user cost or depreciation of zero percent discount rate. From 1976 to 1992, the rent at zero percent of discount rate ranged from 1.25 billion yuan to 2.9 billion yuan. For 5 and 10 percent of discount rates, there was a difference in between. This phenomenon reflected the fact that the discount rate is not very sensitive, as noted by Young and da Motta (1995).

4.4.2 Results

According to the results we estimated the user cost at zero discount rate for consumption of timber. 5 and 10 percent discount rates were chosen to derive the discount factors for each year from 1976-1992. All the discount factors derived here were very close to each other and there was little difference between 5 and 10 percent discount factors. The gross product of the forestry sector was used to find out the value added in the sector. The deduction of the intermediate cost of production provided the value added from 1976 to 1992. Higher discount rates entail higher income for the present time. As the discount rate increases, the user cost gets smaller and in some years with 10 percent discount factor the user cost was zero.

Table 4.7 is the calculation of the value added and the user cost at zero percent discount rate. Column (1) is the gross product of the forestry sector. Column (2) is the value added of the forestry sector. Column (3) is the capital remuneration and Columns (4) is wage. At last Column (5) is the user cost.

Table 4.7 User Cost At Zero Percent Discount Rate
(100 million yuan) (1980 price)

year	GOP	value added	capital remuneration	wage	user cost
1976	83.4	36.1	0.3	12.9	22.9
1977	99.7	50.9	0.6	13.1	37.2
1978	116.1	63.8	0.9	16.8	46.0
1979	166.1	111.2	1.4	17.5	92.2

1980	175.6	127.9	1.9	18.6	107.4
1981	156.2	96.1	2.3	19.4	74.5
1982	148.9	86.9	2.7	20.3	64.0
1983	131.4	68.1	3.0	20.3	44.9
1984	190.9	125.9	3.4	21.6	101.2
1985	189.5	129.1	3.7	21.5	104.5
1986	227.7	165.6	4.0	24.5	137.9
1987	186.1	128.3	4.3	25.2	99.9
1988	161.0	94.3	4.6	28.2	62.8
1989	150.7	91.3	4.8	28.8	59.5
1990	220.8	165.0	5.0	27.2	134.8
1991	192.5	140.0	5.2	29.3	107.7
1992	240.0	182.9	5.4	31.5	148.5

GOP=the gross product of the forest sector
Sources: Calculated by the author from *The Statistical Yearbook of China (1993)* and *Data Volume for Land Resources in China*, vol. 1.

Table 4.8 Calculation of User Cost and Forest Depreciation
(100 million yuan) (1980 price)

year	value added	user cost			income		
		r=0%	r=5%	r=10%	r=0%	r=5%	r=10%
1976	36.1	22.9	1.4	0.1	13.3	34.8	36.1
1977	50.9	37.2	4.5	0.4	13.7	46.4	50.5
1978	63.8	46.0	0.1	0.0	17.8	63.7	63.8
1979	111.2	92.2	1.9	0.0	19.0	109.2	111.1
1980	127.9	107.4	0.9	0.0	20.5	127.0	127.9
1981	96.1	74.5	0.9	0.0	21.7	95.2	96.1
1982	86.9	64.0	3.3	0.1	22.9	83.6	86.7
1983	68.1	44.9	1.9	0.1	23.2	66.2	68.1
1984	125.9	101.2	4.8	0.2	24.7	121.1	125.7
1985	129.1	104.5	5.5	0.3	24.6	123.7	128.9
1986*	165.6	137.9	10.7	0.8	27.7	154.8	164.8

1987*	128.3	99.9	18.3	2.9	28.4	110.0	125.5
1988	94.3	62.8	0.3	0.0	31.4	94.0	94.3
1989	91.3	59.5	5.9	0.4	31.8	85.5	90.9
1990	165.0	134.8	6.5	0.3	30.2	158.6	164.7
1991	140.0	107.7	3.8	0.1	32.2	136.1	139.8
1992	182.9	148.5	4.4	0.1	34.4	178.5	182.7

*Data are from reforestation.
Source: Calculated by the author.

Young and da Motta (1995) claim that the user cost approach is highly sensitive to the depletion period, but not particularly sensitive to the discount rate. The use of 5 percent and 10 percent discount rates also makes little difference in our calculation. The results show that there is a significant difference between using the net price approach and the user cost approach in forest accounts, as has also been result found by other authors (da Motta and May 1992, Young and da Motta 1995). The depreciation of forest resources derived using the net price approach was much higher than that derived with the user cost approach. For a certain number of years the depreciation from the net price approach is even higher than the gross product of the whole forest sector, suggesting a serious inconsistency in the net price approach. We believe that depreciation estimated using the user cost approach was more reliable, because (1) it reflected the correct value of a net loss in the forest sector; (2) the user cost approach is more stable throughout the year of timber production, which is the reality in China for timber production; (3) the user cost approach reflects the real scarcity of forest resources, since deduction from conventional production values is significant only if the actual rate of extraction implies imminent exhaustion of the resources. The results shown here provide reason to question the general application of Repetto's net price approach (1989, 1991) and it may be that this approach is suitable only for specific cases.

4.5 Estimates of Sustainability in the Forestry Sector from Loss of Forests

4.5.1 Adjusted Gross Product of Forestry Sector

Sustainable income is that which maintains intact the present value of the flows anticipated from a natural resource. Therefore, the test of sustainability is not the level of gross investment, but rather the absolute level of *net investment*: whether it is positive or negative. Net investment is positive every year, which implies that total capital stock rose: the accumulation of man-made capital more than offset the depletion of natural capital stocks. The comparison between depreciation and the gross product of the forestry sector is given in Table 4.9. The ratio of depreciation to the gross output of forestry under the user cost approach ranges from 10 to 23 percent. The ratio of depreciation to the gross output of forestry under the net price approach varies from about 50 percent to over 100 percent. For example, in 1992, the gross output was 10.4 billion yuan, the depreciation for that year was 10.5 billion yuan according to the net price approach, and 1.0 billion yuan according to the user cost approach. As noted earlier, depreciation was higher in that year than the gross product of the forest sector under the net price approach. In Table 4.10 the comparison between the depreciations of both approaches to the GNP and the NNP is made. The forest-adjusted net national product according to both approaches is also estimated. The depreciation is higher under the net price approach than under the user cost approach, and accounts for more than 1 percent of the original GNP. The depreciation under the user cost approach accounts for about 0.5 percent of the original GNP.

Table 4.9 Adjusted Gross Product of the Forest Sector under Two approaches (100 million yuan) (1980 price)

year	real GOP (a)	depreciation (user cost) (b)	adjusted GOP (user cost) (c)=(a)-(b)	depreciation (net price) (d)	adjusted GOP (e)=(a)-(d)	depreciation/GOP (user cost) (f)	depreciation/GOP (net price) (g)
1976	83.4	22.9	60.5	43.3	40.1	0.27	0.52
1977	99.7	37.2	62.5	51.3	48.4	0.37	0.51
1978	116.1	46.0	70.1	20.2	95.9	0.40	0.17
1979	166.1	92.2	73.9	29.8	136.3	0.56	0.18
1980	175.6	107.4	68.2	22.8	152.8	0.61	0.13
1981	156.2	74.5	81.7	33.3	122.9	0.48	0.21
1982	148.9	64.0	84.9	51.8	97.1	0.43	0.35
1983	131.4	44.9	86.5	49.8	81.6	0.34	0.38
1984	190.9	101.2	89.7	46.4	144.5	0.53	0.24
1985	189.5	104.5	85.0	47.6	141.9	0.55	0.25
1986*	227.7	137.9	89.8	52.7	175.0	0.61	0.23
1987*	186.1	99.9	86.2	95.7	90.4	0.54	0.51
1988	161.0	62.8	98.2	50.2	110.8	0.39	0.31
1989	150.7	59.5	91.2	83.1	67.6	0.39	0.55
1990	220.8	134.8	86.0	58.4	162.4	0.61	0.26
1991	192.5	107.7	84.8	60.7	131.8	0.56	0.32
1992	240.0	148.5	91.5	57.0	183.0	0.62	0.24

*Data from reforestation.

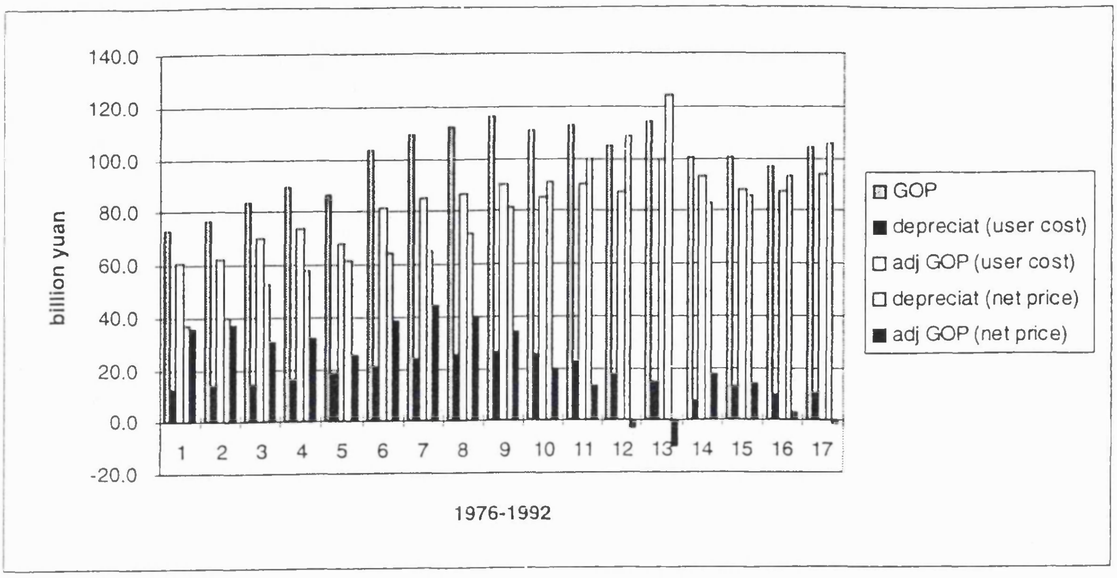
Source: Calculated by the author.

Table 4.10 Comparison of Depreciation and adjusted NNP
(billion yuan) (1980 price)

year	GNP (a)	NNP (b)	depreciation (user cost) (c)	depreciation (net price) (d)	FNNP (user cost) (f)=(b)-(c)	FNNP (net price) (g)=(b)-(d)
1976	269.5	254.6	1.3	4.3	253.3	250.3
1977	291.6	275.2	1.4	5.1	273.8	270.1
1978	390.3	372.3	1.4	2.0	370.9	370.3
1979	430.3	411.2	1.6	3.0	409.6	408.3
1980	455.9	434.1	1.9	2.3	432.2	431.8
1981	473.7	450.5	2.1	3.3	448.4	447.2
1982	509.1	484.1	2.4	5.2	481.7	478.7
1983	561.1	533.5	2.5	5.0	531.0	528.5
1984	643.9	614.2	2.6	4.6	611.6	609.6
1985	719.2	687.9	2.5	4.8	665.4	683.1
1986	786.6	751.2	2.2	5.3	739.0	745.9
1987	850.8	813.6	1.8	9.6	811.8	804.0
1988	973.6	933.0	1.5	5.0	931.5	928.0
1989	1016.0	973.6	0.7	8.3	972.9	965.3
1990	1063.5	1019.7	1.2	5.8	1018.5	1013.9
1991	1147.1	1091.9	0.9	6.1	1091.0	1085.8
1992	1299.5	1299.5	1.0	5.7	1298.5	1293.8

Source: Calculated by the author.

Figure 4. 2 Adjusted Gross Product under Two Approaches



4.5.2 Net Investment

We estimated net investment for the forestry sector. We found that depreciation surpassed investment every year in the forestry sector (see Table 4.11). The net investment in the forestry sector was negative from 1976 to 1992. For example, investment was 760 million yuan in real terms in 1976, depreciation was 2290 million yuan by the user cost approach and 4330 million yuan by the net price approach. Thus net investment in that year was -1530 million yuan and -3570 million yuan under the user cost and the net price approaches respectively. The forest sector was unsustainable development at this stage by estimation of net investment level..

Table 4.11 Net Investment and Sustainability
(100 million yuan) (1980 price)

year	investment	depreciation (user cost)	net investment (user cost)	depreciation (net price)	net investment (net price)
1976	7.6	22.9	-15.3	43.3	-35.7
1977	6.5	37.2	-30.7	51.3	-44.8
1978	9.2	46.0	-36.8	20.2	-11.0
1979	12.4	92.2	-80.2	29.8	-17.4
1980	13.8	107.4	-93.6	22.8	-9.0
1981	13.1	74.5	-61.4	33.3	-20.2
1982	11.5	64.0	-52.5	51.8	-40.3
1983	11.5	44.9	-33.4	49.8	-38.3
1984	12.1	101.2	-89.1	46.4	-34.3
1985	11.5	104.5	-93.0	47.6	-36.1
1986	11.0	137.9	-126.9	52.7	-41.7
1987	11.6	99.9	-88.3	95.7	-84.1
1988	12.5	62.8	-50.3	50.2	-37.7
1989	9.7	59.5	-49.8	83.1	-73.4
1990	9.2	134.8	-125.6	58.4	-49.2
1991	9.8	107.7	-97.9	60.7	-50.9
1992	10.2	148.5	-138.3	57.0	-46.8

Sources: Calculated by the author.

Figure 4.3 GNP and Forest-adjusted NNP

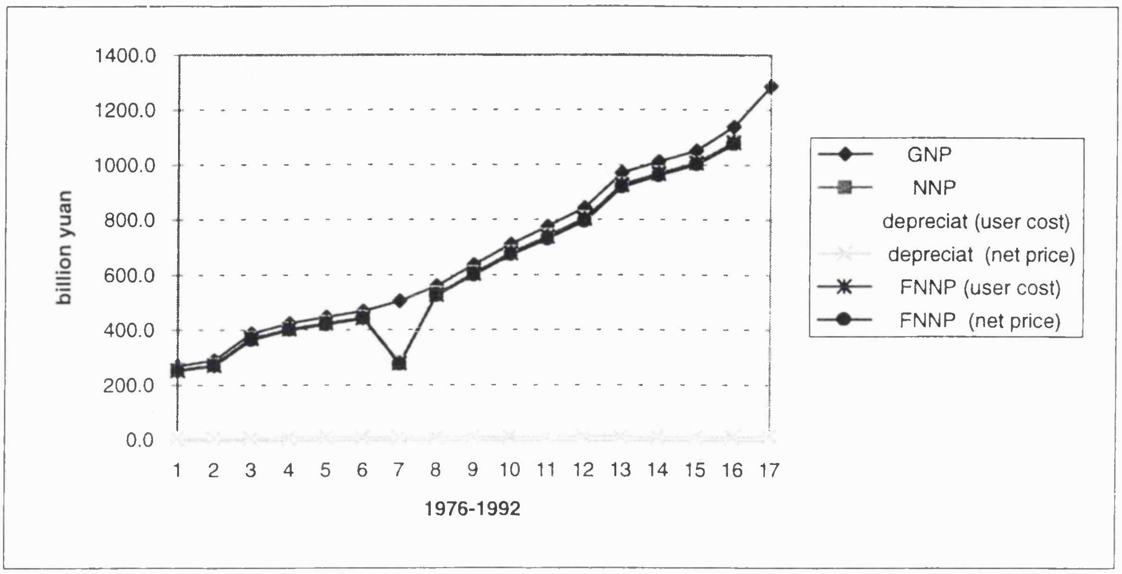
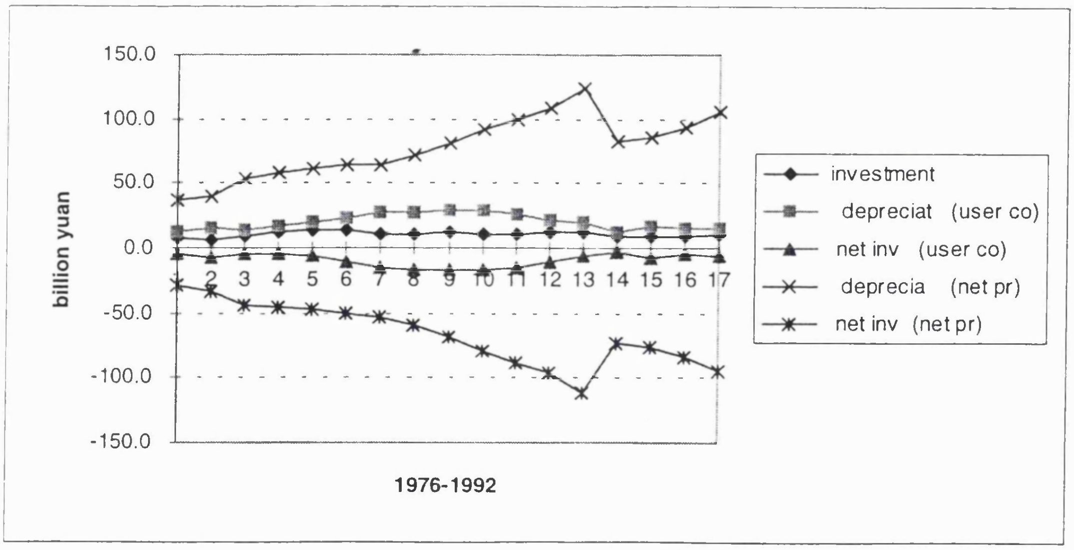


Figure 4.4 Net Investment of the Forest Sector in China



4.6 Conclusion

In this chapter we have calculated stumpage value, forest depreciation and green forestry output using both the net price approach and the user cost approach. It is clear that the depreciation of the forest resources accounts for a high percentage of the gross product of the forest sector. It is also proves to be significant to the overall GNP because the depreciation from both approaches is proved less than 1 percent and more than 1 percent of the GNP, for only one sector is it really high.

The sustainability of the forestry sector has been evaluated. The estimation indicated that there was a loss in forest resources, especially in timber forests. The loss was also reflected in the forest-adjusted-NNP with depreciation of forest capital. The overall investment level in the forestry sector did not show high enough with forest depreciation. The forestry sector should keep the present investment level to maintain sustainable development. The depreciation in the main timber production regions was consistent with our statement that there has been a serious decline in timber forests in China. The analysis suggests a serious situation and hence we will investigate the causes of declining forest resources later in this thesis, proposing certain policies to restore sustainable development in the forestry sector in China.

Appendices

Appendix 4.1: Timber Output from NE & IM
unit: million cubic metres

year	Heilongjiang	Jilin	Inner Mongolia*	total
1976	19.2	6.0	0.0	25.2
1977	19.3	5.9	0.0	25.2
1978	19.5	6.1	0.0	25.7
1979	16.4	6.2	4.0	26.6
1980	16.2	6.3	4.1	26.7
1981	15.4	6.1	4.3	25.8
1982	16.1	6.1	4.5	26.7
1983	16.4	6.1	4.8	27.3
1984	16.7	6.3	4.8	27.8
1985	16.7	6.4	5.0	28.0
1986	17.7	6.9	6.3	30.9
1987	18.5	6.8	6.0	31.3
1988	12.7	6.4	6.0	25.1
1989	12.0	6.2	5.3	23.5
1990	10.7	6.0	5.3	21.9
1991	9.9	5.6	4.8	20.4
1992	9.1	5.2	4.9	19.2

Sources: The Ministry of Forestry: Statistics of Forestry 1984-1992, Beijing.
*Daxinganling forests belonged entirely to Heilongjiang Province during 1969-1978.

Appendix 4.2 Period of Timber Consumption
(100 million cubic metres)

year	stock	reduction	period	r=5%			r=10%		
				(1+r)n	1/(1+r)n	discount	(1+r)n	1/(1+r)n	discount
1976	6766.8	115.1	58.8	17.60443	0.0568	0.9432	271.1980	0.0037	0.9963
1977	6629.0	137.8	48.1	10.45332	0.0957	0.9043	97.9679	0.0102	0.9898
1978	6573.7	55.3	118.9	331.2954	0.0030	0.9970	83785.3783	0.0000	1.0000
1979	6491.1	82.7	78.5	46.12477	0.0217	0.9783	1780.1126	0.0006	0.9994
1980	6424.0	67.1	95.8	107.108	0.0093	0.9907	9229.9269	0.0001	0.9999
1981	6351.4	72.6	87.5	71.36438	0.0140	0.9860	4175.6363	0.0002	0.9998
1982	6248.4	103.0	60.7	19.29413	0.0518	0.9482	324.3703	0.0031	0.9969
1983	6154.1	94.3	65.3	24.13675	0.0414	0.9586	502.3692	0.0020	0.9980
1984	6061.9	92.2	65.8	24.75973	0.0404	0.9596	528.0104	0.0019	0.9981
1985	5966.7	95.2	62.6	21.25611	0.0470	0.9530	391.9235	0.0026	0.9974
1986	5856.6	110.1	53.2	13.4071	0.0746	0.9254	159.3002	0.0063	0.9937
1987	5701.8	154.8	36.8	6.032136	0.1658	0.8342	33.4679	0.0299	0.9701
1988	5650.9	50.9	111.1	225.6095	0.0044	0.9956	39556.3100	0.0000	1.0000
1989	5547.2	103.7	53.5	13.59455	0.0736	0.9264	163.6801	0.0061	0.9939
1990	5459.5	87.7	62.2	20.84123	0.0480	0.9520	377.1193	0.0027	0.9973
1991	5380.5	79.0	68.1	27.7546	0.0360	0.9640	659.9532	0.0015	0.9985
1992	5304.4	76.1	69.7	29.948	0.0334	0.9666	765.6706	0.0013	0.9987

Source: Calculated by the author.

Chapter 5

Coal-Adjusted Account in China

5.1 Reserves and Quality of Coal in China

5.1.1 Reserves of Coal

China is the largest coal producer and consumer in the world. The industrial and economic development in China depends significantly on coal, which is its main energy resource, accounting for about 75 percent of energy consumption. China has large and widespread stocks of coal. In 1992, the geologically surveyed stocks of coal in China stood at 983.3 billion tonnes, of which, proven stocks which can be mined make up 366.7 billion tonnes (*Annual Report of Mineral Resources 1989, 1992*). Of total stocks, coking coal makes up 31 percent, anthracite, 13 percent, bituminous coal, 43 percent and lignite, 13 percent. The proven stocks of coal are used as our research base.

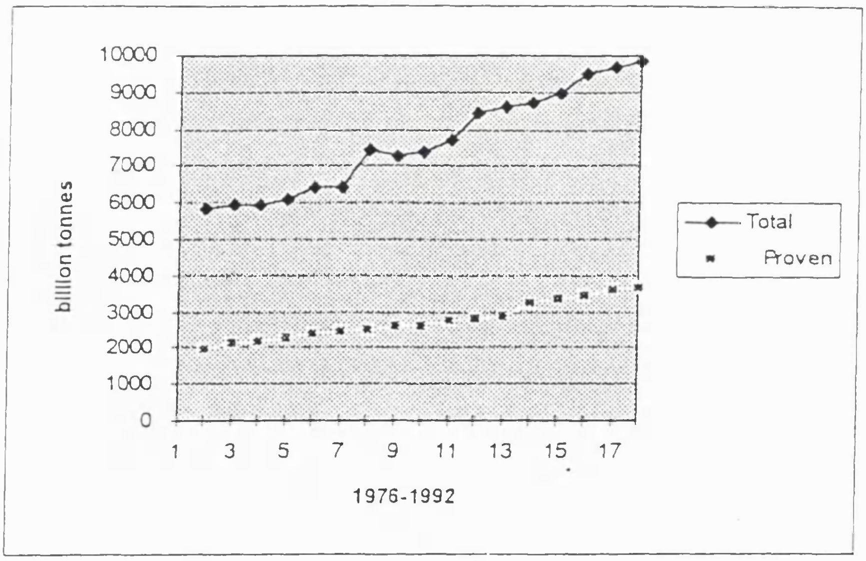
Table 5.1 Stocks of Coal in China
(billion tonnes)

year	total stocks	proven stocks
1976	584.7	197.9
1977	594.7	210.2
1978	596.0	220.7
1979	609.7	230.4
1980	642.5	240.4
1981	642.7	242.8
1982	742.1	251.5
1983	727.6	258.5
1984	737.1	263.2
1985	769.2	275.3

1986	845.9	281.6
1987	859.4	287.7
1988	873.7	323.4
1989	901.5	337.0
1990	954.4	347.4
1991	966.7	365.4
1992	983.3	366.7

Sources: *Annual Report of Mineral Resources 1988, 1992.*
Data provided by the Mineral Information Institute, Beijing.

Figure 5.1 Coal Stocks in China



5.1.2 Quality of Coal

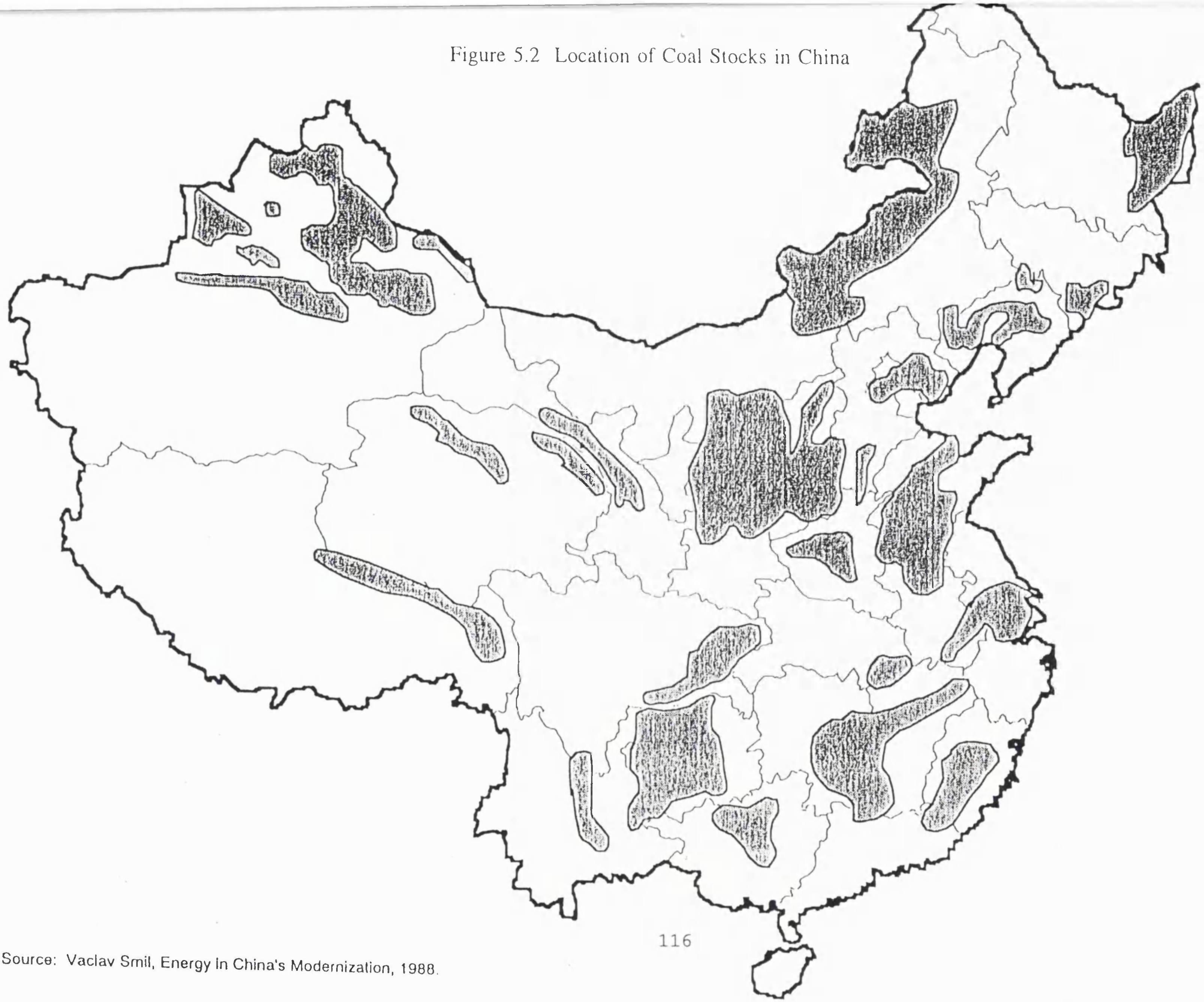
According to *Annual Report of Mineral Resources* (1988, 1992), the average ash content of coal is approximately 20 percent, but the typical ash content of coal used by industrial and utility boilers seems to be higher, at around 20-30 percent. This also reflects the more general problems of quality control in mining and handling, and lack of screening and blending practices throughout the industry. Only 86 million tonnes of coal were washed in 1990, which was about 8 percent of the total output for that year. Most of this coal is coking coal, which must be washed for use in the steel industry.

The following table indicates the ash and sulphur content of Chinese coal reserves:

	ash(%)	sulphur(%)
coking coal	10-40	0.5-4.0
anthracite	20-30	2-5
bituminous coal	5-30	0.5-0.7
lignite	10-30	1.0-3.0

Source: *Annual Report of Mineral Resources*, Resource Management Department, Ministry of Geology and Minerals, Beijing, 1989.

Figure 5.2 Location of Coal Stocks in China



Source: Vaclav Smil, Energy In China's Modernization, 1988.

The quality of coal with respect to sulphur content varies (*Annual Report of Mineral Resources 1988, 1992*). In North China the sulphur content is below 1 percent and about 40 percent of coal reserves have less than 1 percent of sulphur content. In the south, sulphur content is higher. Within coking coal, both ash and sulphur contents are within the medium range, with ash content above 20 percent and sulphur content above 2 percent. Anthracite has low a ash and sulphur content compared with other types of coal; in some areas sulphur content is around 3-5 percent. Bituminous coal has high ash and sulphur contents, as does lignite. Thus, the average sulphur content of coal tends to be between 1.2-1.7 percent. This reflects the fact that much of the coal produced locally is still of poor quality.

Of all the proven reserves, extractable coal constitutes 260 billion tonnes (*Annual Resport of Mineral Resources 1988, 1992*). The rest is difficult to mine using current technology. Most of the coal stocks are in the west and north parts of China. Shanxi, Inner Mongolia and Snaanxi possess over 69 percent of the total reserves in China. Coal quality in the north is better than in the south. Coking coal is primarily located in 9 provinces: Shanxi, Anhui, Shandong, Guizhou, Hebei, Xinjiang, Henan, Shaanxi and Inner Mongolia. Over 91 percent of coking coal is found here. Anthracite occurs mainly located in Shanxi, Guizhou, Henan, Sichuan, Hebei and Beijing, bituminous coal in Shaanxi, Inner Mongolia, Shanxi, Ningxia and Xinjiang while lignite tends to be located in the two provinces: Inner Mongolia and Yunnan. 92 percent of lignite is found here.

5.2 Production of Coal

5.2.1 Production Situation

Coal is used as the main resource in China's energy sector, accounting for 74 percent of energy consumption in 1991. Since 1989 China has been the world's largest producer and consumer of coal. The coal output has increased steadily year by year from 483 million tonnes in 1976 to 1116 million tonnes in 1992 (*China Statistical Yearbook 1988, 1989, 1993, 1994*). Production has grown at an average rate of around 6 percent per annum from 1976-1992. This suggests a large increase in production of 30-60 million tonnes per annum. Most of the coal is used to meet domestic demands. About 60 percent of households use coal as the major source of energy in heating and cooking. Because of the small size of stoves, the utilisation of heat value is low, around 15 percent (Jiang and Jiang 1992). Figure 5.2 shows the output of coal from 1980 to 1990.

Table 5.2 Output of Coal in China (1980-1990)

(million tonnes)

year	total	steam & coking	anthracite	lignite
1980	620	467	129	24
1981	622	467	131	23
1982	666	502	139	25
1983	715	536	152	27
1984	789	589	170	30
1985	872	658	182	32
1986	894	677	185	32
1987	928	703	192	33
1988	980	741	202	37
1989	1054	793	218	43
1990	1080	822	213	45

Source: *China Energy Statistical Yearbook 1991*, China Statistical Press, Beijing, 1992.

Coal mining is widespread throughout China, coal being produced in almost every province. In the northern and western parts of China, coal is produced from local mines close to the market or the end user. However, the industrial regions in the eastern, northeastern and southeastern parts of China are deficient in coal. Yet, these regions rely heavily on coal, which puts pressure on the transport system, mainly rail in China. The size and ownership of coal mines are various, from large, modernised mines to small labour-intensive mines operating on shallow seams. In 1976, 56 percent of coal was produced by mines operated by central government and in 1990, 44 percent of coal was produced by these mines (World Bank 1991). Most of these mines are semi- or fully mechanised. The percentage of coal produced by local mines is increasing and these mines often use traditional mining methods. Much of the increase in coal production over the last eight years has come from local mines, particularly at county level and below. Local mine production was stimulated by the opening up of a free market for coal in the early 1980s. Under this government policy the development of local mines with less investment and little construction work was promoted. The dynamic response of local mines turned out to be essential in meeting the country's coal demand over the past decade. But safety standards in local mines are normally poor and estimates of mortality in these mines are high.

The growth of local mines has given an impetus to the development of the coal industry. But the state-owned mines still operate at low planned prices, subsidised production cost and slow investment approval, all of which leads to economic inefficiency, lack of accountability in production and waste of resources. Low productivity and insufficient utilisation of assets generally characterise such mines. Their productivity is low compared with other coal producing countries.

5.2.2 The Production System

There are more than 80,000 mines. The largest ones (about 600) come under the direction of central government (World Bank 1991). In 1991, the state-owned mines contributed about 40 percent of coal output. These mines normally have advanced equipment and technology, adequate working conditions and sound safety protection. In addition, there are 2000 medium-sized mines owned and administered by provincial governments. 60000 small-mines are financed and operated by local governments, cooperatives, or individuals. Production from locally-administered mines grew by 9.2 percent in 1989, compared to 5.5 percent for the large government-administered mines (*Statistical Yearbook of China Energy 1991*). Engineering and safety standards in the small mines generally fall below the level of the large mines.

Town-and-villageship small mines have more flexibility in marketing their output. This allows them to play an important role in setting coal prices, particularly in local markets. Only a proportion of local mine production comes under central government control, for distribution at fixed prices to state-controlled industries. Local mines must also sell fixed amounts to local industries at below-market prices. A premium is added in some provinces to provide an incentive to producers and mobilise funds for local mine development. Mines can sell any production above quota levels at market prices.

Although costs are higher than the planned prices, production costs are low by international standards; according to Xu (1993) in 1990 the average cost ranged from 45 yuan to 63 yuan per tonne in various mines. Wages and welfare payments are the largest single costs category, making up 30 percent of the total in 1986. Despite increasing mechanisation, productivity in the central government-controlled mines has been stagnant. At the same time, annual wage and welfare outlays per worker have risen by 2.3 percent per year in real terms (Chu and Chen 1992). Production from government-controlled mines will still continue even if unit coal costs exceed prices. In general costs in these mines surpassed prices, in the 1990s. Real increases in costs can be attributed to the increasing price of materials, electricity, transportation, and depreciation charges; all these are caused by escalating prices of material inputs as capital costs, such as cement, timber and steel. The real income of the government-controlled mines is the financial subsidies.

The costs of local mines can be from 10 to 40 percent below the costs of government controlled mines (see Table 5.3). This differential results from several factors. Local mines generally exploit shallower coal seams that require less investment in shafts and underground roadways. These mines have lower operating costs as a result of the lower ground pressures. They offer lower wages and benefits and also operate on lower safety standards. Local mines do not emphasise high extraction rate as do the state-owned mines. Finally, local mines have been known to shift some of their operating costs onto neighbouring state-owned mines, for instance, they may share the power supply network with the state-owned mines with no payment on electricity.

The government has emphasised the development of small coal mines under provincial and local control to maintain output growth in meeting rising demand. With less investment in these mines, it is realised that growth cannot be sustainable, since as these mines mature they will require increasing amounts of capital to work at deeper levels. There is also some concern that the proliferation of small local mines has prevented full exploitation of the large reserves which would have been amenable to mining by more capital intensive, large scale methods. The government has tried to balance the development of lower-cost coal resources in the north, far from the main consumption centres, and those where mining conditions are more difficult but transport constraints less binding. Some state-owned mines have introduced modern, mechanised techniques. Open site mining is rare and new in China and accounts for only a small proportion of production.

5.3 Coal Pricing Policies

5.3.1 Planned Prices

There are currently several pricing policies in China, which seems to have brought complexity to the Chinese coal market and to the producers and consumers. Albouy (1991), Clarke and Winters (1994), the World Bank (1991) and Yan (1994) have observed this problem, which we illustrate in this section.

The planned price of coal in China is the price for coal produced under the government plan. Prices of coal set by the government are normally lower than costs and this leads to financial losses in the coal mines. Large government subsidies are given to coal mines every year. In order to secure larger government subsidies, coal mines often try to use every possible method of raising their production costs. The Ministry of Coal Industry administers coal prices for the 88 Coal Mining Administrations (CMAs) under its control; the provincial authorities administer prices for provincial and county mines. The state plan allocates coal as well as the rail capacity that transports it. Some 25 percent of locally produced coal is also allocated under the plan; the rest is marketed locally and to neighbouring provinces (World Bank 1991).

The classification of coal is determined by the Ministry of Coal Industry, and prices for each category are set by the National Price Bureau. Prices are set in accordance with standards for raw and washed coals and adjusted based on type (coking, steam, lignite), grade (washed, screen, raw, and by limp size), ash, moisture and sulphur content, and location of production. The current pricing method has several weaknesses. One of these is its orientation towards characteristics relevant mainly to coking coals. For example, low ash content is considered rather than heating value, although the heat content of steam coal is the prime indicator of its value to the user. This can result in low-ash lignites being overpriced relative to thermal coal. These price indices are also designed to improve the financial viability of lignite mines. In practice, ash content is simpler to determine than heat value, and requires less sophisticated equipment. Ash content can be used as an indicator of the heat value of steam coal, but only if curves relating the two parameters are developed for each deposit.

Prices for state-owned mines rose quickly from 1976 to 1992. In addition, a 2 yuan per tonne surcharge to the consumer was added in 1983 because price increases had not been sufficient to cover costs (Albouy 1991, World Bank 1991). Prices were again adjusted upwards in 1990. Under a six-year contract signed in 1985, The Ministry of Coal Industry offered a dual price system to provide the mines with an incentive to over-fulfil regional production targets. At the same time, regional and quality-related price differentials were increased in order to move prices closer to costs. Under the dual pricing system, the government charges a certain percentage of premium for all production exceeding an agreed annual quota that is shipped to end-users according to the state transportation plan. The mines can also sell excess coal not included in the transportation plan at negotiated prices. The government has signed similar contracts with each mine under its control, specifying its share of the contract targets. Production quotas are determined on a monthly basis. Individual and collective mines, which represent the majority of local mine production, sell their coal in the free market as long as they can secure transport. Otherwise, they sell to the state coal mining bureaus. The competitive forces acting on such mines reflect local conditions and prices. In regions with shortages, for example, Jiangsu or Liaoning, mines are able to obtain high prices, whilst in regions with a surplus, notably Shanxi, their competitive position is weaker because of insufficient transport.

Table 5.3 Average Cost and Unit Planned Price of Coal

year	AC (yuan)	price (yuan)	deflator (1980=100)	real AC (yuan)	real price (yuan)
1976	16.7	16.8	0.90	18.5	18.5
1977	16.6	16.5	0.91	18.2	18.1
1978	16.1	16.5	0.93	17.4	17.8
1979	17.8	19.2	0.95	18.8	20.3
1980	20.0	21.3	1.00	20.0	21.3
1981	21.5	21.4	1.02	21.1	21.0
1982	21.9	21.6	1.03	21.3	210
1983	22.3	21.9	1.04	21.5	21.1
1984	23.4	22.7	1.09	21.4	20.8
1985	29.3	26.0	1.20	24.4	21.6
1986	32.3	26.5	1.25	25.8	21.2
1987	33.9	26.3	1.34	25.3	19.6
1988	40.0	38.0	1.45	27.5	28.9
1989	53.5	52.0	1.58	33.8	32.9
1990	58.9	54.6	1.68	35.0	32.4
1991	64.8	58.0	1.78	36.5	32.6
1992	74.7	63.0	1.87	39.9	33.7

Sources: *China's Forty Year's Energy, 1992.*
China's Energy, 1994.
Statistical Yearbook of China's Energy, 1991.
Data obtained from the Information Institute of Mineral Resources.

The government has provided several subsidies to encourage coal-producing provinces to supply coal to other regions. In general, the provinces receive a government subsidy for coal produced by the state-owned mines which is shipped elsewhere: 2 yuan/tonne for raw coal and 4 yuan/tonne for washed coal (Albouy 1991). The state also pays provincial governments a premium of 27 yuan/tonne for coal sold to other provinces as a substitute for oil. Rail transport for this coal is centrally allocated.

Production has increased rapidly since the 1980s compared with a slight increase in planned price, resulting in the latter being lower than the production cost. For instance, in the Pingdingshan Mine in 1992, the production cost was 45.8 yuan per tonne, whereas the planned price was just 38.18 yuan per tonne, so that the cost was 20 percent higher than the price (Xu 1993). Although large subsidies were given to the coal mines, this was still not enough to cover all the costs and also provided no funding for future development. The total output value and productivity of the coal industry has increased every year; however, the financial income has decreased. An example is the Yima Mine: from 1985 to 1989, its output value increased by 6 percent and productivity increased 8 percent per year, yet profits dropped by 77 percent on average every year (Xu 1993).

5.3.2 Delivered Coal Prices

In the early and mid-1980s, some areas with high production costs raised coal prices in order to stem financial losses. At the same time, price negotiation within certain defined limits was allowed. These reforms have led to low prices in coal-rich provinces and higher prices in areas that depend on deliveries of coal, since most rail transport capacity is allocated to centrally controlled and provincial mines. This shortage of rail transport leads to uneconomic long-distance shipments by road, and the transportation charges are added to the delivered price. As rail capacity increases in the long term, shipments by road should decrease, bringing coal price down. A comparison of the prices of coal from the same field mined by state, local, and collective miners provides many examples of the price differentials that exist for essentially the same quality coal.

Large enterprises receive coal directly from the mines according to a distribution plan; sales to other users are handled by coal distribution offices. Before 1979, distribution allocations were based on local government estimates of requirements. Wholesale and retail coal prices were fired by the government; distributors received a subsidy to cover any losses. The retail price of coal for household use remained unchanged from 1965 to 1979 (Chu and Chen 1992). The delivered price of coal includes an element to cover non-subsidised interest and management expenses, and also the cost of coal losses in transit. Before 1984, distributors received subsidies on sales to farmers, vegetable farmers (for their domestic requirements only), restaurants, heating plants, and urban households. The subsidies to farms and industry have since been discontinued.

By 1980, coal-importing provinces began to take steps to secure adequate supplies. One example is a form of barter trade by "cooperative coal". This plan swaps coal for goods in high demand-watches, bicycles, steel products and for rice at the state regulated price. Essentially, coal producers make up for a lack of internal cash generation through profits obtained from this trade. Another step involves the coal-short province providing a loan at no charge to a coal producer to develop production facilities in exchange for guaranteed coal supplies at the regulated price. The importing province then services its debt through sales of coal at a higher retail price.

5.3.3 Free-Market Prices

The relatively narrow free market absorbs supply and demand pressures throughout the economy. Prices can fluctuate sharply. In recent years, they have risen faster than inflation. Market prices in Shanghai and Jiangsu are at, or exceed, international levels.

The price differential between market and plan coal widened in the late 1980s. In Nanjing, for example, the maximum price ratio between state and market coal prices was 2.2 times in 1984. The ratio increased in recent years (World Bank 1991). This widening of price differentials reflects the shortage of coal transportation facilities and the inflationary factor is not added into the planned price. The problem with the present pricing system is that the differences come not from economic or quality variations but rather from arbitrary factors--whether the coal is sold on the allocated or free market, and so on. Essentially, then, actual domestic prices are heavily distorted by (a) distortions which raise costs beyond the efficient level, and (b) direct subsidies equal to cost (distorted)-price.

Some authors (Albouy 1991, World Bank 1991, Clark and Winters 1993,) discuss price differences with transportation. Prices in Shanxi rose from 50-60 yuan/tonne in 1986 (World Bank 1991) to about 150 yuan/tonne in 1992 (Xu 1993), while minemouth prices from Xuzhou rose even more-from 90 yuan to 220 yuan/tonne (World Bank 1991). The large margin in market prices between provincial producers and consumers indicates that transport is exaggerating price differentials. Introducing more capacity on the key routes from coal producer could reduce the cost of transporting coal and allow more competitions from different producers.

5.3.4 Effects of the Dual Price System

The emergence of a dual pricing system for coal is possibly a transitional step to a more rational pricing system. Under the dual pricing system consumers pay a price that is closer to the true economic value of coal, improving economic efficiency in the use of coal resources and avoiding the inflation impact associated with applying such a price to all production. In such a case the price of coal increases as production increases. However, the Ministry of Coal Industry found that customers were rejected the higher-priced "above-quota" coal; in 1986, the Ministry averaged the premium for all the coal sold by CMAs, except for sales to households. In 1987, the system was changed again to add a regional differential to the average price premium.

A major deficiency is that the level of revenues and their rates of increases built into the tiered pricing system are rather modest. Direct and indirect subsidies continue to be required to cover operating costs and finance investments. Multiple prices also allow for profits through reselling of low-priced coal at market prices. This may result in greater economic efficiency, but the additional revenue does not accrue to the producer.

More than ten years after the introduction of the dual pricing system, the sale of coal is still dominated by conditions which encourage inefficiency in both production and consumption. As the difference between planned and market prices widens, consumers have to ask for an increase in their quotas of planned prices. In addition, they resort to using whatever coal they can get under the plan allocation system, irrespective of whether the quality or sources makes economic sense.

Since 1994, some areas have freed coal prices while other areas are still under the dual pricing system. Price controls operating for certain consumers serve to reduce the supply of coal to those consumers. A case in point is the household sector, which has little or no access to the anthracite market, even though anthracite should be one of its choice fuels. The price of anthracite to the household sector was seriously distorted: for example, in Jinjiang City in Fujian Province, the price of anthracite to the household sector was 33 yuan per tonne in 1990, but the cost of anthracite from the mine to the market was 143 yuan, therefore, every tonne of anthracite sold required 110 yuan of financial subsidies (Ye 1990).

Furthermore, the rigidity of plan prices gives rise to more volatile price adjustments in the free market, especially in conditions of shortage. Liberalisation of coal prices would use the market mechanism to facilitate adjustments to changes in supply and demand, encouraging consumers and suppliers to be more responsive to market changes by adjusting their production and consumption.

5.4 Calculation of Coal-Adjusted National Account

5.4.1 Considerations and Adjustment

Some discussion on how to modify the SNA empirically has already appeared in the literatures (Ahmad *et al* 1989, The New SNA of UN 1993a, System of Integrated Environmental and Economic Accounts (SEEA) of UN 1993b). More case studies are required, however, to identify the possible approaches in incorporating environmental factors into the national accounts. In particular, since coal is the main energy resource used in China, it is necessary to calculate coal-adjusted national accounts to properly understand the effect of depletion of coal on the development of coal industry and also on the Chinese economy. Since the use of coal also creates air pollution problems, to calculate coal account also help to understand the relationship between energy consumption and economic development (Lin 1992, Hwang and Gum 1992, Tang and Croix 1993, Yang and Yu 1996). In constructing such accounts, it is important to compare the limitations and advantages of the net price approach, the total rent approach and the user cost approach.

The measure of coal resources used for adjusting national accounts in this chapter is the proven reserve figure. Proven reserves refer to those that their stocks have been measured and can be mined with modern technology. In practice only proven reserves have a positive rental value because their net price exceeds their estimated recovery cost. Coal reserves data were obtained from *Annual Report of Mineral Resources* (1988, 1992) and the data obtained from the Information Institute of the Ministry of Geology and Mineral Resources of China.

As regarding treatment of discoveries, we assume that the discoveries are instantaneously capitalised, as suggested by El Serafy (1989). This means that as long as the discoveries are announced, the value of the mine goes up to reflect its new worth. Instantaneous capitalization of discoveries can be handled by using any procedure for calculating depreciation. Hamilton (1994a, 1994b) mentions that in terms of practical national accounting, resource discoveries, valued at the marginal discovery cost, should be added to conventional NNP. Assuming resource discovery costs increase with cumulative discoveries, then marginal discovery costs will be less than resource rents. Hamilton also concludes that "with regard to resource discoveries, the standard national accounts treat most exploration costs as investment. Where the model suggests using marginal discovery costs times the amount discovered, the standard accounts are, in effect, using average discovery costs times amount discovered. This suggests that 'green' accounts need not be adjusted for resource discoveries." In keeping with Hamilton's statement, therefore, all discoveries of coal in China were treated as being capitalised instantaneously and no adjustment was made for discoveries in calculating "green" national accounts.

For the domestic coal price, we find no clear systematic way to adjust it because the domestic prices set by the government are far below costs and cannot reflect the marginal opportunity cost of coal mining. In such a case the world prices are the prices we should use for our analysis. We use the official exchange rate deflated to convert the world prices into domestic currency. We find the official exchange rate deflated by deflators from 1980 to 1992 is quite close to the World Bank 'Market Exchange Rate' (MER) for China.

The gross product of the coal industry (GOP) and GNP should also be adjusted by the world price since we use world price to calculate coal-adjusted net national product. The adjusted gross product of the coal industry is calculated by multiplying output from 1976 to 1992 by the world price. Then the original GOP is subtracted from GNP and the recalculated gross product of the coal industry (GOP*) is added to GNP. The following table shows the recalculated values of GOP* and the resulting adjusted GNP. Thus the adjusted GNP equals :

$$\text{adjusted GNP} = (\text{GNP} - \text{GOP}) + \text{GOP}^* \qquad (1)$$

Table 5.4 Recalculation of GOP of the Coal Sector and GNP by World Price (billion yuan)

year	world price (yuan/tonne)	output (100 million tonne)	GOP*	GNP	GOP	GNP*
1976	88.87	4.83	42.9	268.5	10.7	300.7
1977	89.05	5.50	49.0	289.3	12.1	326.2
1978	90.19	6.17	55.7	387.1	13.6	429.1
1979	89.59	6.34	56.8	422.6	13.7	465.7
1980	85.22	6.20	52.8	447.0	12.5	487.3
1981	112.40	6.22	69.7	468.4	15.2	522.9
1982	121.27	6.66	80.8	505.2	16.3	569.6
1983	105.78	7.15	75.6	559.1	17.4	617.3
1984	127.13	7.89	100.0	636.4	18.3	718.3
1985	120.55	8.72	105.1	711.4	18.4	798.1
1986	133.37	8.94	119.2	775.1	19.0	875.3
1987	115.10	9.28	106.8	842.7	19.2	930.3
1988	126.82	9.80	124.3	968.9	21.8	1071.3
1989	124.51	10.54	131.2	1011.0	26.5	1115.7
1990	159.50	10.80	172.3	1051.4	28.0	1195.7
1991	161.48	10.87	175.5	1137.5	29.2	1283.9
1992	159.89	11.16	178.4	1285.9	32.8	1431.6

Source: calculated by the author.

El Serafy (1989) suggests that mining receipts do not entirely belong to GNP because mining is not human production but the liquidation of an endowment. He does not mean to exclude all mining receipts from measurements of income but acknowledges that a resource-rich country has a real income advantage compared to a resource-poor country. A portion of mining receipts should be counted as value added, a return from mining work. El Serafy suggests actually adding mining receipts to the GNP and deducting what is mined from the capital account. Since deriving "green" NNP is the procedure of deducting capital depreciation and since all the incomes from mining have been already included in the computation of GNP, it is unnecessary to recalculate GNP part. Therefore, the user cost or depreciation part should be deducted from the value of capital assets.

5.4.2 The Net Price Approach

Three approaches are applied here to calculate coal-adjusted national accounts. The first approach is the change of stocks or *the net price approach*. We first calculate the depreciation or capital consumption allowance by using the net price approach. Repetto *et al* (1989) and Solozano *et al* (1991) use this approach for Indonesia and Costa Rica. Here data on the proven stocks of coal from 1976 to 1992 are used. Opening stocks in the physical accounts are the stocks at the beginning of the period and closing stocks are the stocks at the end of the period. Additions to coal reserves in the physical accounts consist of discoveries. According to the official statistics in China, there is a successive increase of proven coal reserves despite coal output increases every year. We treat this additional part of reserves as discoveries. All the prices used in the net price approach are international market prices in the relative year. We use the official exchange rate to convert the international prices into the local currency, yuan. Then we deflate all the converted prices to get real price.

Economic depreciation is the loss in asset value from use. With minerals, the loss is measured as physical shrinkage of the stock of resources. Since depreciation is the degradation in value of coal under assumed optimal use, depreciation in the net price approach may be computed by calculating the value of the asset at the beginning (V_t) and at the end (V_{t+1}) of the period, and taking the difference. Thus, if DEP_t denotes depreciation in year t, we have:

$$DEP_t = - V_t = V_t - V_{t+1} \qquad (2)$$

In empirically applying this principle for calculation of green NNP, we deduct from gross receipts due to mineral production in any one year an amount equal to the depletion, hence, the value of net income from this activity becomes zero. Thus, for example, if the country extracts 100 percent of the natural resources, in the GNP the extraction would contribution to a GNP of 100 and a NNP of zero.

As can be seen in Table 4, the implied depreciation figures are very high and erratic from period to period. We find that as the resource is depleted by the quantity of extraction during the year, the amount of depletion deducted is very large under the net price approach and it is higher than the whole GNP of the year. This is definitely inconsistent with the notion of Hotelling (1925) rent on natural resource depreciation.

Table 5.5 Economic Depreciation for Coal Using the Net Price Approach (billion yuan)

year	opening stock	closing stock	depreciation	GNP	adj GNP
1976		13898.5		300.7	
1977	13898.5	14899.0	(1000.5)	326.2	1326.7
1978	14899.0	16067.0	(1168.0)	429.1	1597.1
1979	16067.0	16305.4	(238.4)	465.7	704.1
1980	16305.4	15666.9	638.5	487.3	-151.2
1981	15666.9	22046.2	(6379.3)	522.9	6902.2
1982	22046.2	25129.9	(3083.7)	569.6	3653.3
1983	25129.9	21789.0	3340.9	617.3	-2723.6
1984	21789.0	27838.7	(6049.7)	718.3	6768.0
1985	27838.7	26475.6	1363.1	798.0	-565.1
1986	26475.6	30280.5	(3804.9)	875.3	4680.2
1987	30280.5	25841.2	4439.3	930.4	-3508.9
1988	25841.2	32110.4	(6269.2)	1071.3	7340.5
1989	32110.4	30552.4	1558.0	1115.7	-442.3
1990	30552.4	43251.3	(12698.9)	1195.7	13894.6
1991	43251.3	45682.3	(2431.0)	1283.9	3714.9
1992	45682.3	43982.0	1700.3	1431.6	-268.7

* Figures in () express appreciation.

Similar erratic result can also be found in Young and da Motta's paper (1995). They argue that the erratic figures obtained from the net price approach are a consequence of its main conceptual flaw, namely that both computed output and income depend on variations in reserves. This is because the net price is Hotelling rent defined as profits on the last ton mined. The net price approach is based on Hotelling's (1925) idea of price minus marginal cost on unit mined. As for the total depletion, one should multiply price minus marginal cost by the total output mined or extracted. However, the net price approach uses changes of the total stocks. When each year there is drastically increase or decrease, this would end up with erratic results on depreciation. Thus Hotelling rent is only valid when applied to the amount mined or extracted. When using Hotelling rent on the stocks of nonrenewable resources, erratic results are bound to appear since there is basic violation of the principle of the total Hotelling rent. This also indicates that the discovery part, which does not belong to output, cannot be measured by the net price. The basic SNA requires income and output depend exclusively on production. From this point of view, the net price approach is not suitable in valuing depreciation of nonrenewable resources.

Repetto *et al* (1989) firstly initiated to calculate environmental accounts by using net price times change of stocks to obtain the depreciation in Indonesia. The basic idea of this method is to examine the change of stocks to the national income. In their study, including the petroleum accounts for Indonesia, the results seem reasonable. However, we find that the reasonable results can be achieved under the net price approach only by: 1) the stocks of the natural resource are not very high; 2) discoveries of the resource are not very high each year; and 3) the resource is mined or extracted at steady speed. When only satisfying these conditions, the net price approach shows reasonable results. In most cases there are few chances which satisfy the three conditions, therefore, using net price approach in deriving depreciation of the nonrenewable resources would encounter with erratic results. As we discussed above, the fundamental mistake for this approach is: it violates Hotelling's principle of calculating depreciation for nonrenewable resources.

5.4.3 The Total Rent Approach

The second approach we applied in this chapter is *the total rent approach.* Hotelling rent is defined as marginal profit per tonne, i.e. price minus marginal cost. Total Hotelling rent is Hotelling rent multiplied by the amount extracted. Hotelling's rule implies that because the natural resource is exhaustible, it will be mined more slowly than if it were in infinite supply (Hartwick and Hageman 1991). Theoretically, the extraction rate should be less than that which would equate marginal revenue to marginal cost. Consequently, even a competitive firm earns rent or profit on the marginal tonne of mined coal. The total Hotelling rent is that portion of profit that accrues to extractive firms because they are mining an exhaustible resource. However, in practice it is difficult to estimate marginal cost. Therefore, following previous empirical studies (Bryant and Cook 1992) and Hamilton (1995), average cost is used as substitute and resulting substitute for Total Hotelling rent is called simply the total rent. The equation of the rent calculation is quite easy:

$$DC = (P - MC\ (AC)) \times Q \qquad (3)$$

where,

DC = depreciation or toal rent of nautral resources

P = price

MC = margnial cost

AC = average cost

Q = quantity extracted or mined

The results of the total rent approach are given in Table 5.6.

Table 5.6 Depreciation of Coal Using the Total Rent Approach

year	output (mi tonnes)	rent[1] (yuan)	total rent (bi yuan)
1976	483	70.2	33.9
1977	550	70.9	39.0
1978	617	72.8	44.9
1979	634	70.8	44.9
1980	620	65.2	40.4
1981	622	90.8	56.5
1982	666	99.9	66.5
1983	715	84.3	60.3
1984	789	105.8	83.5
1985	872	96.2	83.9
1986	894	107.5	96.1
1987	928	89.8	83.3
1988	980	99.3	97.3
1989	1054	90.7	95.6
1990	1080	124.5	134.5
1991	1087	125.0	135.9
1992	1116	119.9	133.8

Source: Calculated by the author.

The results in Table 5.6 are not objectionable in any obvious way. We are thus more confident of the total rent approach than the net price approach which produced such erratic figures in the previous section. The total rent approach can accurately measure economic depreciation with instantaneous incorporation of discoveries each year (Hamilton 1994a, 1994b). The results in Table 5.6 indicate that the total rent approach is a stable and consistent approach, which can be widely applied in calculating the depreciation of nonrenewable resources.

[1]Rent is calculated by unit price - average cost.

5.4.4 The User Cost Approach

The third approach applied is to compute *the user cost* as a measure of coal depreciation. We use EL Serafy's variant of the user cost approach for our calculations. His approach has been followed by a number of people, for example, Young and da Motta (1995) in their empirical work for Brazil. In theory, user cost (DC) as given by El Serafy (1989) is:

$$DC_t = P_t Q_t \frac{1}{(1+r)^{n_t}} \tag{4}$$

where,

P_t = the expected unit rent at time t

Q_t = the expected amount of resource to be extracted at time t

n_t = the expected period of extraction at time t

r = the discount rate

When the discount rate is zero, Equation (3) can be replaced by the following practical version:

user cost = gross operating surplus - normal capital returns (4)

This equation constitute an alternative method of calculating the user cost which is also discussed by Hartwick and Hageman (1991). To compute Equation (4), we need the following 3 equations:

value added = output value - intermediate cost of production (5)

value added = wage + gross operating surplus + social charges (6)

gross operating surplus = user cost + normal capital returns[2] (7)

Table 5.7 shows the calculation of value added and user cost at zero percent discount rate from gross output value in the coal sector.

Table 5.7 Calculation of Value Added of Coal and User Cost at Zero Percent Discount (100 million yuan)

year	GOP*	intermediate cost	value added	total wage	normal capital returns (10%)[3]	user cost (zero percent)
1976	429.3	52.6	371.1	27.4	1.4	342.3
1977	489.8	65.9	417.7	27.1	3.0	387.6
1978	556.5	74.0	476.1	28.5	5.0	442.6
1979	568.0	63.9	500.5	30.4	7.3	462.8
1980	528.4	54.3	474.1	32.8	8.6	432.7
1981	696.9	89.1	609.4	32.6	11.2	565.7
1982	807.7	97.9	712.5	33.4	14.7	664.5
1983	756.4	104.2	656.0	34.2	19.0	602.9
1984	1003.0	114.9	898.0	38.3	23.6	836.1
1985	1051.2	129.0	944.0	50.8	26.6	866.6
1986	1192.3	139.9	1080.5	56.5	30.4	993.5
1987	1068.1	155.2	952.4	57.9	32.9	861.6
1988	1242.8	187.5	1113.7	64.0	34.7	1014.9
1989	1312.4	258.6	1149.0	71.8	36.4	1040.8
1990	1722.6	313.2	1536.5	76.8	40.5	1419.2

[2]In Young and da Motta (1995)'s paper, the value added = wage + social contribution + normal capital return. In China's accounting system, social contribution is already put into the intermediate cost.

[3]The normal cpaital returns is calculated by using the perpetual inventory mehtod.

1991	1755.3	341.4	1563.4	79.5	45.7	1438.2
1992	1784.4	392.7	1574.4	87.6	52.1	1434.8

GOP*=gross output of coal calculated by international prices.
Sources: Statistical Yearbook of China's Energy, 1992.
China Statistical Yearbook, 1993.

We have also calculated the user cost at 5 and 10 percent of discount rates. In Table 7, the stocks of coal are first divided by output of each year to get the figure for the period to depletion. In China the depletion period for coal is between 300 to 400 hundred years. Then, we use EL Serafy's formula to get user cost. The discount rate we choose here is zero percent, 5 percent and 10 percent in order to see the various effects from these discount rates on deriving depreciation of natural resources. For the selection of discount rate, it should be realised "discounting is that it discriminates against future generations" (Pearce 1992). We applied 5 and 10 percent discount rates respectively to get user cost or rent. To our surprise we have found that 5 and 10 percent discount rates in coal ends up with virtually zero user cost.

Table 5.8 Calculation of User Cost and Adjusted Income (100 million yuan)

		user cost			adjusted income		
year	Value Add	0% disco	5% disco	10% disco	0% disco	5% disco	10% disco
1976	371.1	342.4	0.00	0.00	28.8	371.1	371.1
1977	417.6	387.6	0.00	0.00	30.1	417.6	417.6
1978	476.1	442.6	0.00	0.00	33.5	476.1	476.1
1979	500.5	462.6	0.00	0.00	37.7	500.5	500.5
1980	474.1	432.7	0.00	0.00	41.4	474.1	474.1
1981	609.4	565.7	0.00	0.00	43.8	609.4	609.4
1982	712.5	664.5	0.00	0.00	48.0	712.5	712.5
1983	656.0	602.9	0.00	0.00	53.1	656.0	656.0
1984	898.0	836.1	0.00	0.00	61.9	898.0	898.0
1985	944.0	866.6	0.00	0.00	77.3	944.0	944.0
1986	1080.5	993.5	0.00	0.00	86.9	1080.5	1080.5
1987	952.4	861.6	0.00	0.00	90.8	952.4	952.4
1988	1113.7	1015.0	0.00	0.00	98.7	1113.7	1113.7
1989	1148.9	1040.8	0.00	0.00	108.2	1148.9	1148.9
1990	1536.5	1419.2	0.00	0.00	117.3	1536.5	1536.5
1991	1563.4	1438.2	0.00	0.00	125.1	1563.4	1563.4
1992	1574.4	1434.8	0.00	0.00	139.6	1574.4	1574.4

Source: Calculated by the author.

The results shown in Table 5.7 demonstrate that while the user cost at zero percent of discount rate equals profit with deduction of income, the user cost at 5 and 10 discount rates in our coal calculation turns out to be virtually zero. For a large reserve of natural resources, the high discount rates will not have a great influence on the depletion of the resource. It is shown in our calculation that the adjusted income is very high and is actually the full amount of value added of coal output in the year. This closely connects with the intergenerational problem of consuming natural resources and this issue is discussed below.

Through the calculation of the user cost, we definitely prefer the user cost at zero percent discount rate. This effect is supported by the argument that no rate of discount should be applied to natural resources, because wellbeing at one point of time cannot count more than wellbeing at another point of time (Pearce 1993). This environmental concern and intergenerational equity issues just reflect in selecting discount rate. Our empirical work again provides illustration of the notion that higher discount rate will benefit the income of present generation and make the future generation worse off. The user cost approach proves that higher discount rate only contribute to the present income and the depletion is not reflected if stocks of natural resources are large.

The results on different discount rates demonstrate that when the reserve is very large and the depletion period is very long, the zero discount rate is the right discount rate to be chosen. The higher discount rate does not have much influence as zero percent discount rate does because all the depletion just contribute to the current income. This raises two issues: a) For the very large stocks of natural resources, significant positive discount rates cannot correctly lead to reflect current depreciation. b) It may be sensible to confine the use of positive discount rates to evaluate the profitability of investment projects and to use zero percent discount rate for calculating depreciation of natural resource. This is also a point that the user cost at zero discount rate is useful in any case. El Serafy's method is proved more effective in zero percent discount rate than higher discount rates. For these reasons, we actually focus on zero discount rate.

5.5 Adjusted NNP and Net Investment

5.5.1 Comparison of Three Approaches in Adjusting NNP

In Section 5.4 we computed the values of three measures on coal stock depreciation in China. These measures are from the net price approach, the total rent approach and the user cost approach which we can conveniently summarised as follows:

Net price = (price - marginal (average) cost) x change in stocks (8)

Total rent = (price - marginal (average) cost) x amount extracted (9)

User cost at zero percent discount rate = profit - adjusted income (10)

Equation (9) and (10) make clear that the net price value should exceed the total rent value as price exceeds cost. If profit can be identified as price minus unit cost, then equation (10) and (11) show that the user cost measure at zero percent discount rate is similar to the total rent measure - minus adjusted income. El Serafy (1989, 1991) asserts that resource receipts should be modified before they enter gross GNP so that only the legitimate contribution of resources to value added is counted there. User cost, or depreciation of the natural capital is the difference between the value of a capital good, used and well maintained, at the end of an interval and the value of the same capital good when used in production. This intuitively captures the definition of economic depreciation, that is, the loss in value of a capital good from optimal use.

Our empirical results from the net price approach yield unstable figures with sometimes dramatically alternating negative and positive values. This was because the coal stocks minus extraction plus discoveries change year by year. The depreciations on the net price approach are greatly exceeded GNP in magnitude of the year. By contrast, the empirical results for the depreciation of total rent approach are stable, the figures being close to the user cost but smaller than the net price approach. The figures of depreciation from the user cost approach at zero percent of discount rate are of similar magnitude to the total rent approach. These findings are listed in Table 5.9.

Table 5.9 Comparisons of Economic Depreciations from Three Approaches (billion yuan)

year	net price	total rent	user cost (zero discount rate)
1976		33.9	34.2
1977	-1000.5	39.0	38.8
1978	-1168.0	44.9	44.3
1979	-238.4	44.9	46.3
1980	638.5	40.4	43.3
1981	-6379.3	56.5	56.6
1982	-3083.7	66.5	66.4
1983	3340.9	60.3	60.3
1984	-6049.7	83.5	83.6
1985	1363.1	83.9	86.7
1986	-3804.9	96.1	99.3
1987	4439.3	83.3	86.2
1988	-6269.2	97.3	101.5
1989	1558.0	95.6	104.1
1990	-12698.9	134.5	141.9
1991	-2431.0	135.9	143.8
1992	1700.3	133.8	143.5

Source: calculated by the author.

Figures in - denote appreciations.

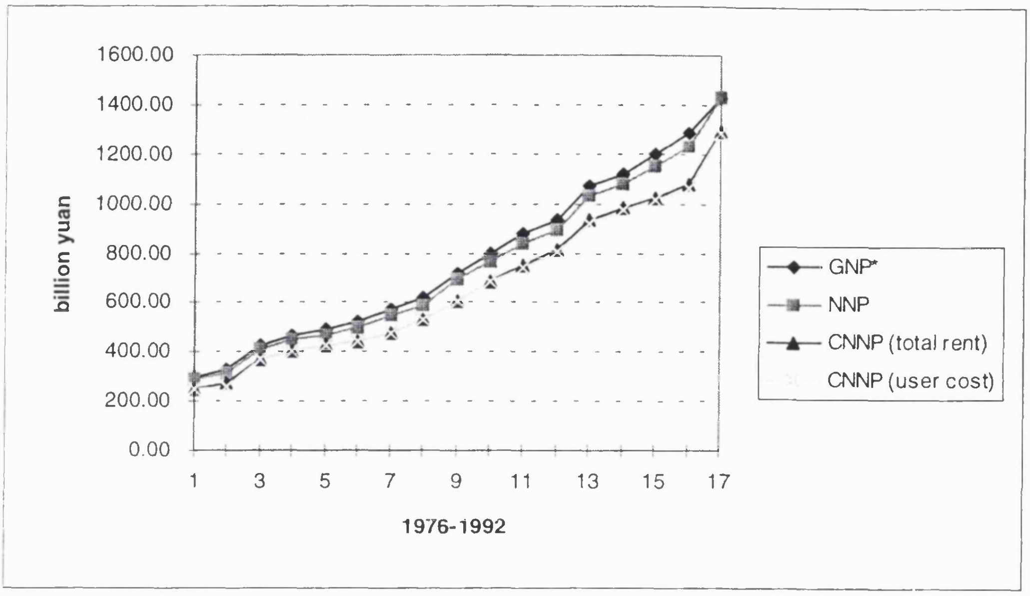
Having obtained coal depreciation figures by the total rent approach and the user cost approach, we then use these figures to derive series of coal adjusted NNP (CNNP). This is GNP less man-made capital depreciation minus coal depreciation. Similarly the depreciation adjusted product of coal sector is defined as its gross product minus coal depreciation (CGOP). These figures are presented in Table 5.10. We also present the figures visually by Graphs 5.3 and 5.4.

Table 5.10 Coal Adjusted NNP and GOP
(billion yuan)

year	adj GNP	NNP	CNNP (TR)	CNNP (user co)	GOP	CGOP (TR)	CGOP (user co)
1976	300.7	285.8	251.9	251.6	42.9	9.0	8.7
1977	326.2	309.7	270.8	271.0	49.0	10.0	10.2
1978	429.1	411.2	366.3	367.0	55.7	10.7	11.4
1979	465.7	446.6	401.7	400.3	56.8	11.9	10.5
1980	487.3	465.6	425.1	422.3	52.8	12.4	9.6
1981	522.9	499.7	443.2	443.1	69.7	13.2	13.1
1982	569.6	544.7	478.1	478.2	80.8	14.2	14.3
1983	617.3	589.7	529.4	529.4	75.6	15.4	15.3
1984	718.3	688.7	605.2	605.1	100.3	16.8	16.7
1985	798.1	766.8	682.9	680.1	105.1	21.2	18.5
1986	875.3	839.9	743.8	740.6	119.2	23.1	19.9
1987	930.4	893.1	809.8	806.9	106.8	23.5	20.6
1988	1071.3	1030.8	933.4	929.3	124.3	27.0	22.8
1989	1115.7	1073.4	977.8	969.3	131.2	35.6	27.2
1990	1195.7	1151.9	1017.4	1010.0	172.3	37.8	30.3
1991	1283.9	1228.7	1092.8	1084.9	175.3	39.7	31.7
1992	1431.6	1431.6	1297.8	1288.1	178.4	44.6	35.0

TR = total rent approach
CNNP = coal-adjusted net national accounts
CGOP = coal-adjusted gross product of coal industry
source: calculated by the author.

Graph 5.3 GNP, NNP and Coal-adjusted NNP



Graph 5.4 GOP and Coal-adjusted GOP

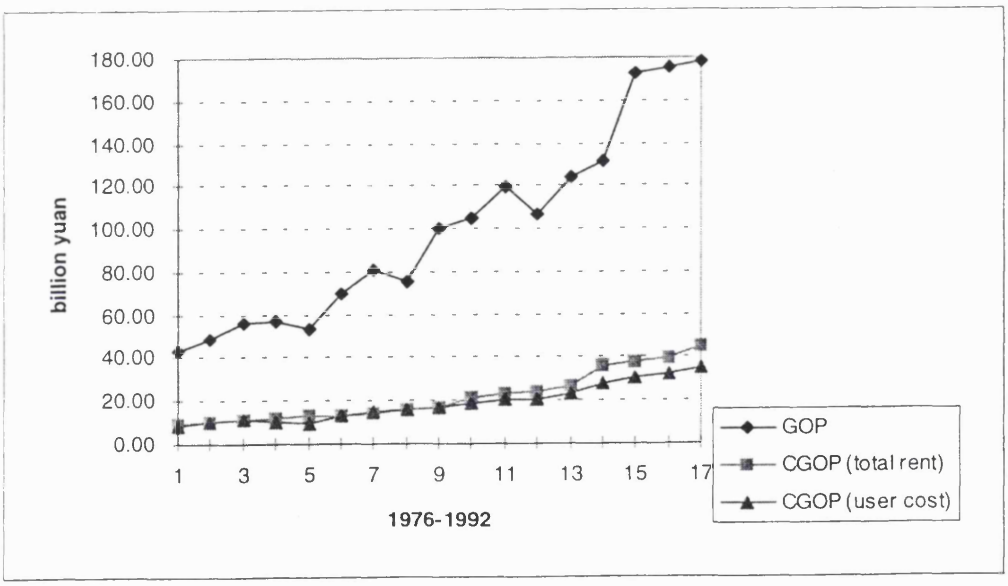


Table 5.11 Ratios of Depreciation to GNP and GOP

year	De/GNP (TR)	De/GNP (user co)	De/GOP (TR)	De/GOP (user co)
1976	0.11	0.11	0.79	0.80
1977	0.12	0.12	0.80	0.79
1978	0.10	0.10	0.81	0.80
1979	0.10	0.10	0.79	0.81
1980	0.08	0.09	0.77	0.82
1981	0.11	0.11	0.81	0.81
1982	0.12	0.12	0.82	0.82
1983	0.10	0.10	0.80	0.80
1984	0.12	0.12	0.83	0.83
1985	0.11	0.11	0.80	0.82
1986	0.11	0.11	0.81	0.83
1987	0.09	0.09	0.78	0.81
1988	0.09	0.09	0.78	0.82
1989	0.09	0.09	0.73	0.79
1990	0.11	0.12	0.78	0.82
1991	0.11	0.11	0.77	0.82
1992	0.11	0.10	0.75	0.80

De/NNP: Depreciation to GNP.
De/GOP: Depreciation to gross output of coal industry.

Table 5.11 shows ratios of depreciation to GNP and GOP under the total rent approach and the user cost approach. The depreciation of coal by using the total rent approach is about 10 percent of GNP of these years and the depreciation of coal by applying the user cost approach is also about 10 percent of GNP of that year. The ratio of depreciation to the gross output of coal by using the total rent approach is around 70 to 80 percent of the adjusted gross product of the coal industry in that year. The ratio of depreciation to the gross output of coal industry by using the user cost approach is above 80 percent generally. The similarity of the two approaches in our calculation empirically supports the theoretical statement made by EL Serafy (1989,1991) and Hartwick and Hageman (1991) that the user cost approach at zero percent discount rate and the total rent approach are closely related.

5.5.2 Net Investment

In Table 5.12, net investment for each year (1976-1992) has been derived by the user cost approach and the total rent approach. We find that net investment was always negative by both approaches. Of course, this implies that the investment was not high enough for output growth in the coal industry to be sustainable. The negative net investment by both approaches was very high, for example, in 1992, the adjusted GNP was 1431.6 billion yuan and the net investment in that year was -126.8 billion yuan for the total rent approach and -136.5 billion yuan for the user cost approach, accounting for about 10 percent of GNP.

Table 5.12 Net Investment and Depreciation of Coal (billion yuan)

year	investment in coal sector	coal depreciation (user cost)	net investment (user cost)	coal depreciation (total rent)	net investment (total rent)
1976	2.1	34.2	-32.2	33.9	-31.8
1977	2.4	38.8	-36.4	39.0	-36.6
1978	3.6	44.3	-40.7	44.9	-41.3
1979	3.4	46.3	-42.8	44.9	-41.5
1980	3.5	43.3	-39.8	40.4	-37.0
1981	2.4	56.6	-54.2	56.5	-54.1
1982	3.1	66.4	-63.4	66.5	-63.5
1983	4.1	60.3	-56.2	60.3	-56.2
1984	5.5	83.6	-78.1	83.5	-78.0
1985	5.1	86.7	-81.6	83.9	-78.8
1986	5.1	99.4	-94.2	96.1	-91.0
1987	4.9	86.2	-81.3	83.3	-78.4
1988	4.7	101.5	-96.8	97.3	-92.7
1989	4.6	104.1	-99.5	95.6	-91.0
1990	5.7	141.9	-136.3	134.5	-128.8
1991	6.5	143.8	-137.3	135.9	-129.4

1992	7.0	143.5	-136.5	133.8	-126.8

Source: calculated from the data of Abstract of Statistics in Coal Industry 1993.

Negative net investment is damaging to even weak sustainable development in China. As Pearce *et al* (1994) have stressed:

> "Weak sustainability means that we are indifferent to the form in which we pass on the capital stock. We can pass on less environment so long as we offset this loss by increasing the stock of roads and machinery or the man-made capital. Alternatively, we can have fewer roads so long as we compensate by having more wetlands or meadows or more education. Weak sustainability therefore assumes that the forms of capital are completely substitutable for each other."

Moreover, "non-renewable resources should be used to generate human well-being, but the requirement for sustainability would suggest that they be used in such a way that their substitution by renewable resources (solar, wind and wave energy, for example) is encouraged at the same time" (Pearce 1994). In the light of Pearce's statements, we would conclude that China's coal sector is decidedly unsustainable on either the total rent approach or the user cost approach. The net price approach cannot be applied in case of coal for measurement of sustainable development.

5.6 Conclusion

In this chapter, we discussed coal reserves, production and pricing problems. The coal industry has problems of low productivity and low efficiency. The multitiered pricing system has brought chaos to the Chinese coal market. Coal pricing is the main problem in the sector. Given large subsidies from the government, the sector is still incurred in financial losses. The chaos in prices should be eased by reforming the system towards market pricing. The dual pricing system should therefore be abandoned in order to price coal in a more rational way.

Then the coal reserve depreciation and coal-adjusted national accounts have been calculated. Three approaches were used. The first is the net price approach, which yielded erratic and unreliable figures for coal depreciation. The second was the total rent approach. This approach gave sensible results and its depreciation reached about 10 percent of GNP. The third is the user cost approach, the depreciation derived by using this approach at zero percent discount rate being similar to the total rent approach because theoretically they are also comparable. However, for user cost at 5 and 10 percent discount rates, figures indicated virtually zero depreciation of coal.

The coal-adjusted accounts show that the net investment of the coal sector was negative in all years from 1976 to 1992 by both the total rent approach and the user cost approach. This in general indicates that the sector is not in sustainable development. This implies that throughout the whole period the development of coal industry has not been sustainable and should invest more to keep coal sector sustainable.

Appendix

Appendix 5.1 World Prices of Coal

year	world price (US Dollar)	WP in yuan	Exchng rate	deflator (1980=100)	WP (yuan)	MER* (yuan)	MER WP
1976	53.56	80.34	1.50	0.904	88.87	1.94	103.90
1977	54.26	81.39	1.50	0.914	89.05	1.86	100.92
1978	55.74	83.61	1.50	0.927	90.19	1.68	93.64
1979	56.50	84.75	1.50	0.946	89.59	1.56	88.14
1980	55.70	85.22	1.53	1.000	85.22	1.50	83.55
1981	65.24	114.17	1.75	1.019	11.04	1.71	111.56
1982	64.93	124.67	1.92	1.028	12.27	1.90	123.37
1983	55.51	109.91	1.98	1.039	105.78	1.98	109.91
1984	49.67	139.08	2.80	1.094	127.13	2.32	115.23
1985	45.32	145.02	3.20	1.203	120.55	2.94	133.24
1986	44.85	166.84	3.72	1.251	133.37	3.45	154.73
1987	41.49	154.34	3.72	1.341	115.10	3.70	153.51
1988	49.50	184.14	3.72	1.452	126.82	3.80	188.10
1989	52.25	196.98	3.77	1.582	124.51	3.80	198.55
1990	56.16	268.44	4.78	1.683	159.50	3.80	213.41
1991	54.00	287.28	5.32	1.779	161.48	3.80	205.20
1992	52.00	299.00	5.75	1.870	159.89	3.80	197.60

Sources: A Review of China's Energy Policy, Berkeley, 1994.
BP Statistical Review of World Energy, 1976-1992.

Chapter 6

Oil Account in China

6.1 The Oil Situation in China

6.1.1 Oil Reserves and Production

China has some reserves of oil but compared with its coal reserves and the size of its population[1], its level of oil reserves per capita is still quite low. There is little natural gas in China, accounting for only 1 to 2 percent of total energy consumption[2] (*Annual Report of Mineral Resources* 1988, 1992, *BP Statistical Review of World Energy* 1995). Few statistical series exist for natural gas. Hence, this chapter will deal mainly with oil. Most of the oil reserves are located in the eastern part of China. Some are located in the remote inland areas, such as the Tarimu Basin, which are not easily accessible. In recent years, oil has also been discovered in the offshore seas, but the volume of these new discoveries is also very limited and exploiting them is also constrained by the high costs of extraction. From 1976 to 1992 China's oil reserve fluctuated between 2.4 to 3.2 billion tonnes owing to new discoveries (*BP Statistical Review of World Energy* 1981-1993). Many oil companies have idle equipment and employees, waiting for new discoveries to explore each year. Since 1993, China has become a net oil importer.

In 1992, the total oil reserves in China was 3.2 billion tonnes (*BP Statistical Review of World Energy* 1993); its oil production made up around 19 percent of total energy production while the rest of the energy production consisted of 74 percent coal, 5 percent hydroelectricity and less

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[1]China's coal reserves stood at 366.7 billion tonnes in 1992 (Annual Report of Mineral Resources 1988, 1992 (in Chinese)). The oil reserves per capita in China is 2.75 tonnes, compared with 24.9 tonnes per capita of world level (BP Statistical Review of World Energy 1995).

[2]China's natural gas accounted for 0.7 percent of the total production in the world (BP Statistical Review of World Energy 1993).

than 2 percent natural gas (*Statistical Yearbook of China* 1993).

China's oldest oil fields are Yumen and Keramay in the northwestern part of the country. Daqing oil field was discovered and started to produce oil in 1960s. In 1970s and 1980s some new oil fields were discovered in the eastern part of China: Shengli, Zhongyuan and Dagang. The recent exploration in the Tarimu basin has added to the new record of oil reserves in China.

About 90 percent of oil in China is produced from the oil fields in the eastern part (see more details). The output from Daqing, Shengli and Liaohe comprises 75 percent of the total output. The output from offshore seas was about 1 percent in 1991, 2 percent in 1992 and 5 percent in 1995. According to the published figures on oil production in 1990, the total output in that year was 138 million tonnes, ranking number 5 in the world. Production from the eastern part of China was 124 million tonnes, from the northwestern part, 13 million tonnes and from the sea, 1.3 million tonnes. In 1991 the total output was nearly 140 million tonnes, of which, the offshore output constituted 2.4 million tonnes (Zhong and Zhang 1993).

From 1981 to 1985, there was a decrease in oil output. But the output from the Daqing Oil field was stable (Zhou 1993). The output from the Shengli Oil Field also reduced at first, then increased in 1985. During the later part of this period, the output increased smoothly by 10 percent per annum. The growth rate of consumption of crude oil was controlled by the government within 4.9 percent. There was an increase in oil exports during the later part of the period. The export level reached 30 million tonnes per annum (Shi and Xu 1993).

During 1986-1990, the industrial growth rate reached 7.5 percent (*Statistical Yearbook of China* 1993). For the first part of that period, the output from the Daqing Oil Field increased due to high investment during the period. During the later part of the period, because priority was given to coal and electricity, investment in petroleum was reduced. In 1988 the output from the Dagang and Huabei oil fields decreased rapidly. The output of oil in 1989 increased 0.4 percent compared with that of 1988. In 1990 the increment was 0.6 percent. During that time the growth rate of the economy was 10 percent, and the incremental demand for energy was 6 percent.

From 1991 to 1995, the output of oil was 145 million tonnes per annum, including 5 million tonnes from the new discoveries in the western part of China. The overall output target for 1995 was to have 145 million tonnes of inland output plus 8 million tonnes of offshore output. In 2000, the output is expected to reach 165 million tonnes (Zhong and Zhang 1993).

From 1987 to 1992, China invested 133.7 billion yuan in oil and natural gas (Zhou 1993). The additional production capacity for oil increased to 76 million tonnes. In recent years some new oil fields have been discovered, for instance, those in the Liaohe-Jilin area, in Tarimu, Turufan-Hami and the Zhungel basin in Xinjiang. Presently, the annual extraction capacity in Xinjiang has reached 7 million tonnes. Oil production in the sea has developed rapidly and there are 7 oil fields located in Buohai, the eastern part of Nanhai and the western part of Nanhai. The Huizhou oil field is the largest sea oil field in China with a capacity of 1.5 million tonnes per annum. At present the Suizhong 36-1 oil field, the Wei11-4 oil field, and the Lufeng 13-1 oil field are under construction. The Xijiang 24-3 and 30-2 oil fields, and the Jinzhou 9-3 oil field will soon be constructed. Offshore oil production has been increased from 714,000 tonnes in 1987 to 3.9 million tonnes in 1992. The incremental output was 630,000 tonnes per annum on average (Zhou 1993, Zhong and Zhang 1993).

Figure 6.1 Location of Oil Fields in China

Radius scaled to 1988 production.

Source: Energy Statistical Yearbook of China, 1989.

Refineries in China are normally located away from the oil production fields. Refinery technologies vary across the country. Some use modern technology while others still use antiquated equipment. For certain components of crude oil, the obsolete equipment cannot fully refine them, and burning these components in the oil fields and refineries is the usual way of treatment. Recently, many small refineries and oil processing plants have been established over all the country. These small plants operate basically far below an economically optimal scale, use very poor technology and equipment and waste relatively scarce oil resources. These plants take advantage of the price difference between planned and market prices to produce some low quality products.

Table 6.1 Stocks and Production of Oil in China
million tonnes

year	output	consumption	stocks
1976	83.6	76.9	2700
1977	93.6	82.0	2700
1978	104.1	84.7	2700
1979	106.1	91.1	2700
1980	105.8	88.0	2800
1981	101.0	84.8	2760
1982	101.7	82.4	2700
1983	106.0	84.7	2600
1984	114.5	86.5	2600
1985	124.9	90.3	2400
1986	130.7	100.0	2400
1987	132.9	105.3	2400
1988	137.0	110.2	3100
1989	137.6	112.3	3200
1990	138.3	110.3	3200
1991	139.8	117.9	3200
1992	142.0	129.0	3200

Sources: *China Energy Statistical Yearbook 1991.*
BP Statistical Review of World Energy 1976-1992.

China Energy Databook 1992.

Figure 6.2 Oil Stocks, Production and Consumption in China

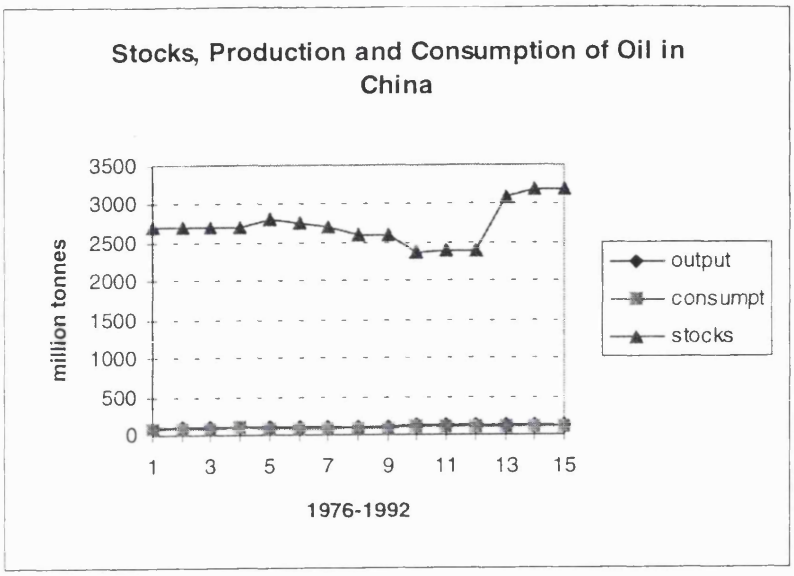
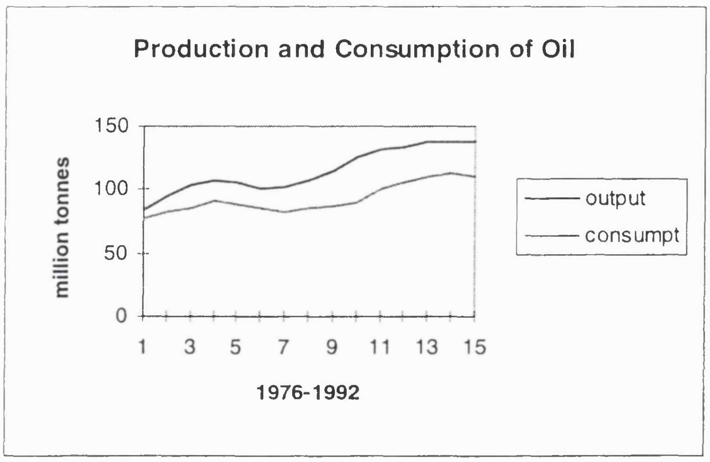


Figure 6.3 Oil Production and Consumption



6.1.2 Situation of the Oil Fields

Eastern Part

According to Zhong and Zhang (1993) and Zhou (1993), the production capacity of the Daqing Oil Field, the largest oil field in China, was 55.62 million tonnes in 1991. Daqing will maintain this level of output until the year 2000. The Shengli Oil Field produced 33.55 million tonnes of oil in 1991, ranking number two in China. The Liaohe Oil Field started extracting petroleum in 1969. Its production capacity was 13.6 million tonnes in 1990, which accounted for 9.8 percent of the total output. The Huabei Oil Field started to extract oil in 1975. From 1975 to 1979 its extraction capacity was 17 million tonnes per annum. Thereafter, the output from the field has decreased yearly. In 1990 the output was 5.35 million tonnes. Its output was 5.01 million tonnes in 1991. Dagang's was 3.81 million tonnes, Xinjiang's was 7.02 million tonnes, Zhongyuan's was 6.01 million tonnes, Erlian's was 2 million tonnes and Tarimu's was 0.6 million tonnes, in 1991.

Western Part

1) Tarimu Basin. This oil field was discovered in Xingjian in 1989. It has a capacity of 4898[3] tonnes of oil and 340,000 cubic metres of natural gas per day. It is planned that from 1996 to 2000, the capacity will reach 15-20 million tonnes per annum. 2) Zhunger Basin. This oil field is located in the north part of Xinjiang. Keramay is the main oil field, with a capacity of 5 million tonnes per annum. 3) Tulufan Basin. In 1991 the Shanshan Oil Field commenced extraction and in 1992 the Liling Oil Field started to operate. The capacity of the Shanshan Oil Field was 0.5 million tonnes per annum and that of the Liling Oil Field, 1 million tonnes per annum. It is expected that in 1995, the total capacity will be 3-4 million tonnes per annum. 4)

[3]Classification of the production capacity of oil is as follows: a capacity below 5000 tonnes per pay counts as low capacity, between 5000-10000 tonnes per day is average capacity and above 20000 tonnes per day is high capacity.

Chaidamu Basin. The total capacity here is 1.1 million tonnes per annum.

Offshore Oil Fields

The output of offshore oil was 1.27 million tonnes in 1990 and 2.39 million tonnes in 1991. There are 6 oil fields and 8 natural gas fields. In joint-ventures with foreign firms, the extraction capacity in 1993 was 5 million tonnes, 8 million tonnes in 1995 and will be 10 million tonnes in 1997 (Zhong and Zhang 1993). Most of the oil fields in the eastern part have been exploited over a period of 30 years, and their output has decreased gradually. In order to maintain the oil output, most of these oil fields need to be filled up with water for oil extraction. The water content of the crude oil is normally 80 percent, that is, 4 tonnes of water is filled for every tonne of oil extraction. Thus, dewatering is a necessary procedure in oil extraction. In addition, increasing the density of well numbers, acidization and pressurization in old wells, preventing sand drilling and maintenance lead to a much higher cost for oil production (Li 1993).

Table 6.2 Production of Oil in Each Oil Field (million tonnes)

oil field	1986	1987	1988	1989	1990	1991
Daqing	55.6	55.6	55.7	55.6	55.6	55.6
Shengli	28.7	31.6	33.3	33.3	33.5	33.5
Liaohe	9.8	11.3	12.7	13.3	13.6	13.7
Zhongyuan	6.1	6.8	7.2	7.0	6.3	6.1
Xinjiang	5.5	5.8	6.2	6.4	6.8	7.0
Huabei	10.0	7.9	6.0	5.5	5.3	5.0
Dagang	3.9	4.2	4.2	4.1	3.8	3.8
Jilin	2.3	2.9	3.1	3.4	3.5	3.4
Henan	2.5	2.5	2.6	2.5	2.5	2.4
Changqing	1.5	1.4	1.5	1.4	1.5	1.5
Jianghan	1.0	1.0	1.0	0.9	0.8	0.7
others*	3.4	2.4	2.7	3.2	3.7	4.5
Total	130.3	133.4	136.3	136.7	137.0	137.1

*Others are oil fields from: Yumen, Erlian, Jiangsu, Qinghai, Sichuan and Tarimu.
Source: Zhong and Zhang (1993) "The Situation and Development of Oil and Natural Gas in China", *Energy of China*, no 11.

6.2 The Crude Oil Pricing System in China

6.2.1 Planned Price

The crude oil price system in China was set up in 1957 by the government based on the overall price level at that time. This centrally planned price system did not change for over twenty years (Zhang 1990, Yang 1993 and Yang 1994). During this period, the cost increased dramatically and the international oil level also increased from 1.8 US dollar/barrel in 1957 to 32 US dollar/barrel in 1980 and now is about 14.8-17.2 US dollar/barrel. The oil price in 1987 was only 110 yuan per tonne, which was equivalent to 30 US dollar per tonne and 4.1 US dollar per barrel (Annual Report of Mineral Resources 1988, 1992). Oil pricing in China also has not set prices according to quality. For example, the sulphur content of crude oil in the Daqing Oil Field is only 0.08 percent, while the sulphur content in the Shengli oil field reaches 2.09 percent, and yet the prices from the two oil fields are the same.

The irrational energy prices cause financial loss in oil production, a situation also discussed by Clark and Winters (1993), Li (1993) and Li (1993). Until 1990 the loss from oil and natural gas was 4.7 billion yuan even though 1 billion yuan of subsidies was given to oil production. The planned price of oil increased from 110 yuan/tonne in 1987 to 201 yuan/tonne in 1991 in the eastern part of the oil fields. In the western part of the oil fields, the planned price was 216 yuan/tonne in 1991. The market price of oil from the eastern part was 589 yuan/tonne and 519 yuan/tonne from other regions (Chen and Li 1992, Zhong and Zhang 1993). In 1992 the planned price of crude oil in China was 249.1 yuan/tonne, and the market price was 670 yuan/tonne. According to the dual pricing policy in 1989 crude oil from China was sold at a price of 429 yuan/tonne in the market. In 1990 the price was sold 728 yuan/tonne.

Starting from 1981, the output of oil reached 100 million tonnes/annum (Yan 1994). The pricing policy was also changed to a system of contracting for production. Within the limits of contracts, oil is sold at the planned prices. Beyond these limits, oil is sold at the market prices. This dual pricing policy has dominated oil production until now. As for the profit income, 85 percent of the profit is used as a petroleum exploration fund for further production while 15 percent is allocated as welfare and bonus to the enterprises.

The average cost of oil production in 1987 was about 146 yuan/tonne in some oil fields and in 1989 the average cost was 218 yuan/tonne. The Yumen Oil Field is one of the highest-cost fields in China, its average cost in 1989 being 500 yuan/tonne (Li 1993). The production cost of oil has increased successively. There are several reasons for the cost increases:

1) production conditions get increasingly worse and the depth of an oil well is 400-500 metres deeper than in 1960s;

2) because of the depletion in the main oil fields, new oil fields are mostly drilled in the periphery area of the existing fields, which have a relatively lower ground pressure, incur a higher production cost and produce lower output;

3) most of the oil fields in China are in the last phase of production. For oil to be extracted, the well must be filled with a large volume of water;

4) due to the remote location of new discoveries, the degree of difficulty in extraction from new oil fields increases;

5) price increases for all the raw materials such as inputs, electricity, land use fees and so on have caused an increase in cost.

6.2.2 The Dual Pricing System

Although the output of oil increased on a yearly basis from 1949 to 1978, in 1979 output decreased. In 1981 the output of oil had decreased from 106 million tonnes in 1979 to 101 million tonnes. In response to this problem, the Ministry of Oil Industry adopted a policy of contracting for production. Under the contracting system, the ministry sets up a target that 100 million tonnes of crude oil should be produced annually under the state plan, and extra output can be produced to meet the remaining market demand at market prices. In other words, there is a dual pricing system for oil distribution. The dual pricing system is that within the quota of 100 million tonnes, oil is sold at the planned price and beyond this quota, oil can be sold at a higher price close to the international price level. This contracting for production policy started the dual pricing system for oil in China. All oil products: gasoline, kerosene, diesel oil, lubricating oil and so on implement the dual pricing system accordingly.

From 1981 to 1988, almost 29 billion yuan of petroleum exploration funds were raised, 9 billion more than the investment made by the state during the same period (Statistical Yearbook of Energy 1991). The creation of the dual pricing system is a necessary step and a historical selection for the price reform and the development of the oil industry. There are four reasons to which the dual pricing system can be attributed:

1. According to Yan (1994), before 1981 the price of oil was so low that it did not reflect the real value of oil and the demand of the market. The unreasonable price also gave no incentive to the oil production sector. Since the low price of oil could not cover the production cost before the introduction of the dual pricing system, it was necessary to select such a system as a transitional stage.

2. Since there was no market mechanism in 1981, complete liberalisation of the planned oil price would not have been a suitable course of action for a centrally planned economy like China at that time, and would definitely have caused chaos on the oil market. The dual system

could function as a transitional step from the centrally planned pricing system to the market pricing system.

3. Because of the shortage of oil resources in China, it was thought that the limited resources should be used for the most important sectors and industries. If the market price had come into effect immediately in 1981, some important projects would not have got sufficient supplies of oil at a low price, leading to adverse effects on the economy.

4. At that time the dual pricing system allowed the oil sector raise more funds for production and investment via the income from the difference between the two price levels.

While the dual pricing system has some positive features, over ten years have passed since its establishment, and this period is long enough to move to market pricing if the Chinese authorities really plan to do so. Unfortunately, the dual pricing system is still dominant in the oil market, and problems inevitably continue to arise. Under the dual pricing system, only the oil output beyond the state quota is parallel to the international price level. The rest of the oil product is still sold at under the planned price, which is lower than the cost. The dual pricing policy is rigid all the time. Therefore, even when the cost exceeds the planned price, the price is not allowed to be raised. This evidently means that most of the oil fields are faced with an economic loss. Starting from 1988, the whole oil sector has suffered from economic loss.

The original purpose of raising funds by the dual pricing system has become weaker. Because the planned price has been raised, and the ex-quota price has been decreased several times, there is still a gap between the two prices but the difference has got smaller: fewer funds can be raised in this way. The demand for funds for oil extraction increases sharply, in line with the increasing difficulty in exploration. New discoveries are for the most part located in remote areas or in desert, marshland, mountains, or shallow sea areas with depths of extraction above 4000-5000 metres. At present the main oil fields in the east of China have entered the last stage of extraction, characterised by the wells filling up with a large volume of water in production.

The average water content in the country has increased from 55 percent in 1980 to 77 percent currently. The daily oil output per oil well has reduced from 14.8 tonnes in 1985 to 8.1 tonnes in 1992 (Yan 1994). At the same time, the amount of underground work amount in wells has increased 1.3 times and water demand for extraction has also increased 1.3 times (Li 1993). With worsening difficulties with extraction, the technical requirements have grown and accordingly there is a greater demand for funding in production. Hence the price difference from the dual pricing system is not by itself adequate to meet the ever increasing demand for money in oil production and investment.

As discussed before, the original purpose of setting up the dual pricing system was to raise funds for the oil industry. However, with the lessening fund raising capacity of the dual pricing system, recent years have seen a regular shortage of funds for oil investment. In order to raise the funds for production, by the end of 1990 the whole oil sector had accumulated debts of 36.8 billion yuan, of which 4.2 billion US dollars constituted foreign debts (Chu and Chen 1992). The dual pricing system cannot secure the financing for direct production. The direct inputs for production, such as electricity, land use, raw materials and other charges have all increased in price. The dual pricing system is impotent when confronted with such circumstances, production costs have increased greatly and the whole oil sector suffers from economic loss. The dual pricing system has also brought corruption. Many intermediate dealers seize the chance to make money by manipulating the difference between the planned and the market price. People try to exploit the price difference to get more and more benefits. The same quality of oil can be sold at the planned price or at the market price, depending totally on private benefits and personal relationships in oil transactions. The dual system provides an opportunity for these illegal deals, from which there are high profits to be made.

The dual pricing system weakens oil production and exploration. According to Chu and Chen (1992) from 1986 the growth of oil output has slowed down. In 1989, the output of crude oil was 137.6 million tonnes, and the increment only 0.4 percent. In 1990, the output of crude oil was 138.3 million tonnes with 0.47 percent of increment. The exploration of new discoveries is seriously affected by the shortage of funds. Take the Daqing Oil Field as an example: since 1976 this field has steadily increased its output by 50 million tonnes each year, but its new discoveries are lower than the yearly output. This will soon lead to depletion (Zhong and Zhang 1993). The low planned prices are an incentive for higher demand and waste of energy. According to the statistics the Ministry of Energy of China[4], in the production of one US dollar of GNP, France spends 8719 joule of energy, Japan spends 9787 joule, and China spends 43394 joule. In other words, China's energy consumption is 4.97 times higher than that of France and 4.43 times higher than that of Japan per unit of output.

The dual pricing system also encourages thriving oil processing industries. Since the price of crude oil is very low, processed oil products are very profitable. In 1987, for example, in 1987 for every one tonne of crude oil sold to oil processing industries, the oil sector received only 26 US dollar (96.7 yuan) of income, whereas one tonne of polyester processed from oil was sold at a price of 2650 yuan (Zhong and Zhang 1993). As discussed earlier, the low price of crude oil also stimulates the establishment of small scale refineries and oil processing plants with inefficient production and heavy wastage of oil. The effective way to solve all these problems in the oil sector is to abandon the dual pricing system and to fully liberalise oil prices to be determined by the market mechanism in adjusting the demand and the supply.

6.3 China's Oil Accounts

6.3.1 Accounting Adjustments

As with the coal accounts in China, we have calculated the oil accounts and oil-adjusted national accounts to show the effect of oil depletion on the development of the oil sector and also on the economy as a whole.

[4]World Energy 1988-1989, the Ministry of Energy, China.

Our calculation procedures are similar to those used in the coal accounts. Firstly we calculated depreciation or capital consumption allowance using the net price approach. Here the stocks of oil from 1976 to 1992 are used to derive the account. China is not an oil-rich country, and relative to its resources, consumption is very large, with extraction exceeding discoveries in certain years.

In China oil is sold under the dual pricing system and the planned price is normally set below the level of production cost, of which is below the market price. As illustrated in the previous discussion the dual oil pricing issue, the prices set by the government in this case cannot reflect the real value of oil. Accordingly, the shadow price is used to calculate the oil accounts in our research. It is not possible to use the present market prices either, since under the dual pricing system, the market prices should take certain advantages from the imperfect market mechanism and as such, are not the true market prices of a market economy. Consequently, this research uses the international oil prices as the price for calculation of oil depreciation. Oil is treated as a tradable good here.

Thus, all prices used in our calculations are international market prices in the corresponding year. We use official exchange rates to convert the international prices in US dollar into the local currency, yuan. We then deflate all the converted prices to subtract the inflation factor (1980 = 1). The unit cost is simply the cost published by the official statistics, which is also deflated. We then derived the net price by deducting the unit cost from the shadow price.

Table 6.3 shows the actual calculation procedures of the production costs and the converted prices. The data of the production costs are obtained from field work and deflated against deflators (1980= 1) to subtract the inflation factor. The world price is the price per barrel of oil in US dollar. Since the conversion factor from barrel to tonne is 7.3 (*BP Statistical Review of World Energy*), we convert the price from barrel to tonne. The prices are also identically deflated by deflators.

Table 6.3 The Price and Cost of Crude Oil

year	unit cost yuan/t (a)	world price US$/barrel (b)	world price US$/t (c)	deflator (1980=1) (d)	exchange rate yuan/US$ (e)	real world price yuan/t (f)=(c)x(e)/(d)	real cost yuan/t (g)=(a)/(d)
1976	31.9	11.3	82.5	0.904	1.50	136.8	35.3
1977	33.5	13.4	97.9	0.914	1.50	160.6	36.7
1978	36.4	13.4	98.2	0.927	1.50	158.9	39.2
1979	40.7	21.1	154.8	0.946	1.50	245.5	43.0
1980	43.6	27.5	201.6	1.000	1.53	308.4	43.6
1981	47.9	35.0	256.6	1.019	1.75	440.6	47.0
1982	52.9	35.0	256.6	1.028	1.92	479.2	51.4
1983	54.6	34.0	249.2	1.039	1.98	474.9	52.6
1984	56.2	29.0	212.6	1.094	2.80	544.1	51.4
1985	61.2	29.0	212.6	1.203	3.20	565.4	50.8
1986	69.1	14.4	105.4	1.251	3.72	313.4	55.3
1987	78.4	18.4	135.1	1.341	3.72	374.8	58.4
1988	97.6	17.5	128.4	1.452	3.72	329.0	67.2
1989	144.1	18.2	133.4	1.582	3.77	317.9	91.1
1990	177.6	23.8	174.5	1.683	4.78	495.7	105.5
1991	208.2	20.1	147.0	1.779	5.32	439.5	117.0
1992	238.2	19.4	142.0	1.870	5.75	436.6	127.4

*7.33 barrels=1 tonne, given by *BP Statistical Review of World Energy*. Sources: *Forty Years Development of China's Energy* (1990). Yang *et al* (1994) *A Review of China's Energy Policy*. Data obtained from departments concerned.

The next step is to recalculate the gross product of the oil industry and the GNP by using the world price in order to get consistent results in accounting. The formula for adjusting the gross product of the oil industry is as follows:

GNP - GOP + GOP* = GNP*

The adjusted gross product of the oil industry is recalculated by multiplying the output from 1976 to 1992 by the real world price (1980 = 1). Then the original GOP is subtracted from the GNP and the recalculated gross product of the oil industry (GOP*) is added to the GNP. Table 6.4 presents GOP* and GNP*.

Table 6.4 Calculation of GNP* and GOP* by the World Price
unit: billion yuan

year	output (mi tonnes) (a)	world price (yuan) (b)	GOP* (c)=(a)x(b)	GNP (original) (d)	GOP (original) (e)	GNP* (f)=(d)-(e)+(c)
1976	83.6	136.8	11.4	268.5	14.0	265.9
1977	93.6	160.6	15.0	289.3	15.6	288.7
1978	104.1	158.9	16.5	387.1	15.8	387.8
1979	106.1	245.5	26.0	422.6	16.6	432.1
1980	105.8	308.4	32.6	447.0	15.8	463.8
1981	101.0	440.6	44.5	468.4	15.1	497.8
1982	101.7	479.2	48.7	505.2	15.3	538.6
1983	106.0	474.9	50.3	559.1	16.3	593.1
1984	114.5	544.1	62.3	636.4	16.7	682.0
1985	124.9	565.4	70.6	711.4	16.9	765.1
1986	130.7	313.4	41.0	775.1	18.5	797.5
1987	132.9	374.8	49.8	842.7	21.8	870.7
1988	137.0	329.0	45.1	968.9	20.8	993.1
1989	137.6	317.9	43.7	1011.0	22.9	1031.8
1990	138.3	495.7	68.6	1051.4	25.4	1094.6

1991	139.8	439.5	61.4	1137.5	26.9	1172.0
1992	142.0	436.6	62.0	1285.9	32.7	1315.2

WP = the world price
All values here are deflated real values (1980 = 1).
Source: calculated by the author.

Oil resources used for adjusting national accounts are reserves published in the Chinese statistics and *BP Statistical Review of World Energy*. These data are reliable. The reserves refer to those that have already been discovered. In practice only these reserves have a positive rental value because their net price exceeds their estimated recovery cost.

According to the BP statistics and some data provided by the Chinese department concerned, oil reserves from 1976 to 1992 were altered due to exploration; in some years extraction was greater than discoveries. Therefore, we treat this additional part of the reserves as positive or negative discoveries. The treatment of new discoveries is not discussed here since the treatment of new discoveries for the mineral resources was dealt with in the previous chapter.

6.3.2 The Net Price Approach

Three approaches are applied in the oil accounts. The first approach used is the *net price approach.* Oil is a nonrenewable natural resource: the stock of oil is a part of the discovered stock and the economic depreciation is the loss in asset value from use. Oil is treated in the same way as coal in Chapter 5: on the net price approach the depreciation of oil is the depletion in value of the capital assets or stocks of oil. The difference in value at the beginning of the period and at the end of the period is the depreciation.

In calculating the net price, we set up both the physical and the economic account. The stocks of oil from 1976 to 1992 are listed at the beginning of the year as opening stocks and at the end of the year as closing stocks. The items of addition and depletion are also listed. In the physical account it is shown that in certain years the net change is zero because the stocks of oil did not change; for example from 1976 to 1979, the stocks were all 2700 million tonnes (*BP Statistical Review of World Energy* 1981), and therefore, the net change was zero in such a case.

Although in the physical account, there is no change between opening stocks and closing stocks for certain years, the monetary values are not same for these years because net prices differed. We take the depletion as the depreciation. In this sense, it does not matter what value of the net change is; the figure of depletion is more important. The depletion is an important factor in the accounts under the net price approach.

We still find in the calculation that the net price approach is not stable although the figures are not very high due to the small size of oil stocks mentioned before. What we discover here is that the depletions have changed on a large scale both positively and negatively under the net price approach. Hence, the calculation results are parallel to the results in the coal accounts with erratic results from year to year. As the oil resources are depleted by the quantity of oil extraction during the year, the amount of the deducted depletion alters from year to year and for most years we have appreciations rather than depreciations. Again we find that the net price approach is unacceptable.

It is understood that the unstable situation is affected by discoveries. Hamilton (1994a, 1994b) mentions that in terms of practical national accounting, resource discoveries, valued at the marginal discovery cost, ought to be added. Assuming that resource discovery costs increase with cumulative discoveries, then marginal discovery costs will be less than resource rents. We treated all discoveries of oil in China as being capitalised instantaneously, with no adjustment being made for discoveries in calculating "green" national accounts. It is understood that resources of oil are decreasing with extraction and that oil is an exhaustible natural resource, and as a result it is absurd to have appreciations. The net price approach here again proves to be unreliable. The table below shows the results from the net price approach.

Table 6.5 Calculation of the Net Price Approach
unit: billion yuan

year	(1) opening stocks	(2) closing stocks	(3) depreciate	(4) GNP	(5) adj GNP
1976		274.2		265.9	
1977	274.2	334.6	-60.5	288.7	349.2
1978	334.6	323.2	11.4	387.8	376.4
1979	323.2	536.6	-213.3	432.1	645.4
1980	536.6	741.6	-205.0	463.8	668.8
1981	741.6	1086.3	-344.7	497.8	842.5
1982	108.3	1154.9	-68.6	538.6	607.2
1983	1154.9	1140.3	14.6	593.1	578.5
1984	1140.3	1281.0	-140.7	682.0	822.7
1985	1281.0	1235.0	46.0	765.1	719.1
1986	1235.0	619.7	615.4	797.5	182.1
1987	619.7	759.1	-139.5	870.7	1010.2
1988	759.1	811.6	-52.5	993.1	1045.6
1989	811.6	725.8	85.8	1031.8	946.0
1990	725.8	1248.5	-522.8	1094.6	1617.3
1991	1248.5	1031.9	216.6	1172.0	955.4
1992	1031.9	989.4	42.5	1315.2	1272.7

Source: calculated by the author.

Table 6.5 shows clearly that overvaluation and undervaluation occur in the calculation when using the net price approach. Because the oil stock is relatively small compared with the stock of coal in China, the results of depreciation are less than the GNP (in the case of coal, the results are higher). what is important in calculating the "green" NNP is to deduct the depletion of resources from the original GNP, to value the impact of types of depletion such as changes in social welfare, and to measure the level of sustainable development. Thus, based on the reasons explained above, the erratic results imply that this approach is not acceptable since it cannot be used to derive a reasonable "green" NNP for nonrenewable resources.

6.3.3 The Total Rent Approach

The second approach is *the total rent approach.* Economic depreciation is equal to total profits from ownership of the stock in such a situation. We realise that the Hotelling rent is defined as price minus marginal cost while the total Hotelling rent is the Hotelling rent multiplied by the amount extracted. Since in practice it is extremely difficult to get the marginal cost, substituting this by the average cost is viable (Bryant and Cook 1992). Thus, the average cost is used here to derive the total rent. All the costs and prices have been deflated to reflect the real value of the rent. Based on this definition we simply treat each year's profit on extraction as depreciation of oil. By using the total Hotelling rent concept, the total Hotelling rent equals depreciation. It is believed that the total rent approach is a valid one because a) it precisely measures depreciation of the natural resources; b) it can be used to measure the welfare level in deriving such depreciation and c) it can be used to measure sustainability of the economy.

The total rent should be equivalent to the amount extracted times the unit rent, thus equivalent to depreciation. The total rent approach indicates that because oil resources are exhaustible, oil should be extracted more slowly than if it were in infinite supply. Hotelling's rule could have been employed to construct an optimal time path of oil extraction. For oil, we can compute the total Hotelling rent by multiplying the Hotelling rent by the amount extracted. In this way, we can measure true income as defined by Hicks.

The value of the net revenues is expected to be proportional to the gross product of the oil industry and the GNP, assuming an optimal schedule of drilling. The total rent approach can be employed to construct an optimal time path of oil extraction. For the reasons mentioned above, we believe that it is logical to use the total rent approach in calculating the oil accounts.

Table 6.6 Calculation of Total Rent Approach

year	output (10^6 tonnes)	rent (yuan)	total rent (10^9 yuan)
1976	83.6	101.5	8.5
1977	93.6	123.9	11.6
1978	104.1	119.7	12.5
1979	106.1	202.4	21.5
1980	105.8	264.9	28.0
1981	101.0	393.6	39.8
1982	101.7	427.8	43.5
1983	106.0	422.3	44.8
1984	114.5	492.7	56.4
1985	124.9	514.6	64.3
1986	130.7	258.2	33.7
1987	132.9	316.3	42.0
1988	137.0	261.8	35.9
1989	137.6	226.8	31.2
1990	138.3	390.2	54.0
1991	139.8	322.5	45.1
1992	142.0	309.2	43.9

Source: calculated by the author.

Rent in Column 2 of Table 6.6 is rent per tonne, that is, price minus average cost. For example, in 1981 the price of oil was 136.8 yuan per tonne and the unit cost was 35.3 yuan, hence, the rent was 101.5 yuan. TR is the total rent, which is calculated by rent times the amount extracted. In our calculation of the total rent approach, we treat depreciation of oil by price minus average cost times the amount extracted. The reason for this is that oil is also a nonrenewable resource and extraction implies reduction of the resource stocks. The table above shows a series of stable depreciations from 1976 to 1992. Thus we confirm here as in the chapter on coal, that the total rent approach is suitable for valuing nonrenewable resources in national accounts. For the reasons mentioned above, we believe that it is viable to simply take the total rent for oil as depreciation. The results show that there is no overvaluation of oil in the total rent approach.

6.3.4 The User Cost Approach

Thirdly, let us consider *the user cost approach.* In this chapter we still try to apply this approach. The costs of resource depletion and degradation resulting from economic activity are deducted from the conventional gross output value of oil. But since the depletion period is shorter and the stocks of oil are relatively small, it seems that this kind of calculation appropriate in the oil accounts. Thus in our total rent approach we find our calculation results to be quite convincing because they are stable.

We think that it is comparable to use this approach in adjusting oil in the national account. As in the chapter on coal, by using El Serafy's user cost approach we find out a way to the nonrenewable resources and it is appropriate to compare the results given by the total rent approach and the user cost approach in estimating oil depletion. Again, Young et al (1995) carried out a convincing empirical work for mineral accounts in Brazil by applying El Serafy's User Cost approach.

The contribution of El Serafy's approach is that resource receipts are already modified when they enter the gross GNP. The legitimate contribution of resources to the value added is counted there, since the user cost or depreciation of the resource is the difference between the value of a natural capital, used and extracted, at the end of an interval and the value of the same capital. For deriving oil accounts with the user cost approach, we assume that the economic depreciation is the loss in the value of oil in China from optimal use. The depreciation is simply the depletion in value of oil under optimal use. The value of an oil field at a given time is computed by summing up the discounted net revenues expected from the oil field each year, for as long as it continues to operate.

The value added is the difference between the gross output and the intermediate cost of production; from an input standpoint, it is the total of payments to primary factors, namely labour, produced capital, and oil stock. Using oil stock becomes parallel to the use of land, except that there is stock diminution in mineral stock use. From an accounting point of view the adjustment for economic depreciation of mineral stocks makes the treatment of mineral stock use the same as that for land use. It is significant to apply empirically El Serafy's claim (1989) that total mining receipts do not belong to the GNP because mining is not human production but rather the liquidation of an endowment. Thus, the value added in oil extraction from the income side is the wage bill, the produced capital rentals, land rentals and mineral capital rentals. These are the primary input costs per period of using a mineral stock. Value added on the product side is the full NNP, that is, all output values minus all depreciations from capital consumption.

We use the gross product of oil minus the intermediate cost to obtain the net output value or the value added. This intermediate cost includes all the costs, social charge and capital remuneration, except for wages. As discussed in the chapter on coal, this practice is different from other countries, in China all the cost should be deducted from the calculation. This also proves the reason of low efficiency by showing high intermediate cost. After we deducted wages we derived rent. This is the first step.

The stocks of oil are then divided by the output of each year to obtain the period of depletion. In China the consumption period for oil is about 25-28 years (see Appendix 1), showing that oil is a very limited natural resource. Once again we use El Serafy's formula to get the discount rate. The discount rates we choose here are zero percent, 5 percent and 10 percent. For the selection of the discount rates, it should be noted, as in the previous chapter, that discounting discriminates against future generations, and in calculating the depreciation of natural resources it is not necessary to calculate depreciation with the higher discount rate. Because of this, we prefer the zero discount rate. We use 5 and 10 percent discount rates respectively to get discounted rent only for the purposes of comparison and future investment. The results we obtained in deriving user cost show that there is a difference between zero, 5 and 10 discount rates. Unlike the user cost in coal, here we still get positive user cost for 5 and 10 percent discount rates. This effect implies that natural resources with large reserves, higher discount rates have little influence on the depletion of the resource. But for relatively small-sized natural resources, the discount rates are effective.

Table 6.7 Calculation of User Cost
(100 million yuan)

year	GOP* (a)	intermediate cost (b)	value added (c)=(a-b)	wage (d)	normal capital return (e)[5]	user cost (f)=(c-d-e)
1976	114.4	75.1	39.3	3.3	1.1	34.9
1977	150.3	83.5	66.8	3.3	2.2	61.3
1978	165.4	84.7	80.7	3.5	3.7	73.4
1979	260.4	88.9	171.6	3.8	5.1	162.7
1980	326.3	84.8	241.5	4.1	6.1	231.3
1981	445.0	85.4	359.6	4.0	7.6	348.0
1982	487.3	90.9	396.4	4.1	9.7	382.7
1983	503.4	101.4	402.1	4.1	12.0	385.9
1984	622.9	75.0	547.9	4.7	14.4	528.8
1985	706.2	65.9	640.4	5.0	16.9	618.4
1986	409.7	83.5	326.2	5.6	20.1	300.6
1987	498.0	87.9	410.1	5.7	22.9	381.5
1988	450.8	103.6	347.2	6.4	25.7	315.1
1989	437.5	135.0	302.5	6.6	28.6	267.3
1990	685.5	132.9	552.6	6.8	31.3	514.6
1991	614.4	144.7	469.7	10.5	34.3	424.9
1992	619.9	179.1	440.8	12.3	38.1	390.4

GOP*=gross output of oil.

In Table 6.8 the user cost at zero, 5 and 10 percent discount rates is calculated for the oil industry in China, along the lines of El Serafy (1989). We found that the higher the discount rate, the higher the sustainable income, and the lower the user cost. For example, in 1992, the

[5]Normal capital return is calculated using perpetual inventory method.

adjusted income with zero percent, 5 percent and 10 percent of discount rates is 5.0 billion yuan, 29.4 billion yuan and 38.9 billion yuan respectively. On the other hand, the user cost with zero, 5 and 10 percent of discount rate are 39.0 billion yuan, 14.6 billion yuan and 5.1 billion yuan respectively, showing, as expected, that high discount rates encourage high consumption in the present and are not favourable to future generations. In our empirical study, we select a zero percent discount rate to derive the oil account. The high discount rates are mainly used for future investment.

Table 6.8 Calculation of User Cost and Oil Depreciation
(100 million yuan)

		user cost			adjusted income		
year	value added	0% discount rate	5% discount rate	10% discount rate	0% discount rate	5%discount rate	10 discount rate
1976	39.3	34.9	8.1	1.8	4.4	31.2	37.5
1977	66.8	61.3	16.3	4.3	5.5	50.4	62.5
1978	80.7	73.4	22.8	6.8	7.3	57.9	73.9
1979	171.6	162.7	49.6	15.2	8.9	122.0	156.4
1980	241.5	231.3	66.4	19.4	10.2	175.1	222.1
1981	359.6	348.0	94.8	26.6	11.6	264.8	333.0
1982	396.4	382.7	108.5	31.6	13.7	287.8	364.8
1983	402.1	385.9	121.5	38.8	16.1	280.6	363.3
1984	547.9	528.8	181.0	62.9	19.1	367.0	485.0
1985	640.4	618.4	250.8	102.6	22.0	389.6	537.8
1986	326.2	300.6	133.2	56.7	25.6	193.0	269.5
1987	410.1	381.5	169.9	73.4	28.7	240.2	336.8
1988	347.2	315.1	115.1	40.2	32.1	232.1	307.0
1989	302.5	267.3	97.3	33.0	35.1	205.2	269.5
1990	552.6	514.6	178.7	60.9	38.1	373.9	491.7
1991	469.7	424.9	153.7	53.0	44.8	316.0	416.7
1992	440.8	390.4	146.8	51.5	50.4	294.0	389.4

Source: calculated by the author.

6.4 Comparison of Three Approaches and Measuring Sustainability of Oil Sector

6.4.1 Comparison of Three Approaches

A comparison among the three approaches described in the last section was undertaken. The results indicate that the net price approach is erratic and cannot be accepted. The depreciation on the total rent approach is stable and the figures are larger than the user cost approach. The depreciation on the user cost approach at zero discount rate is also stable, but is smaller than the total rent.

Table 6.9 Comparisons of Depreciation on Three Approaches
(billion yuan)

year	net price	total rent	user cost
1976		8.5	3.5
1977	-60.5	11.6	6.1
1978	11.4	12.5	7.3
1979	-213.3	21.5	16.3
1980	-205.0	28.0	23.1
1981	-344.7	39.8	34.8
1982	-68.6	43.5	38.3
1983	14.6	44.8	38.6
1984	-140.7	56.4	52.9
1985	46.0	64.3	61.8
1986	615.4	33.7	30.1
1987	-139.5	42.0	38.1
1988	-52.5	35.9	31.5
1989	85.8	31.2	26.7
1990	-522.8	54.0	51.5
1991	216.6	45.1	42.5
1992	42.5	43.9	39.0

Source: calculated by the author.

Table 6.9 shows the economic depreciation on the three approaches. The net price approach produces the very erratic estimates. The total rent approach indicates a series of stable and rational depreciations throughout the years, while the depreciation on the user cost approach is also stable though it is less than the total rent approach. A comparison between the total rent approach and the user cost approach with the GNP and the gross product of the oil industry in China is shown below.

We made comparisons between the total rent approach and the user cost approach at zero percent discount rate with the GNP*, NNP and the gross product of the oil industry (GOP*). By deducting man-made capital depreciation, the NNP is derived. The NNP is further deducted by depreciations from the total rent approach and the user cost approach to get the oil-adjusted NNP (ONNP). The gross product of the oil industry is deducted by the depreciations to get the oil-adjusted gross product of the oil industry.

Figure 6.4 Depreciation by Three Approaches

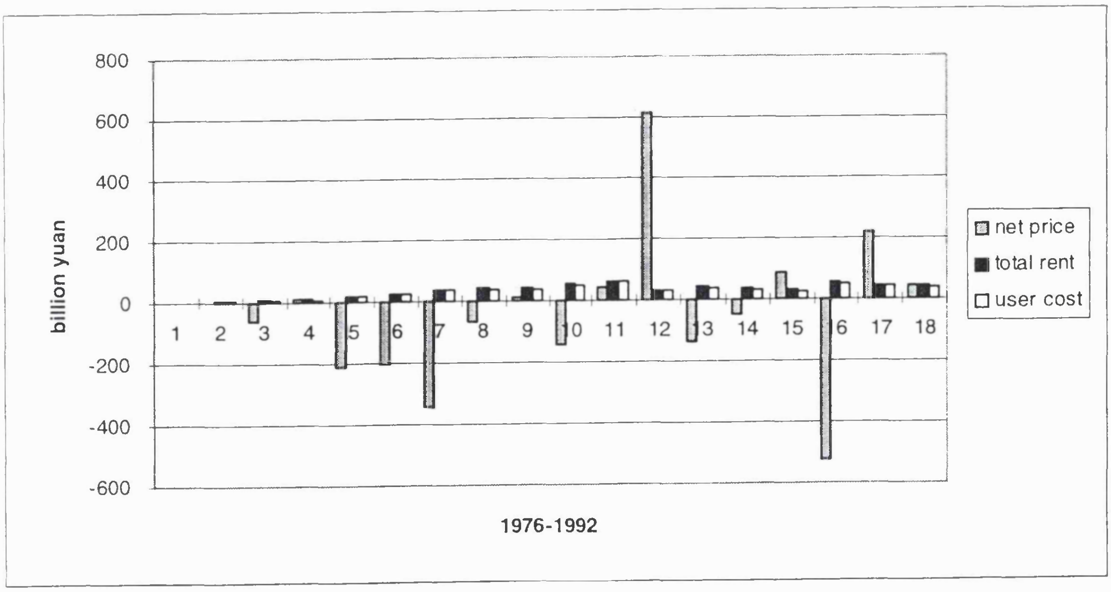


Table 6.10 Oil-adjusted NNP and GOP of Oil Industry
unit: billion yuan

year	GNP* (a)	NNP (b)	oil dep (total rent) (c)	ONNP (total rent) (d)=(b-c)	oil dep (user cost) (e)	ONNP (user cost) (f)=(b-e)	GOP* (g)	adjusted GOP (total rent) (h)=(g-c)	adjusted GOP (user cost) (i)=(g-e)
1976	265.9	253.6	8.5	245.1	3.5	250.1	11.4	2.9	8.0
1977	288.7	272.9	11.6	261.3	6.1	266.7	15.0	3.4	8.9
1978	387.8	369.1	12.5	356.7	7.3	361.8	16.5	4.1	9.2
1979	432.1	403.5	21.5	382.0	16.3	387.2	26.0	4.6	9.8
1980	463.8	425.2	28.0	397.2	23.1	402.1	32.6	4.6	9.5
1981	497.8	445.2	39.8	405.4	34.8	410.4	44.5	4.7	9.7
1982	538.6	480.2	43.5	436.7	38.3	441.9	48.7	5.2	10.5
1983	593.1	531.5	44.8	486.7	38.6	492.9	50.3	5.6	11.7
1984	682.0	606.7	56.4	550.3	52.9	553.9	62.3	5.9	9.4
1985	765.1	680.1	64.3	615.8	61.8	618.2	70.6	6.4	8.8
1986	797.5	739.7	33.8	697.6	30.1	709.6	41.0	7.2	10.9
1987	870.7	805.5	42.0	769.6	38.1	767.3	49.8	7.8	11.7
1988	993.1	928.3	35.9	897.1	31.5	896.8	45.1	9.2	13.6
1989	1031.8	968.6	31.2	914.7	26.7	941.9	43.7	12.5	17.0
1990	1094.6	1007.6	54.0	962.6	51.5	956.2	68.6	14.6	17.1
1991	1172.0	1082.3	45.1	1037.2	42.5	1039.8	61.4	16.4	18.9
1992	1315.2	1315.2	43.9	1271.3	39.0	1276.2	62.0	18.1	23.0

ONNP = oil-adjusted net national product.
Source: calculated by the author.

Table 6.10 shows that the depreciation of oil using the total rent approach is slightly higher than the user cost approach in the year. Using the total rent and user cost approaches, the net investment in the oil industry is negative every year. A comparison between the total rent approach and the user cost approach at zero percent discount rate was conducted. We confirm that the value in the total rent approach in our calculation of oil accounts is plausible for the reasons we have already mentioned several times, namely that the total rent approach follows the principle of the Hotelling rule and also coincides with the theory of Hicksian income. From our point of view, we find the total rent approach preferable because it reasonably reflects the depletion of oil theoretically and empirically. The total rent approach in this chapter can also represent the correct value of the depreciation of oil which should be deducted from the GNP. With the comparison between oil depreciation and the gross product of the oil industry in China, the depreciation of certain years under the total rent approach accounts for about one third of the recalculated gross output value (GOP*) of the year. For instance, in 1980, GOP* was 32.6 billion yuan, the depreciation using the total rent approach was 28.0 billion yuan, and the user cost at zero percent discount rate was 23.1 billion yuan.

Finally, the ratios between oil depreciation, the gross national product and the gross output of the oil industry are derived. It is interesting that the ratios between depreciation and the gross national product are around 3 to 9 percent on the total rent approach, and a slight lower percentage on the user cost approach at zero percent. The ratios between depreciation and the gross product of the oil industry are from 61 to 134 percent on the total rent approach and about 24 percent to 119 percent on the user cost approach. This also demonstrates that the depreciation of oil accounts for a large proportion of the income of the oil industry.

Table 6.11 Ratios of Oil Depreciation to GNP* and GOP*

year	Odep/GNP* (total rent)	Odep/GNP* (user co)	Odep/GOP* (total rent)	Odep/GOP* (user co)
1976	0.03	0.01	0.61	0.24
1977	0.04	0.02	0.75	0.37
1978	0.03	0.02	0.79	0.44
1979	0.05	0.04	1.30	0.93
1980	0.06	0.05	1.77	1.38
1981	0.08	0.07	2.63	2.18
1982	0.08	0.07	2.84	2.37
1983	0.08	0.07	2.74	2.24
1984	0.08	0.08	3.38	3.00
1985	0.08	0.08	3.80	3.46
1986	0.04	0.04	1.82	1.63
1987	0.05	0.03	1.93	1.76
1988	0.04	0.03	1.72	1.50
1989	0.03	0.03	1.36	1.15
1990	0.05	0.05	2.13	1.97
1991	0.04	0.04	1.67	1.58
1992	0.03	0.03	1.34	1.19

Odep/GNP* = oil depreciation to GNP*.
Odep/GOP* = oil depreciation to GOP*.

6.4.2 Net Investment and Sustainability

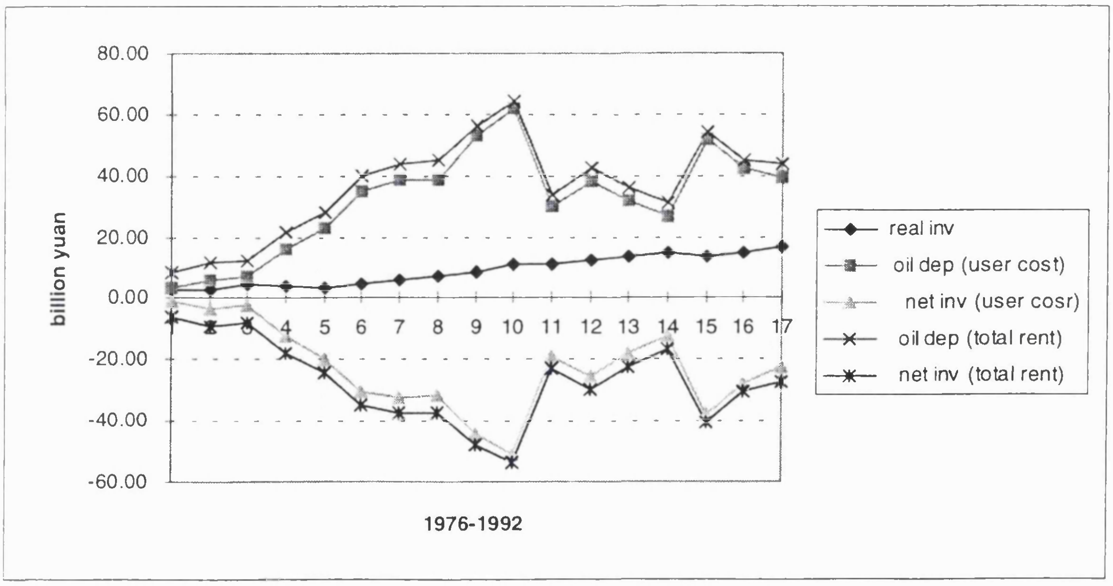
In Table 6.12 below, the net investment for each year (1976-1992) is derived, using the total rent approach and the user cost approach. With the total rent approach and the user cost at zero percent discount rate, all the net investment is negative. This also indicates that development in the oil sector is not sustainable since the net investment is negative. As was discussed in connection with our forest-adjusted national accounting, the negative net investment indicates that the country did not invest high enough to keep its development sustainable; it should invest more to keep the net investment positive.

Table 6.12 Net Investment and Sustainability
unit: billion yuan

year	investment (a)	oil dep (user cost) (b)	net inv (c)=(a-b)	oil dep (total rent) (d)	net inv (e)=(a-d)
1976	2.6	3.5	-0.9	8.5	-5.9
1977	2.6	6.1	-3.5	11.6	-9.0
1978	4.8	7.3	-2.5	12.5	-7.7
1979	3.8	16.3	-12.4	21.5	-17.7
1980	3.6	23.1	-19.6	28.0	-24.5
1981	4.6	34.8	-30.2	39.8	-35.2
1982	6.0	38.3	-32.2	43.5	-37.5
1983	7.1	38.6	-31.4	44.8	-37.6
1984	8.6	52.9	-44.2	56.4	-47.8
1985	10.8	61.8	-51.0	64.3	-53.4
1986	11.0	30.1	-19.1	33.8	-22.8
1987	12.4	38.1	-25.8	42.0	-29.6
1988	13.6	31.5	-18.0	35.9	-22.3
1989	14.7	26.7	-12.0	31.2	-16.5
1990	13.7	51.5	-37.7	54.0	-40.2
1991	14.5	42.5	-28.0	45.1	-30.6
1992	16.8	39.0	-22.2	43.9	-27.1

Source: calculated by the author.

Figure 6.5 Net Investment in the Oil Sector



6.5 Conclusion

In this chapter, we discussed the oil situation in China. China is not rich in oil and has limited reserves. Its production increased steadily from 1976 to 1992, but discoveries of oil did not increase as quickly.

The pricing system was set up in 1957 and changed little until 1980. The centrally planned price is lower than the production cost, and each year the oil sector receives subsidies from the government. The financial and economic subsidies have been calculated, the results showing that the correct pricing system should be the international price level. As of 1981, the government introduced the dual pricing system in order to raise oil production and investment funds. This dual pricing system probably has its uses historically, but it also seems that the system is disadvantageous in many ways, providing little incentive to raise funds, creating opportunities for speculation in the oil market, encouraging corruption in dealing with oil sales, favouring small scale refineries with low efficiency and as a result, wasting oil resources. The only solution which suggests itself is to open up the market and let the prices by guided by market supply and demand.

We calculated the oil accounts, using three approaches: the net price approach, the total rent approach and the user cost approach. The net price approach is not stable in the calculation although the stocks of oil are not very large and the depletion period is short. The results obtained with the net price approach are unsatisfactory. The results yield by the total rent approach is stable and shows the considerable depreciation of the oil resources in China. The results of the user cost approach at zero, 5 and 10 percent discount rates are also stable although they are slightly less than the total rent approach.

The depreciation of oil to the GNP, NNP and the gross output value of oil was made using the total rent approach and the user cost approach. The results with the two approaches are stable, and the results from the total rent approach are acceptable. The user cost approach shows that the higher the discount rate, the higher the sustainable income, but the lower the depreciation to the natural capital. Sustainable development was also measured by deriving the net investment in the oil industry. The calculation demonstrates that while the net investment from the total rent approach and the user cost approach is negative for all the years from 1976 to 1992. The ratios of depreciation to the gross national product and the gross product of the oil industry were derived. The negative net investment is indicative of the unsustainable development of the oil industry, meaning that China should invest more in its oil industry.

Appendix 6.1 Exhaustible Period and Depletion Factors
(billion yuan)

				r = 5%			r = 10%		
year	stocks	output	period of consumption	$(1+r)^n$	$1/(1+r)^n$	discount factor	$(1+r)^n$	$1/(1+r)^n$	discount factor
1976	2700	83.6	32	4.8344	0.2069	0.7931	21.7193	0.0460	0.9540
1977	2700	93.6	29	4.0854	0.2448	0.7552	15.6322	0.0640	0.9360
1978	2700	104.1	26	3.5447	0.2821	0.7179	11.8464	0.0844	0.9156
1979	2700	106.1	25	3.4611	0.2889	0.7111	11.3070	0.0884	0.9116
1980	2800	105.8	26	3.6373	0.2749	0.7251	12.4583	0.0803	0.9197
1981	2760	101.0	27	3.7934	0.2636	0.7364	13.5247	0.0739	0.9261
1982	2700	101.7	27	3.6521	0.2738	0.7262	12.5580	0.0796	0.9204
1983	2600	106.0	25	3.3093	0.3022	0.6978	10.3584	0.0965	0.9035
1984	2600	114.5	23	3.0280	0.3303	0.6697	8.7081	0.1148	0.8852
1985	2400	124.9	19	2.5536	0.3916	0.6084	6.2427	0.1602	0.8398
1986	2400	130.7	18	2.4496	0.4082	0.5918	5.7555	0.1737	0.8263
1987	2400	132.9	18	2.4135	0.4143	0.5857	5.5911	0.1789	0.8211
1988	3100	137.0	23	3.0162	0.3315	0.6685	8.6422	0.1157	0.8843
1989	3200	137.6	23	3.1101	0.3215	0.6785	9.1753	0.1090	0.8910
1990	3200	138.3	23	3.0923	0.3234	0.6766	9.0729	0.1102	0.8898
1991	3200	139.8	23	3.0551	0.3273	0.6727	8.8608	0.1129	0.8871
1992	3200	142.0	23	3.0027	0.3330	0.6670	8.5663	0.1167	0.8833

Source: calculated by the author.

Chapter 7

Estimating Energy Sector Subsidies in China

7.1 Introduction

Environmental economists have argued for some time that one of the most important measures for reducing worldwide environmental degradation is through the reduction of economic policy distortions (Pearce and Warford 1993, Larsen 1994 and de Moor 1996). Such distortions include subsidies to agricultural inputs, controls on output prices, subsidies to irrigation water, energy and forest clearance. Global estimates are hazardous. de Moor (1996) suggests they may be of the order of at least $1 trillion. However, estimating the actual size of subsidies is far from straightforward. Definitions of subsidy vary and estimation is difficult given the complex contexts in which such subsidies occur. In this chapter we look at one such context: the 'dual pricing' of energy in China. Dual pricing refers to the fact that part of the market for energy is controlled, both in terms of price and output, whilst the remainder of the market is liberalised and in which market prices are charged.

As Larsen (1994) notes, the removal of fossil fuel subsidies is a first order priority in instituting economic policies to protect local and global environments. While subsidy removal is difficult, it can have major beneficial effects. First, the resulting rising prices encourage fuel efficiency and conservation measures. Second, higher prices encourage new energy technologies which otherwise cannot compete with low priced fossil fuels. Associated with reduced energy use are reduced local and regional emissions of pollutants such particulate matter, nitrogen oxides (NO_2 is a precursor of tropospheric ozone) and sulphur oxides. The burning of fossil fuels also results in carbon dioxide releases, contributing to the problem of global warming. China is in fact the third largest emitter of greenhouse gases, being ranked behind only the USA (first) and the former Soviet Union (World Resources Institute 1994). Using the World Resources Institute index, China emitted just under 10 x 10^9 tonnes of emission targets under the Framework

Convention on climate change, being a non-Annex 1 country, the future of any climate control effort must involve major reductions in China's emissions. Third, reducing subsidies frees government resources for higher productivity outlets.

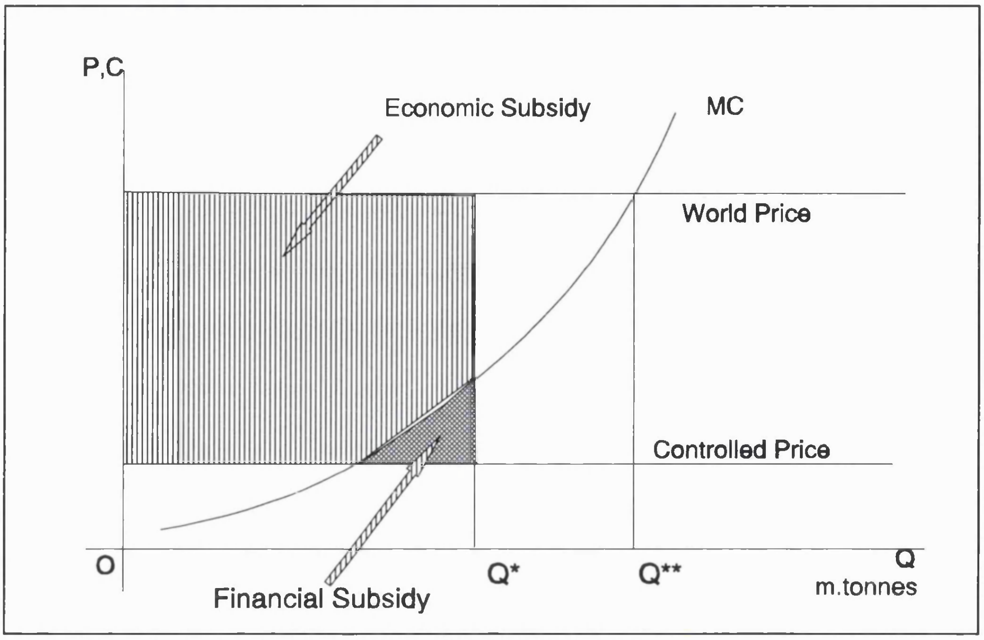
7.2 Energy Pricing in China

China depends heavily upon fossil fuels, and coal in particular, for its energy resources. Out of 750 million tonnes of oil equivalent primary energy consumption in 1994, some 76% if met by coal, 19% from oil, 2% from natural gas, 2% from hydroelectricity and a fraction from nuclear power (British Petroleum, annual). For many years the prices of China's energy supplies have been below the cost of production. The resulting large subsidies have been reduced in recent years due to partial liberalisation of energy prices.

Financial subsidisation of the coal industry started in the early 1980s. At that time oil and natural gas production was still profitable at ruling prices. For example, in 1985, there was a 2.2 billion yuan financial loss in the coal industry, but other energy production were thought to be in financial balance (Chu and Chen 1992). However, as production costs increased, the oil and natural gas industries also gradually suffered from financial loss.

The current situation is shown conceptually in Figure 7.1. A 'dual market' operates. Part of output, OQ* is subject to a controlled price and a controlled quantity. Thus OQ* has to be sold at the controlled price. At least part of this controlled output is sold below the cost of production. The resulting financial subsidy is shown as the heavy shaded area under the marginal cost curve MC. The remaining output Q*Q** is subject to market forces. Strictly, this means that domestic prices for this output should converge on the world (border) price, otherwise profitable opportunities for export are being lost. In practice, a range of market prices up to and including the world price are charged since China trades only a small part of energy production.

Figure 7.1 Financial and Economic Subsidies of Coal



Q* = Output produced under the planned price.

Q** = Output produced without of the planned price.

Figure 7.1 illustrates two concepts of subsidy. A *financial subsidy* is defined as the difference between the market price and the average cost of production. In terms of Figure 7.1 this is also equivalent to the area under the marginal cost curve and the controlled price. An *economic subsidy* is defined as the difference between the ruling market price and the world price. An economic subsidy measures the extent to which domestic consumption of the resource forgoes foreign exchange through forgone exports. Alternatively, it measures the savings from domestic production given that the alternative to domestic production is imports. Economic subsidies are not of great interest in the China context since domestic demand for energy is driven by very rapid economic growth rates that put pressure on domestic energy supplies. China is not therefore forgoing export revenues since it would have to import energy if it was not supplied domestically. In some cases, the segmented nature of the market and continuing controls have meant that market prices, in Shanghai and Jiangsu for example, are at, or exceed, international levels.

7.3 The Coal Sector

7.3.1 Coal Pricing

Coal pricing policies in China are complex. There are planned prices, negotiated prices, delivery prices and free-market prices. The planned price of coal in China is the price for coal produced under the government plan. Prices of coal set by the government normally are lower than costs, leading to financial losses in coal mines. The Ministry of Coal Industry established a dual price system to provide the mines with an incentive to over-fulfil regional production targets in 1985. At the same time, regional and quality-related price differentials were increased to move prices closer to costs. Under the dual pricing system, the government charges a 50 percent premium for all production exceeding an agreed annual quota that is shipped to end-users according to the state transportation plan. The mines can also sell excess coal not included in the transportation plan at negotiated prices. In practice, these negotiated prices have been at about the level of the 100 percent quota coal.

Coal production increased rapidly in the 1980s in light of a slight increase of planned price. Nonetheless, planned prices remained lower than production costs. For instance, in 1992 in Pingdingshan Mine in the central part of China, the production cost was 45.8 yuan per tonne, but the planned price was 38.2 yuan per tonne, implying a 16 percent subsidy on cost (Xu, 1993). Although large subsidies were given to the coal mines, the amounts were still not enough to cover all the costs and also provided no funding for future development.

Individually owned and collective mines, representing the majority of local mine production, sell their coal in the free market as long as they can secure transport. Otherwise, they sell to the state coal mining bureaus. In the early and mid-1980s, some areas with high production costs raised coal prices in order to stem financial losses. At the same time, price negotiation within certain defined limits was allowed. These reforms have led to low prices in coal-rich provinces and higher prices in areas that depend heavily on longer range transport, since most rail transport capacity is allocated to centrally controlled and provincial mines.

The price differential between free market and planned coal widened in the late 1980s. Both the level of revenues and their rates of increases built into the tiered pricing system are rather modest. Direct and indirect subsidies continue to be required to cover operating costs and to finance investments. Multiple prices also allow for profit-making through the reselling of low-priced coal at higher market prices, ie an arbitrage market has emerged. This may result in greater economic efficiency in some respects, but the additional revenue does not accrue to the producer and hence does not help with investment financing.

7.3.2 Coal Subsidies

Table 7.1 shows estimates of financial subsidies to coal. The coal industry started to have financial losses in 1977 and starting from 1981 the coal sector received subsidies. Subsidies reached a high of US$ 1.4 billion in 1987, followed by a decline, then rising again to reach a new high of $2.3 billion in 1992. Larsen (1994) has a higher estimate of US$3.3 billion. Chu and Chen (1992) suggest that the figures are even higher. A comparison of their figures and our own estimates is given below:

	Chu and Chen (current price) 10^9 yuan	This study (current price) 10^9 yuan
1988	2.5	1.3
1989	3.5	1.0
1990	5.4	2.8

The Chu and Chen estimates systematically exceed our own, probably reflecting our use of an annual average price and cost which obscures some of the variation within the year. In more recent years (1993 onwards) there has been a reduction of the financial subsidies from the government by partial liberalisation of coal prices.

Economic subsidies are not shown here but our estimates suggest these amounted to some US$ 24.5 billion in 1992 and at 1992 prices.

Table 7.1 Calculation of Financial Subsidies to Coal

year	Average cost (yuan), current prices	Domestic price (yuan), current prices	Financial subsidy (yuan per tonne) current prices	Quantity (10^6 tonnes)	Total subsidy (10^6 yuan), current prices	Deflator 1992=1	Total subsidy (10^6 yuan) at 1992 prices	Total subsidy (10^6 US$) at 1992 prices
1976	16.69	16.77		483		0.484		
1977	16.61	16.52	0.09	550	50	0.489	24	16
1978	16.12	16.52		617		0.496		
1979	17.80	19.25		634		0.506		
1980	20.05	21.33		620		0.535		
1981	21.54	21.45	0.09	622	56	0.545	30	17
1982	21.95	21.58	0.37	666	246	0.550	135	70
1983	22.33	21.92	0.41	715	293	0.556	163	82
1984	23.37	22.73	0.64	789	505	0.586	296	106
1985	29.33	26.05	3.28	872	2860	0.644	1842	576
1986	32.33	26.51	5.82	894	5203	0.670	3486	937
1987	33.90	26.28	7.62	928	7071	0.718	5077	1364
1988	39.97	38.00	1.97	980	1931	0.777	1500	404
1989	53.55	52.00	1.55	1054	1634	0.847	1384	367
1990	58.91	54.60	4.31	1080	4655	0.901	4194	878
1991	64.87	58.00	6.87	1087	7468	0.952	7109	1336
1992	74.70	63.00	11.70	1116	13057	1.000	13057	2270

Source: Author's calculations based on data from the Financial and Accounting Department of the Ministry of Coal Industry, Beijing.

7.4 The Oil Sector

7.4.1 Crude Oil Pricing

The oil price system in China was set up in 1957 by the government based on the overall price level at that time. This centrally planned price system did not change for over twenty years. During this period costs increased dramatically and the international price also increased from 1.8 US dollar/barrel in 1957 to 32 US dollar/barrel in 1980, and now is about 14.8-17.2 US dollar/barrel (BP 1995). The Chinese oil price in 1987 was only 110 yuan per tonne, which was equivalent to 30 US dollar per tonne and 4.1 US dollar per barrel (*Annual Report of Mineral Resources*, 1988, 1992).

Oil pricing in China has also not set prices according to environmental quality. For example, the sulphur content of crude oil in Daqing oil field is only 0.08 percent, and in Shengli oil field it reaches 2.09 percent, but the prices from the two oil fields are the same. The irrational energy prices cause financial losses in oil production. Up to 1990 the loss from oil and natural gas was 4.7 billion yuan although 1 billion yuan in subsidies was given to oil production. The planned price of oil increased from 110 yuan/tonne in 1987 to 201 yuan/tonne in 1991 in the eastern part of the oil fields. In the western part of the oil fields, the planned price was 216 yuan/tonne in 1991. The market prices of oil in the east were 589 yuan/tonne and 519 yuan/tonne for other regions (Zhong and Zhang 1993). In 1992 the planned price of crude oil in China was 249 yuan/tonne, while the market price was 670 yuan/tonne. Starting from 1981, the pricing policy was changed to a system of contracting for production. Within the limits of contracts, oil is sold at the planned prices. Beyond these limits, oil is sold at the market prices. This dual pricing policy prevails currently. Table 7.2 shows the picture of oil pricing in China in recent years. It is apparent that the planned prices were much lower than the market price while market prices were close to the world price level.

Table 7.2 Comparison of Planned and Market Prices for Crude Oil

year	planned price yuan/tonne	planned price (converted) USD/tonne	market price yuan/tonne	market price (converted) USD/tonne	world price USD/tonne
1987	110	29.6			135.1
1991	201 216	37.8 40.6	589 519	110.7 97.5	147.0
1992	249.1	41.9	670	116.5	142.0

Sources: Zhong and Zhang (1993) and authors' calculations.

7.4.2 Crude Oil Subsidies

Since 1987, the oil industry has suffered from financial losses. Because the price is lower than the cost, each year the government subsidises the difference between the price and the cost to the oil industry. In 1987, the average cost of extracting oil was 146 yuan per tonne in some oil fields, but the price of oil was only 110 yuan per tonne, a 36 yuan loss per tonne extraction. In 1992 the average cost of oil was 238 yuan per tonne, but the average price was only 218 yuan. The calculation of financial subsidies to crude oil is shown in Table 3. Subsidies have generally been of the order of less than US$ 100 million per annum, but in 1992 reached some US$ 350 million. Economic subsidies are not shown separately but our estimates suggest these are of the order of $US 60 billion in 1992 prices.

Table 7.3 Financial Subsidies to Crude Oil Production

year	unit price (yuan/tonne) current prices	average cost (yuan/tonne) current prices	unit subsidy (yuan/tonne) current prices	total subsidy (10^6 yuan) current prices	real value (10^6 yuan), 1992 prices	total subsidy (10^6 US$)
1987	110	113	3	300	161	43
1988	142	144	2	200	155	42
1989	142	154	12	1200	1016	269
1990	172	177	5	500	450	94
1991	206	208	2	200	190	21
1992	218	238	20	2000	2000	348

* The average cost varied in 1987. The average cost was 78.4 yuan in the whole country (Forty Years of China's Energy 1990), but some fields reached 146 yuan per tonne. 113 yuan is an average.

Comparatively little information is available on petroleum product price subsidies. Part of the product subsidy is already calculated in the crude oil subsidies above, but it is clear that further subsidisation has also occurred. All oil products - gasoline, kerosene, diesel oil, lubricating oil - implement the dual pricing system. Larsen and Shah (1994) suggest current price subsidies to petroleum of $US 10.3 billion. Deducting our estimate of US$0.3 billion for the crude oil subsidy suggests that the subsidy to petroleum products is actually of the order of $US10 billion. There should be subsidies to petroleum products, however, due to the shortage of data, we cannot estimate subsidies of petroleum products.

7.5 Total Subsidies

Table 7.4 brings the various estimates together.

Table 7.4 Total Financial Subsidies to Energy in China

year	Coal (10^6 1992 US$)	Crude oil (10^6 1992 US$)	Total (10^6 1992 US$)
1976			
1977	16		16
1978			
1979			
1980			
1981	17		17
1982	70		70
1983	82		82
1984	106		106
1985	576		576
1986	937		937
1987	1364	43	1407
1988	404	42	446
1989	367	269	636

1990	878	94	972
1991	1336	21	1357
1992	2270	348	2618

Sources: calculated by the author.

7.6 Conclusion

Subsidies give no incentive for raising production efficiency, for minimising cost and for controlling air pollution emissions. Ten years after the introduction of the dual pricing system, a large amount of coal and oil sales are still made under conditions that encourage inefficient and wasteful practices. As the gap between plan and market prices widens, some consumers make wasteful decisions on the assumption that their quota will be raised - or as leverage for having it raised. In addition, they tend to use whatever energy they can get under the plan allocation system, irrespective of whether the quality or sources makes economic sense. The rigidity of plan prices causes more volatile price adjustments in the free market - particularly in periods of shortage - because of the narrower base for adjustment. A broadening of the free market would reduce the amplitude of price fluctuation and that, in turn, would facilitate adjustments to changes in supply and demand, encouraging consumers and suppliers to be more responsive to those changes by adjusting their behaviours.

Appendix 7.1 Output of Coal in China (1980-1990)

(10^6 tonnes)

year	total	steam & coking	anthracite	lignite
1980	620	467	129	24
1981	622	467	131	23
1982	666	502	139	25
1983	715	536	152	27
1984	789	589	170	30
1985	872	658	182	32
1986	894	677	185	32
1987	928	703	192	33
1988	980	741	202	37
1989	1054	793	218	43
1990	1080	822	213	45

Source: *China Energy Statistical Yearbook 1991*, China Statistical Press, Beijing, 1992.

Appendix 7.2 Larsen's Estimates of Total World Subsidies (10^6 US$)

country	**coal**	**gas**	**petroleum**	**total**	**total/GDP**
Former USSR	17000	63000	65000	145000	10-13%
China	**3300**		**4600**	**7900**	**1.8%**
Poland	6600	130		6730	10.0%
Czechoslovakia	2100	460	380	2940	6.0%
Brazil		50	900	950	0.2%
Venezuela		1750	3600	5350	10.6%
Mexico	90	600	1550	2150	1.0%
India	2550		4250	6800	2.3%
Indonesia			5100	5100	5.0%
Saudi Arabia			5000	5000	4.8%
South Korea	1650		1100	2750	1.2%
South Africa	1550			1550	
Egypt		350	3000	3350	10.7%

Iran		2300	9100	11400	8.0%
Romania	600	800		1400	3.7%
Bulgaria	750		450	1200	6.0%
Total	**36190**	**69440**	**104030**	**209660**	

Source: Larsen (1994).

Chapter 8

Air Pollution in China

8.1 Introduction

Air pollution, especially total suspended particulate (TSP), is widely recognised as having severe health effect to human beings (Ostro 1994, Ostro *et al* 1995, Schwartz *et al* 1993, Schwartz and Dockery 1992, Pope *et al* 1992, Pope *et al* 1995, Xu *et al* 1994). Calculating the damage caused by air pollution, and especially its effect on human health, is one of the most important aspects of evaluating environmental damage. This chapter focuses on an analysis of the air pollution situation in China, its control, the damage to human health caused by particulate matter, and the value of such damage as an element in the national accounts.

Air pollution is a very serious problem in most developing countries, and China is no exception. The problem has worsen in recent years in most industrial cities, and emissions are generally above the air quality standards set by the government. Emissions of air pollution are attributed to the combustion of over one billion tonnes of coal per year, largely uncleaned and burned with minimal or no air pollution controls, supplying China with three-quarters of its entire primary energy. Since 1981 China has spent some resources on air pollution control (*Data Collection of China Environmental Statistics 1981-1990*), but this is far below what is actually required. Only a small number of the largest, most modern, coal-fired power plants are equipped with electrostatic precipitators or flue gas desulphurisation equipment. Most medium-size boilers have at best only mechanical dust separators, such as wet scrubbers, and millions of small pollution sources remain completely uncontrolled.

Emissions of air pollution are widespread throughout the country. But as roughly half of all emissions are released in or around industrialised urban areas, high concentrations of particulates arise in major cities, especially in the North (Florig 1993, World Bank 1991). Concentration of airborne smoke and dust surpass China's environmental standards by three, five, or sometimes even ten times. Chronically high, prolonged exposures to such particulate matters is thought to be a major cause of respiratory diseases, of which the most common is chronic bronchitis.

There have been a number of studies on the health effects of air pollution in China. Wang *et al* (1989) studied the incidence of upper respiratory diseases and allergies as a function of air pollution levels in and around Chengdu, in the Sichuan Province. Three-fold increases in particulate levels were associated with a 50 percent increase in chronic nasal inflammation, an 80 percent increase in chronic throat inflammation, and a 250 percent increase in the proportion of the population suffering from allergies. A study by Xu *et al* (1991) of chronic obstructive pulmonary disease in Shenyang showed that the prevalence of chronic bronchitis increases by 6 percent for every increase of 100 $\mu g/m^3$ in outdoor ambient TSP levels. Xu *et al* combine results from a number of epidemiological studies of morbidity and air pollution in Chinese cities. They conclude that particulates are responsible for 50-60 percent of all cases of upper respiratory inflammation, chronic bronchitis, asthma, and emphysema in these urban areas, with roughly equal risks to the population ascribed to indoor and outdoor exposures. Ye (1989) studied the relationship between lung cancer and air pollution from coal in Tianjin, a large city in North China. Both Smil (1983) and Edmonds (1994) describe the serious impact of air pollution on health damage. A study by Florig (1993) also links air pollution to health damage in China and a more recent study by Xu *et al* (1994) reveals the event of the damaging impact of air pollution on health in Beijing.

8.1.1 Total Suspended Particulates (TSP)

TSP consists of dust particles, metal and hydrocarbon traces and smoke. It is the most serious airborne pollutant in China at the present time, and presents the greatest local health risk. The amount of particulate emissions depends on the ash content of the coal, the temperature of combustion and design of the boiler or furnace. High particulate concentrations can cause or contribute to chronic asthma, chronic bronchitis and other respiratory problems. Health damage is particularly linked with particulate matter of less than 10 micro diameters, i.e. PM_{10}, because this is more easily absorbed by the lining of the lungs. PM_{10} contains most of the toxic or carcinogenic elements associated with coal combustion. Because of the difficulty of removing PM_{10}, respiratory disease is one of the most widespread in the country (Florig 1993, Xu *et al* 1994) .

TSP, especially PM_{10}, is the only common air pollutant with a well-established association with increased mortality. A number of both longitudinal and cross-sectional epidemiologic studies were published in the United States by Schwartz and Dockery (1992), Schwartz (1993) and Pope III *et al* (1992 and 1995). All demonstrated a relationship between particulate concentrations and population mortality. Longitudinal studies, which compare time series of particulate concentrations with daily death statistics in an individual city, represent the best methods of calculating the acute mortality increases resulting from episodes of elevated particulate levels. Cross-sectional studies, which compare annual average pollution levels and mortality rates across many different cities, are used to record those deaths caused by the chronic effects of pollution. In his study, Schwartz (1993) demonstrates that respiratory deaths in Birmingham, Alabama increased significantly when the concentration of PM_{10} increased. Pope III *et al* (1995) revealed the link between of PM_{10}, sulphate particles and smoking and respiratory disease and heart attacks. Surveys on the contribution of air pollution to health damage have also collated some of the evidence in this area. Major 'meta studies' of air pollution-health links are those of Rowe *et al*'s New York survey (1995), Desvousges *et al* (1995), and Finch *et al* (1995). These studies summarise the positive correlations between PM_{10}, sulphate particles and smoking on one hand, and respiratory disease and heart attacks on the other.

The use of obsolete equipment in coal combustion without any filtration, isolation or other treatments for emissions of coal ash and smoke is the main cause of TSP emissions in China. Coal accounts for over 75 percent of China's energy resources and most of the coal remains unwashed before combustion. The Chinese epidemiological literature refers repeatedly to an increasing frequency of respiratory morbidity and mortality in all large urban areas (Florig 1993, Edmonds 1994, Xu *et al* 1994), where the air quality has been further declining owing to large areas of construction associated with a rapid increase in industrial dust (eg. uncovered processing equipment, cement works, construction sites and loss of natural vegetation). All large Chinese cities now have a photochemical smog problem that is asymmetric to the fugitive dusts.

Total emissions of dust equalled 14.2 million tonnes in 1981 and 7.8 million tonnes in 1990 according to the official statistics. This statistical decline implies a significant progress in emission controls, since coal consumption actually went up by more than 60 percent during the same period, from 594.5 million tonnes to 987 million tonnes (*Statistical Yearbook of China's Energy 1991*). This raises doubts as to the validity of the official statistics, and the true figure for TSP emissions in the late 1980s is probably higher than the official statistics. According to the World Bank (1991), the daily mean concentration for total suspended particulate is more than 300 $\mu g/m^3$ in urban areas, and 500 $\mu g/m^3$ in industrial and heavy traffic zones. The average concentration in Beijing is 375 $\mu g/m^3$ (Xu *et al* 1994) and in Jinan 500-600 $\mu g/m^3$. Northern cities commonly average 500-1,000 $\mu g/m^3$, and during the worst days the most polluted areas go up to 2,000 $\mu g/m^3$.

As in any other heavily affected country, China's particulate air pollution presents two problems: firstly, the environmental, health and other damaging effects cause major losses that cannot be tolerated in the long run, yet effectively controlling these emissions requires either massive conversion to cleaner fuels or the extensive installation of costly technology. Secondly, as resources of oil and natural gas are limited (see Chapter 6), fuel-switching seems very difficult in most areas, while installation of more efficient pollution control equipment, such as electrostatic precipitator (ESP), is held back by a shortage of funds for many industrial polluters. An ESP in China costs 10 times more than a wet scrubber.

8.1.2 Sulphur Dioxide (SO_2)

Various authors report on the serious and widespread damage caused by sulphur dioxide (SO_2) in China (Xu *et al* 1994, Florig 1993). The official statistics suggest only a slight increase in total emissions from 1981 to 1990. For example, in 1981 SO_2 emission equalled 13.7 million tonnes and in 1990 it was 15 million tonnes (*Data Collection of China Environmental Statistics 1981-1990*). The official figures obviously do not reflect the true amount of SO_2 emissions. If the consumption of coal rose by 60 percent from 606 million tonnes in 1981 to 1034 million tonnes in 1990, then SO_2 emissions should also have increased by about 60 percent to over 20 million tonnes, unless there was widespread installation of desulphurisation equipment during this time or use of low-sulphur coal. Yet sulphur dioxide emissions are currently largely uncontrolled in China, apart from some sulphur fixation in domestic briquettes. The main damage caused by SO_2 emission is the subsequent acid rain and the combination of nitrogen oxides into acid aerosols (sulphur and nitric acid). Based on the information from the National Environmental Protection Agency (NEPA), to date, installation of desulphurisation equipment is very rare in China, and only recently (1996) have financial charges been imposed the emission of SO_2. Considering that coal is the main energy resource there, the emission of acid gases from coal combustion can be expected to be quite high in China, especially in the southern and southwestern regions. It is known that about 90 to 95 percent of the sulphur in coal is oxidised into sulphur dioxide during combustion.

Important factors determining the level of SO_2 emissions are the sulphur content of the coal and the quantities of coal used. It has already been pointed out that the sulphur content of coal in the southern part of China is higher than in the northern part. This is one of the reasons why there is a greater acid rain damage in southern of China, e.g. in the Guizhou and Sichuan Provinces. These southern places are featured as the relatively humid climate, low content of alkaline particulate matters in the air and soil hard to attenuate acid emissions. SO_2 emissions not only damage the health of human-beings, but also crops, coniferous trees and buildings. This widespread damage makes SO_2 one of the most serious air pollutants.

The daily mean concentration of SO_2 in large urban areas is commonly between 100 and 400 $\mu g/m^3$, and during the heating season in northern cities it surpasses 600 $\mu g/m^3$ (World Bank, 1991). For comparison, winter levels in North American cities are currently 20-100 $\mu g/m^3$. Small tea boilers (below 1 tonne), using loose coal for restaurant combustion, inefficient domestic coal stoves and furnaces are also responsible for the unacceptably high indoor winter levels of SO_2. With 15 million tonnes of SO_2 emissions in 1990, China is one of the world's principal emitters. The World Bank (1991) estimates that in 1990, global anthropogenic SO_2 emissions amounted to at least 100 million tonnes, with coal combustion generating about two-thirds of the total. As China's coal extraction and combustion are so heavily concentrated in the North, the region's average densities of SO_2 generation are high in comparison with western countries which consume relatively much larger amounts of fossil fuels. If the eastern parts of North America and Europe are experiencing acid rain, it is to be expected that China, as a larger coal consumer, should also be experiencing strong acid precipitation.

As mentioned by the World Bank (1991) and Edmonds (1994), in North China, vast inland deserts and desertification surrounding the industrial areas, deforested bare mountains, and eroded lands are the sources of alkaline particulate matter picked up by prevailing winds. Consequently, the region has very high airborne concentrations of calcium, potassium and magnesium compounds which neutralise the emitted SO_2 and keep the acidity of precipitation close to, or even above, the normal level.

However, the situation in several areas of South China is different. According to the World Bank (1991) the acid precipitation has been measured in about fifty different cities, and large areas of Sichuan, Guangxi, Hunan, Jiangxi and Guagdong are experiencing acid deposition as a growing regional phenomenon. The lowest annual PH averages, between 4 and 4.5, occurred in and near Chongqing and Yibin in Sichuan, Naning and Liuzhou in Guangxi, Shaoguan in Guangdong, Pingxiang in Jiangxi, and Changsha and Hengyang in Hunan. Coniferous forests are thought to be the first ecosystem to be seriously damaged by low-PH rains. In Sichuan the damage is worst in pine and fir growths, and the pollution damage accelerates pest invasions, and thereby making the trees more susceptible to other environmental stresses. It is reported that in Sichuan's most seriously damaged area, Wan County, about 15,000 ha of pine trees had died, while another 38,000 ha were dying in the mid-1980s. Massive tree death has also been found in Fengjie County and in the vicinity of Chongqing (World Bank 1991).

During the 1980s the southern precipitation acidity has been steadily expanding from its previous urban and suburban confines. With coal combustion expected to have increased by another 60 percent during the 1980s, and with a gradually rising average sulphur content of Chinese coal, there can be little doubt that there will be more widespread damage to coniferous forests, and eventually also to susceptible crops.

8.1.3 Other Pollutants

Carbon Dioxide (CO_2). There are no official statistics on emissions of CO_2 in China. The amount of CO_2 emissions depends on the carbon content of coal and the quantity actually combusted. However, the emission level of CO_2 in China would be expected to be very high due to the combustion of coal. Coal combustion releases roughly 25 percent more CO_2 than oil combustion and 100 percent more CO_2 than natural gas combustion. According to the World Resources Institute, CO_2 emissions from energy use in China represented 10 percent of global industry-related carbon dioxide emissions in 1985, up from 5 percent in 1965 (World Bank 1991). Although the United States, the former Soviet Union and Western Europe are much larger contributors to CO_2 emissions, China's emissions will grow continuously as coal consumption further expands (Polemske and Lin 1993, Sinton and Levine 1994, Rose *et al* 1996).

Nitrogen Oxides (NO_X). There are also no official statistics for emissions of NO_X. Nitrogen oxides derive from nitrogen and oxygen from the air during the combustion process. The higher the temperature of combustion, the larger the quantity of NO_X released. There are no specific measures taken in China to control NO_X emissions at present and this pollutant is not even monitored in China. With the increasing number of motor vehicles, NO_X emissions in China are expected to rise. Edmonds (1994) has suggested two figures, 4.5 million tonnes in 1981 and 6.12 million tonnes in 1986. These two figures were chosen to represent two periods of pollution quantities, from 1981 to 1985 the level was 4.5 million tonnes, and from 1986 to 1990 the level was 6.12 million tonnes. We use linear interpolation by assuming that each year there is a proportional increase in NO_X emissions.

Volatile Organic Compounds (VOCs). VOCs basically result from the combustion of petro-products, such as gasoline and diesel. It has been observed that emissions of VOCs affect human health, and the combination of VOCs and NO_X may possibly form a low level ozone layer around the earth. There is no information on this pollutant in China to date.

Emissions of air pollutants from 1981 to 1990 are shown in Table 1. Four specific pollutants are shown here: sulphur dioxide (SO_2), total suspended particulate (TSP), smoke and nitrogen oxides (NO_X). Little faith can be placed in the figures, given that they show an absolute decline in emissions despite substantial increases in coal consumption.

Table 8.1 Emission of Air Pollutants
unit: million tonnes

year	SO2	dust[1]	black smoke	NOx[2]
1981	13.7	14.2	14.5	4.5*
1982	12.7	13	14.6	4.8
1983	12	10.9	13.5	5.2
1984	12.4	11.3	13.1	5.5

[1]Dust refers to fugitive dust emitted in the air and 'black smoke' means untreated smoke from stacks.

[2]The emissions of NO_x in 1981 and 1986 are obtained from Edmonds (1994); the emissions for the rest of the years are interpolated. We assume that the emission of NO_x in year t equals $\alpha + \beta t$, thus:

NO_x in 1982 = $4.5 + \beta 1981$, and
NO_x in 1987 = $6.12 + \beta 1986$

α represents the emissions in 1981 and 1986. $\beta = (6.12 - 4.5)/5$.

1985	13	12.8	13.2	5.8
1986	12.1	10.7	13.7	6.1*
1987	14.1	9.3	14.9	6.4
1988	15	9.1	14.6	6.8
1989	15.5	7.6	14	7.1
1990	15	7.8	13.3	7.4

Sources: 1) *Data Collection of China Environmental Statistics 1981-1990*, China Environmental Science Press, Beijing, 1994. 2) Edmonds, R *Patterns of China's Lost Harmony*, 1994.

8.2 Current Air Pollution Control in China

8.2.1 Pollution Control Situation

Table 8.2 shows the total expenditure by the Chinese government on abatement investment. Of the total spent, China spent 28 percent to 36 percent on air pollution control between 1981 and 1990. The fund is mainly used to install smoke and dust abatement equipment. From 1981 to 1990 the expenditure on pollution control increased from 1444 million yuan to 4544 million yuan without adjustment for inflation. These expenses account for less than 0.5 percent of the GNP.

Table 8.2 Total Expenditure on Pollution Control
(million yuan) (current prices)

year	total	water pollution	air pollution	solid waste	noise	other	air/total	total(mi US$)
1981	1444							825.1
1982	1610							838.5
1983	1462	634	406	187	44	191	0.28	738.4
1984	1956	762	545	197	59	393	0.28	698.6
1985	2209	993	719	199	54	244	0.33	690.3
1986	2880	1267	959	304	91	259	0.33	774.2

1987	3600	1569	1242	398	111	280	0.35	967.7
1988	4190	1865	1504	411	123	287	0.36	1126.3
1989	4354	1935	1577	396	128	318	0.36	1154.9
1990	4544	2162	1480	511	117	274	0.33	950.6

Sources: *Data Collection of China Environmental Statistics (1981-1990).*

Currently, China's total investment in pollution control accounts for less than 0.5 percent of the GNP[3]. This level of investment in pollution control is greater than that of many other developing countries, but it is only one-half to one third of the investment-GNP ratio of the developed industrial countries. Considering the depth and extent of China's pollution problems, the investment seems far below what is required for sustainable development.

China has introduced several important fuel conversion programmes, especially in the large northern cities. The installation of highly efficient electrostatic precipitators at all medium-sized and large combustion sources poses no real technical difficulties, but it requires considerable adjoining space for fly ash disposal, a large amount of funds and an increased supply of electricity, which is already in short supply. There is also a practical way to drastically reduce emissions from small coal stoves by using central heating and by switching to liquified petroleum gas (LPG) for cooking. According to the survey made by the National Environmental Protection Agency (NEPA) in Jinan, the district central heating so far accounts for less than 10 percent of domestic heating in urban areas, and limited oil resources prevent wide use of LPG. Unlike large power plants or industrial boilers with tall stacks, household stoves release pollutant fallout or acid precipitation and they can create excessively high localised concentrations of the air pollutants, with chronic health effects on those exposed tp them.

Treatment of SO_2 has been considerably more difficult, until very recently, and even many rich

[3]Florig (1993) mentions that China spends 0.6 percent of the GNP on pollution control. Our study shows that China in fact spends less than that figure.

countries have avoided this costly commitment. Given the high capital costs of desulphurisation equipment, it is most likely that China will start installing them in large power plants during the 9th 5-year Plan (1996-2000), as emission charges on SO_2 will start in 1996. Some new techniques, for example, one for improving boiler efficiencies, are currently being researched and developed.

Gradually reducing emissions of air pollution and speeding up the process of modernisation in pollution control is actually much easier for most developed countries. If the Chinese economy were coming into a stage of mature development, that required substantially lower rates of growth of the combination of primary energy supply, the situation would also not be that difficult, since by that stage sufficient funds can be generated and used in pollution control. However, in many aspects China still has a long way to go before reaching the stage in question. At the same time, low conversion efficiencies, the irrational pricing of fuels and electricity, and numerous opportunities for rationalisation of industrial production offer great potential for energy conservation, and hence for easing of environmental impacts.

8.2.2 Level of Pollution Charges

China is one of many developing countries that has stipulated an environmental protection law. It also has various regulations and emission standards for pollutant discharges. The ambient air quality standard set by the government is not particularly strict[4] (see Table 8.3), but most industrial cities still cannot meet it. A provisional system of pollution charges was also introduced in 1982. The Law on Air Pollution and Prevention was passed by the People's Congress and put into effect in 1987. The pollution charges were intended to control emissions, but as they are not set at a level to cover pollution costs, in practice pollution charges provide no incentive for control. Because the pollution charges are lower than the costs of air pollution control, most industrial polluters prefer to pay pollution charges rather than control the pollution.

[4]The WHO has recommendated the following exposure limits: a daily mean of 100-150 μg/m^3 for SO_2 and 150-230 μg/m^3 for TSP (WHO, Global Environmental Monitoring System - urban air pollution, 1973-1980).

Table 8.3 Ambient Air Quality Standards

unit:μg/m³

	time period	class I	class II	class III
TSP	daily average max. at any time	150 300	300 1,000	500 1,500
TSP	daily average* max. at any time	50 150	150 500	250 700
SO_2	annual average daily average max. at any time	20 50 150	60 150 500	100 250 700

* < 10 microns.

Sources: *Air Quality Standard*, published by the Environmental Protection Leading Group of the State Council, 1982.

In the cases where the original pollution charges are set at a level covering pollution control costs, that level should be adjusted with the level of inflation year by year in order to encourage installation of pollution control equipment. At the very least, the penalties should cover pollution abatement costs and give incentives for pollution control. In this way, compared with the standard setting, charges may tend to be a lower-cost approach of achieving a given standard. The problem of the low pollution charges is clearly illustrated by the data which are provided by the Jinan Environmental Protection bureau. The present low level of pollution charges as compared to the consumption level of coal to the control of pollution is shown in Table 8.4.

Table 8.4 Cost of Pollution Control and Energy Consumption in Jinan City

unit: million yuan

Company	total pollution charges/year (1)	cost of energy/year (2)	total pollution control costs (3)	total pollution control costs (planned) (4)	% pollution chrgs/energy costs (5)=(1)/(2)	% pollution chrgs/control costs (6)=(1)/(3)
Minhu	1.2	5.4	2	3	22	60
HeatCo	0.5/4 months					
Mach2	0.2	11	7-8 (1985-1995)	24	1.8	2.8
Motor	0.4	207	5	30	0.2	8
Beijiao	0.05	74	1.6	12	0.06	3.4
New CHP			1.1-1.2			
Cem-old	0.36	35	11 MY since 1982	2/year	1	3.2
Cem-new	0.96	66	8.1 since 1991	18	1.5	12
I&S	1.6	613	201	165	0.3	0.8

Source: Author's estimation based on data provided by Jinan Environmental Protection Bureau, 1995.

From Table 8.4, we can see that the ratio of pollution charges to energy costs is very low, ranging from 0.02 percent for Jinan Iron and Steel Works to 1.8 percent for No 2 Machine Tool Plant. Minghu Heat and Power Plant is an exception, as the ratio between pollution charges and energy costs here is 22 percent. The ratio of pollution charges to current pollution control costs is extremely low, ranging from 0.8 percent for the Iron and Steel Works to 12 percent for the Shangdong Cement Works. The ratio for Minghu is 60 percent, although, even the charges at Minghu level are too low, because the cost recovery charges should be at least 40 percent more in order to equal the average cost level.

China started keeping statistics on environmental pollution in 1980. In general its statistical data can be used as a basis to trace environmental pollution in China. Given the shortage of monetary funds and modern statistical methodology, the statistics on pollution are still very basic; some details of pollutants, such as nitrogen oxides (NO_X) and carbon dioxide (CO_2), are not included. In general, China has made some progress in its pollution control; however, in absolute terms, pollution is still a very serious problem here.

8.2.3 Economic Approaches to Health Damage

There are two approaches to valuing health damage to human beings: the contingent valuation (willingness to pay) and the human capital approach.

Contingent valuation. Measurement of willingness to pay is an economic model of individual choice under uncertainty. The proposes of analysing the models here include deriving hypotheses about the determinants of an individual's willingness to pay for a reduction in the risk of mortality and morbidity. In the willingness to pay approach it is important to examine the relationship between these predicted willingness-to-pay measures and other economic variables such the individuals's earnings and purchase of life insurance. However, measuring willingness to pay is a time consuming method, as it requires collection of a large sample database.

Conceptually, willingness to pay represents a comprehensive measure of the private valuation individuals place on small reductions in the risk of death. Although the survey method of willingness is superior to the human capital approach, there remain serious problems with its application, involving the ability of individuals to respond rationally and consistently to abstract and complex questions about hypothetical risk. Since we are not able to collect such data, we must use the alternative approach, which we outline now.

Human Capital. The human capital approach to valuing life has a long history, dating back to the works of Petty (1699) and Farr (1876). In the standard human capital approach, it is assumed that the value to society of an individual's life is measured by future production potential, usually calculated as the present discounted value of expected labour earnings. Freeman (1994) states that the human capital approach is an alternative to calculate the premature death of an individual who is presently of age t. Rice (1967) in her pioneering article "Estimating the Costs of Illness", effectively codified the emipirical application of the technique. Since standard human capital estimates are constructed from society's perspective, labour earnings are evaluated before taxes as representing the actual component of the GNP, rather than after-tax earnings which represent the relevant magnitude to the individual. Landefeld and Seskin (1982) and Hufschmidt *et al* (1990) restate that human capital estimates the economic value of life with reformulation of the method. Risk aversion works in the same direction, resulting in a risk premium that causes a divergence between the marginal productivity of capital and the individual's rate of time preference.

Landefeld and Seskin (1982) and Pearce and Ulph (1994) state that the problem of choosing a discount rate arises in the evaluation of investments in most public programs and the life expectancy greatly magnifies the difficulty in estimating human capital. Despite the conceptual problems associated with the human capital approach, the technique is widely used. To some extent this is an artifact of the relative ease in computation since the necessary data are not difficult to obtain. Further more, the standard human capital approach has the advantage of providing numerical estimates that are indisputable measures of what they say are: objective numbers based on life expectancy, labour force participation and project earnings.

8.3 Calculation of Health Damage from TSP

8.3.1 The Model

The underlying model for valuing health effects under ambient air quality is shown below:

$$dH_i = b \cdot POP_i \cdot dA_j \qquad (1)$$

where d = absolute change

H = health effect

i = index of health effect

b = slope of dose response function

POP_i = population at risk from health effect

A_j = ambient air quality

j = index of pollutant

Since different pollutants affect health in different ways, it is reasonable to allow the coefficient to depend on both i and j. Thus we generalise equation (1) to:

$$dH_i = b_{ij} \cdot POP_i \cdot dA_j \qquad (2)$$

where b_{ij} is the slope of the dose-response function (DRF). Ambient air quality is related to emissions either through some diffusion model or through an approximation involving a relationship such as,

$$dA_j/A_j = dE_j/E_j \qquad (3)$$

where E_j = emissions of pollutant j. We can generalise the equation to:

$$dA_j/A_j = h_j \, dE_j/E_j \qquad (4)$$

for some coefficient h_j; thus, Equation (3) is the special case where $h_j = 1$. In Equation (4), a percent change in emissions leads to a h_j percent change in ambient concentrations. Each health effect, h_i, has a unit value P_i so that,

$$P_i \cdot dH_i = P_i \cdot b_{ij} \cdot POP_i \cdot dA_j \qquad (5)$$

and the sum D_j of damages from pollution j is:

$$D_j = \Sigma_i P_i \cdot dH_i = [\Sigma_i P_i \cdot b_{ij} \cdot POP_i] dA_j \qquad (6)$$

The DRF could begin at some threshold value for A_j beneath which no damage occurs. The general result from the mets-studies, however, is that no thresholds are discernible.

8.3.2 Dose-Response Function (DRF) for PM_{10}

Health damage appears to be related mainly to particulate matter of less than 10 microns diameter, i.e. PM_{10}. Concentrations of TSP are measured in various ways. One problem is that the various measurements need to be converted into units of PM_{10} as implicated by health damage. Ostro (1994) suggests the following conversions (in $\mu g/m^3$):

$$PM_{10} = 0.55 \, TSP \qquad (7)$$

sulphate = 0.14 TSP

sulphate = 0.25 PM_{10}

$BS = PM_{10}$

BS refers to 'British smoke'. Equation (7) can be interpreted in the following two virtually equivalent ways:

a) Of every unit volume of air containing TSP, 55 percent by weight of that TSP is actually PM_{10} matter.

b) Every μg of TSP ambient concentration brings about only 0.55 times of health damage brought about by 1 μg/PM_{10}.

Based on an analysis of DRFs, Ostro (1994) concludes that the consensus DRF for 'excess' mortality from particulate matter is:

$$\%dH_{MT} = 0.096 \cdot dPM_{10} \quad (8)$$

where dH_{MT} is the change in mortality in the central bound. The coefficient makes due allowance for other compounding factors such as smoking. The above equation states that a 1 μg/m^3 change in PM_{10} concentrations is associated with approximately a 0.1 percent change in mortality, or a 10 μg/m^3 change in PM_{10} concentrations is associated with a 1 percent change in mortality. Upper and lower bounds for the above equation are given as:

$$\%dH_{MT} = 0.130 \cdot dPM_{10} \quad (9)$$

$$\%dH_{MT} = 0.062 \cdot dPM_{10} \quad (10)$$

Where 0.062, 0.096 and 0.130 represents coefficients for lower, central and upper bounds. The absolute change in mortality is given by:

$$dH_{MT} = b_{ij} \cdot dPM_{10} \cdot CMR \cdot POP \cdot 1/100 \quad (11)$$

where b_{ij} = 0.062, 0.096 and 0.130 for lower, central and upper bounds respectively. CMR is the crude mortality rate and 1/100 converts the percentages to absolute numbers.

On the basis of this DRF, air pollution and health estimates can be applied to estimate the impact of PM_{10} on premature mortality in China. Although there are no systematic statistics related to actual exposure, the analysis in this chapter provides a general measure of the effect on health of air quality, which is apparently related to ultimate exposure. The dose-response functions have been identified and adapted from published epidemiologic and economics literature by Ostro (1994) and Finch *et al* (1995).

<u>8.3.3 Estimation of Mortality Damage (1981-1990)</u>

According to the official statistics, the urban population of China ranged from 200 million people in 1981 to 300 million people in 1990. The urban population accounts for 20 to 25 percent of the total population (The Statistical Yearbook of China 1993). The urban population includes people from all cities regardless of size. This population is the basic figure for calculating health damage in terms of TSP. In terms of assigning damages to anthropogenic sources, PM_{10} in the above equations is taken to 0.7 of average PM_{10} concentrations because it is assumed that 70 percent of emissions are anthropogenic (Pearce and Crowards 1996). According to Xu *et al* (1994), the concentration of TSP in Beijing is 375 $\mu g/m^3$ and this level of concentration of TSP is used in the present study. Thus, from the above mentioned DFR, we find that:

1) 0.00096 is the central consensus dose response coefficient for absolute mortality from particulate matter, and 0.00062 and 0.0013 are the lower and upper bounds respectively.

2) Since PM_{10} = 0.55 TSP, 375 TSP x 0.55 = 206 PM_{10} and anthropogenic PM_{10} is estimated to be 70 percent, 206 PM_{10} x 0.7 = 144 PM_{10}.

Table 8.5 shows the procedure used in the calculation of health damage. From 1981 to 1990, urban population, unit value of industrial output and yearly deflators are listed in the table. The last column gives the total mortality figures which are derived from data published by the Ministry of Public Health in 1990. According to the Ministry, the proportion of deaths from respiratory diseases is 921.8 people in the large cities and 1596.7 people in the small cities (county level) per million people in China.

The calculation procedure for Table 8.6 is described below. Firstly, we must establish the death toll from respiratory diseases. Using the official statistical figures, the total industrial output and average product per capita from 1981 to 1990 is listed in column (a) and (b). The industrial outputs from 1981 to 1990 are divided by the total employees in industrial sectors to obtain the average value of output per employee. This average figure was 1059 yuan in 1981 and 2221 yuan in1990. All unit output values were deflated by 1980 prices to obtain the real value. Column (c) provides the deflator and (d) gives the real output value. Since the death rate in the large cities is 921.8 people and in the small cities 1596.7 people per million of population, the mean of the death rate is used here, which equals 1256 people per million of population. Thus in column (g), the death toll from respiratory diseases is derived as urban population times 1256 people per million of population. The death percentage from respiratory diseases makes up 15.76 percent of total deaths in large cities and 24.82 percent in small cities. Therefore, in order to get the number of deaths from PM_{10}, the number of deaths from respiratory diseases is divided by the mean percentage (20.3 percent) from large cities and small cities, see column (h).

In Table 8.6, total deaths are multiplied by consensus lower, central and upper bounds so as to obtain the number of deaths at 1 $\mu g/m^3$ of PM_{10}. The figure of 375 $\mu g/m^3$ for average urban PM_{10} concentration is multiplied by 0.55 TSP in order to derive the correct mortality estimate. The concentration in such an adjustment is 206 $\mu g/m_3$. 206 $\mu g/m^3$ times 0.7 'anthropogenic' percentage of emissions equals 144 $\mu g/m^3$. Deaths from PM_{10} are derived and listed in Table 8.6.

Table 8.5 Calculating Health Damage of TSP

year	(a) Q (bi yuan)	(b) Q/n (yuan)	(c) deflator (1980 prices)	(d)=(b)/(c) real Q/n (bi yuan)	(f) real Q/n/day (yuan)	(g) URBPOP (mi p)	(h) deaths 1256/mi	(i) total death 0.203
1981	540.0	1080.0	1.019	1059.9	3.5	200	251200	1237438
1982	581.1	1139.4	1.028	1108.4	3.7	210	263760	1299310
1983	646.1	1242.5	1.039	1195.9	4.0	220	276320	1361182
1984	761.7	1437.2	1.094	1313.7	4.4	240	301440	1484926
1985	971.6	1735.0	1.203	1442.2	4.8	250	314000	1546798
1986	1119.4	1930.0	1.251	1542.8	5.1	260	326560	1608670
1987	1381.3	2302.2	1.341	1716.8	5.7	270	339120	1670542
1988	1822.4	2939.4	1.452	2024.3	6.7	280	351680	1732414
1989	2201.7	3551.1	1.582	2244.7	7.5	290	364240	1794286
1990	2392.4	3738.1	1.683	2221.1	7.4	300	376800	1856158

Q = industrial output
Q/n = industrial output per employee
URBPOP = urban population
144ug/m3 is derived by 375 ug/m3 multiplying 0.55 times 0.7 anthropogenic emissions.
other sources: *China Statistical Yearbook 1993*.

Table 8.6 Calculation of Health Damage of TSP (mortality)

year	total death (people) (a)	lower 0.00062 (people) (b)	central (0.00096) (people) (c)	upper (0.0013) (people) (d)	lower 144μg/m^3 (people) (e)=(b)x144	central 144μg/m^3 (people) (f)=(c)x144	upper 144 μg/m^3 (people) (g)=(d)x144
1981	1237438	767	1188	1609	110479	171063	231648
1982	1299310	806	1247	1689	116002	179617	243231
1983	1361182	844	1307	1770	121526	188170	254813
1984	1484926	921	1426	1930	132574	205276	277978
1985	1546798	959	1485	2011	138098	213829	289561
1986	1608670	997	1544	2091	143622	222383	301143
1987	1670542	1036	1604	2172	149146	230936	312725
1988	1732414	1074	1663	2252	154670	239489	324308
1989	1794286	1112	1723	2333	160194	248042	335890
1990	1856158	1151	1782	2413	165718	256595	347473

Source: Calculated by the author.

Summing up the calculation procedure for death from PM_{10}, we can take 1981 as an example. The urban population in that year stood at 0.2 billion. This figure is multiplied by 1256 people to obtain mortality from respiratory diseases, that is 251200 people in 1981, this figure is then divided by 20.3 percent to get total deaths of 1237438 people. Multipling by 0.00096 the central bound of the dose response function, we get mortality figures for 1 μg/m^3 of PM_{10} and 144 μg/m^3 of PM_{10} by the following step:

200 x 1256/0.203 = 1237438 (people)

1237438 x 0.00096 x 144 = 171063 (people)

The figures for 1 μg/m^3 of PM^{10} in the lower and upper bounds are 767 and 1609 people using the coefficients of 0.00130 and 0.00062. These results imply that mortality in the lower and upper bounds is 110479 and 231648 people in 1981. This procedure is the same for all years from 1981 to 1990. (See Table 8.6 for details).

The human capital approach is based on the assumption that the value of an individual alive is equal to what he or she produces and that productivity is accurately measured by earnings from labour. In using the human capital approach, earnings before taxes are measured in order to reflect the government's and society's interest in each individual's total productivity. Obviously, with the death of an individual, output is lost. The human capital approach is used here for estimating the social value of a statistical 'life'. Table 8.7 shows the procedures for calculating the economic value of mortality from 1981 to 1990, including the calculation of human capital. Since the age distribution of the population at risk is unknown, we assume a normal distribution[5], so that the average age can be taken. The life expectancy in China was 68.2 years

[5]The equation of the normal distribution function is given by the following mathematical expression:

$$f(x)=\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left[\frac{-1/2\,(x-\beta)^2}{\sigma^2}\right],\ -\infty<x<\infty$$

(UNDP, *Human Development Report 1995*) and the average age is 34.1 years. Taking 1981 as an example, when the output value was 1059 per person, we can get the social value of a "life" as:

$$VOSL^{6} = \sum_{t=0}^{34.1} (1059)(1+y)^{t}(1+i)^{-t} \qquad (12)$$

where,

y = expected income growth proportion

i = discount rate

Given 10 percent as a discount rate and 8.2 percent of expected income growth, we take the concentration figure of 144μg/m³ for average urban PM_{10} concentration, along with the total urban deaths from 1981 to 1990. With the lower, central and upper bounds of the dose-response coefficient, the value of statistical (VOSL) life from 1981 to 1990 in China attributable to PM_{10} exposure is derived in Table 8.7. Again, we take 1981 and 1990 as examples. In 1981 the VOSL for one person is 27853 yuan and in 1990 it is 58371 yuan. The same procedure is applied to the remainder of the years. The total economic damage from premature mortality is calculated by multiplying the VOSL by the deaths derived from the lower, central and upper bounds. For instance, in 1981, the figures were 3.1, 4.8 and 6.5 billion yuan respectively from the lower, central and upper bounds. Table 8.7 shows the economic value of social life from 1981 to 1990.

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where exp [ ] denotes the exponential function e^{a}. The mean β and σ^2 are the parameters of the normal distribution. The normal probability density function is a symmetric bell-shaped curve centered at β, its mean value. Thus the normal distribution is used in our assumption.

[6] The calculation procedure is as follows:
(1.082)/(1.1)=0.9836
$0.9836^{34.1} = 0.568999$
(1-0.568999)/(1-0.9836) = 26.28

Table 8.7 Total Premature Mortality Damage from TSP (mortality) (1980 prices)

year	GNP per capita (yuan) (current price) (a)	GNP per capita (yuan) (real value 1980=1) (b)	VOSL (yuan) (c)	lower (billion yuan) (d)*	central (billion yuan) (e)*	upper (billion yuan) (f)*	daily value (yuan) (g)
1981	1080.0	1059.9	27853	3.1	4.8	6.5	3.6
1982	1139.4	1108.4	29128	3.4	5.2	7.1	3.8
1983	1242.5	1195.9	31427	3.8	5.9	8.0	4.1
1984	1437.2	1313.7	34524	4.6	7.1	9.6	4.8
1985	1735.0	1442.2	37902	5.2	8.1	11.0	5.8
1986	1930.0	1542.8	40544	5.8	9.0	12.2	6.4
1987	2302.2	1716.8	45116	6.7	10.4	14.1	7.7
1988	2939.4	2024.3	53200	8.2	12.7	17.3	9.8
1989	3551.1	2244.7	58991	9.4	14.6	19.8	11.8
1990	3738.1	2221.1	58371	9.7	15.0	20.3	12.5

VOSL is derived from (1.082)t/(1.1)t exponential 34.1.
*8.2% is the expected income growth.
*10% is the discount rate.
*34.1 is the average age of life expectancy 68.2 years in China.
*(d), (e) and (f) are derived by (c) x number of mortality people at the lower, central and upper bounds.

However, in order to reflect the correct opportunity cost of the VOSL and calibrate the distorted price in China, the VOSL can be adjusted as:

$$\text{VOSL (China)} = \text{VOSL (USA)} \cdot [\text{GNPcap (China)/GNPcap (USA)}]^{\alpha-\beta} \qquad (13)$$

This is based on the benefit transfer approach. Where α is the income elasticity of demand of China and β is the elasticity demand of the USA (which we assume to be 0.33[7]). α - β is the real income elasticity of China and we assume that this is the real income elasticity (Blackobby

[7]In Alberini *et al*'s paper (1995) on Taiwan, the income elasticity of demand in Taiwan is 0.33 and here we assume the same income elasticity for the USA.

and Russel 1989, de La Granville 1989). GNPcap (China) is the GNP per capita of China and GNPcap (USA) is the GNP per capita of the USA. From an economic point of view, this adjustment is made because VOSL (USA) is used as the calculation base. When adjusting the VOSL we need to be aware of the fact that the income difference between the two countries is large and deflated real value should be obtained when converting US dollar to Chinese yuan. Table 8.8 shows the adjusted VOSL, which is different from the VOSL calculated by using the industrial GOP per capita. Here we assume that VOSL (USA) is 2 million US dollars. To select a proper income elasticity of demand is very important in the adjustment. Alberini *et al* (1995) assume an income elasticity of 0.33 in their willingness to pay study on health effects in Taiwan. Based on their calculations, we assume that since the income level in China is lower than that in Taiwan, the environment is a luxury good. The implication is that when income is low, the environment is relatively expensive for people to spend money on and is income-elastic. With increase in income, the environment becomes less expensive and the income elasticity of demand for risk reduction also decreases. Table 8.9 shows the procedure for selecting the income elasticity. Thus, the income elascticity in China should be higher than it is in Taiwan. According to economic notions, an elasticity greater than 1 is considered elastic. Thus, we tried to use 0.99, 1.09 and 1.19 as the income elasticity in China and chose 1.19 - 0.33 = 0.86 to be the income elasticity of China relative to the USA[8] because it appears reasonable to the level of income in China for calculating health damage.

The VOSL derived from the adjustment with the US VOSL is used to calculate the health damage from mortality from emissions of TSP. The health damage from mortality (1981-1990) is shown in Table 8.10. It was assumed that the damage should be calculated at the lower, central and upper bounds. Columns 1-3 show the number of deaths from the three bounds, Column 4 is the adjusted VOSL in yuan (at 1.19 - 0.33 = 0.86 income elasticity of demand). The health damage from mortality is derived by multiplying the number of deaths with the adjusted VOSL. It should be emphasised here that the health damage from this calculation

[8]As explained previously, the exact income elasticity of USA is unknown. 0.33 is an assumption based on the study of Taiwan (Alberini *et al* 1995). The income elasticity in China is calculated as 1.19 - 0.33 = 0.86.

differs from the the health damage from above unadjusted calculation. The VOSL in the two approaches is also different. The VOSL in the human capital approach is increasing over time. By contrast, in the adjusted approach the trend of VOSL is decreasing over time. This reveals that the proportion of GNP per capita of China to GNP per capita of the USA is declining over time. Table 8.8 compares the two approaches:

Table 8.8 Comparison of Two VOSL Approaches (in 1980 price)

year	human capital approach (yuan)	benefits transfer approach (yuan)
1981	27853	76420
1982	29128	76682
1983	31427	78580
1984	34524	61888
1985	37902	58943
1986	40544	54585
1987	45116	56830
1988	53200	61712
1989	58991	61618
1990	58371	51124

Source: Calculated by the author.

Table 8.9 Selection of Income Elasticity and Adjusted VOSL
unit: yuan

year	CHGNP per capita (a)	USGNP per capita (b)	ratio CHGNP/US GNP (c)=(a)/(b)	income elasticity* 0.99-0.33=0.66 (d)	income elasticity* 1.09-0.33=0.76 (e)	income elasticity* 1.19-0.33=0.86 (f)	adjusted VOSL (0.66) (yuan) (g)=(d)xVOSL	adjusted VOSL (0.76) (yuan) (h)=(e)xVOSL	adjusted VOSL (0.86) (yuan) (i)=(f)xVOSL
1981	471	20975	0.022	0.08	0.05	0.04	163280	111704	76420
1982	501	22219	0.022	0.08	0.06	0.04	163709	112042	76682
1983	547	23566	0.023	0.08	0.06	0.04	166811	114490	78580
1984	613	34902	0.017	0.07	0.05	0.03	138879	92709	61888
1985	677	40749	0.017	0.07	0.04	0.03	133779	88800	58943
1986	727	47848	0.015	0.06	0.04	0.03	126119	82971	54585
1987	777	48825	0.016	0.06	0.04	0.03	130082	85980	56830
1988	879	50201	0.017	0.07	0.05	0.03	138595	92491	61724
1989	904	51699	0.017	0.07	0.05	0.03	138413	92351	61618
1990	926	65826	0.014	0.06	0.04	0.02	119936	78304	51124

*Here 0.99-0.33, 1.09-0.33 and 1.19-0.33 are based on the idea of deriving the real income elasticity as discussed previously in the text. After many attempts at choosing a proper income elasticity, the listed three elasticities are chosen.
Source: calculated by the author.

Table 8.10 Premature Death Damage from TSP (mortality) (in 1980 price)

year	mortality (lower bound) (people) (a)	mortality (central bound) (people) (b)	mortality (upper bound) (people) (c)	VOSL (income elasticity 0.86) (yuan) (d)	health damage (lower bound) (billion yuan) (f)=(a)x(d)	health damage (central bound) (billion yuan) (g)=(b)x(d)	health damage (upper bound) (billion yuan) (h)=(c)x(d)
1981	110479	171063	231648	76420	8.4	13.1	17.7
1982	116002	179617	243231	76682	8.9	13.8	18.7
1983	121526	188170	254813	78580	9.5	14.8	20.0
1984	132574	205276	277978	61888	8.2	12.7	17.2
1985	138098	213829	289561	58943	8.1	12.6	17.1
1986	143622	222383	301143	54585	7.8	12.1	16.4
1987	149146	230936	312725	56830	8.5	13.1	17.8
1988	154670	239489	324308	61724	9.5	14.8	20.0
1989	160194	248042	335890	61618	9.9	15.3	20.7
1990	165718	256595	347473	51124	8.5	13.1	17.8

Source: calculated by the author.

It is apparent that the health damage from mortality due to emissions of TSP is different under the adjusted approach and under the unadjusted human capital approach. We choose to use the results of the adjusted approach for estimating health damage. The results indicate that health damage is very high due to emissions of TSP.

8.3.4 Estimation of the Damage from Morbidity (1981-1990)

Measures of morbidity must take into account the fact that, unlike mortality, morbidity is not a discrete event but a process involving time. There are several categories of degree of activity impairment, such as "restricted activity days", "bed disability days" and "work loss days". These terms represent ill health conditions. Freeman III (1994) illustrates all of the categories of morbidity that resulted in a recovery period or in mortality. Pearce and Crowards (1995) have followed Rowe *et al* (1995) by 'borrowing' the relevant dose-response functions from US work for morbidity estimates in the UK. Their methodology also can be used in our study of China, with some necessary adjustments, e.g., for the size of urban population.

Epidemiological studies have associated particulates with a variety of obstructive airway diseases including chronic bronchitis, asthma, emphysema and respiratory infection. Hall *et al* (1992) estimate that the annual number of restricted activity days per person caused by these conditions rises by about 5.5 days/year for each 100 $\mu g/m^3$ increase in average ambient PM_{10} concentration. A restricted activity day (RAD) is a day missed from work, spent in bed, or otherwise significantly constrained. Given time and population-weighted average TSP exposures in the order of 375 $\mu g/m^3$ in China and assuming a 55 percent PM_{10} fraction, the annual number of particulate-induced RADs for the entire population in 1990 were respectively 1.2, 2.5 and 3.4 billion days from the lower, central and upper bounds from our calculation.

The procedure for estimation of morbidity from 1981 to 1990 is made step by step for six categories of morbidity. Although there are no statistics on respiratory hospital admissions, emergency room visits and lower respiratory illness, the calculation we conducted employs the estimates made by Rowe *et al* (1995). Given 144 μg/m^3 of anthropogenic emissions, the number of people who suffer from respiratory disease from the lower, central and upper bounds is derived using the coefficients from Rowe et al's (1995) paper (see Appendix 4).

We know the unit output value per year from previous calculations and tables. For example, in 1981 the figure was 1080 yuan and in 1990 the figure was 3738 yuan. In China there were 6 working days per week in the past, plus some holidays. Thus, a total of 300 hundred working days per year seems to be an appropriate assumption. 1080 yuan of the non-deflated daily value was divided by 300 days to get the average output value created by one employee per day. For example the value is 3.6 yuan per day in 1981 and 12.5 yuan per day in 1990. The non-deflated daily value is used for deriving health damage from morbidity. The health damage from morbidity is deflated after finishing the calculation.

The coefficients listed in Appendix 4 are used for calculating each type of morbidity from the lower, central and upper bounds in China. The key assumption is that the above dose response functions can be 'transferred' to the Chinese situation at least as a first approximation. The numbers of respiratory hospital admissions (RHS), emergency room visits (ERV), restricted activity day (RAD), asthma attacks (AA), respiratory symptoms (RS) and new chronic bronchitis cases (CB) are computed based upon the listed coefficients and the urban population size in China. These numbers are multiplied by the anthropogenic concentration of TSP emissions to obtain the total numbers of morbidity from air pollution in China.

The calculation for each type of morbidity is pursued by applying Rowe *et al*'s morbidity dose response functions for PM_{10}. The calculation starts from the estimation of the population in each category: respiratory hospital admissions (RHA), emergency room visits (ERV), restricted activity day (RAD), asthma attacks (AA), respiratory symptoms (RS) and chronic bronchitis (CB). We calculate economic loss at the lower, central and upper bounds by multiplying the monetary value. For respiratory hospital admissions and emergency room visits, 150 yuan is assumed to be spent in both cases. According to the data from the Ministry of Public Health, the medical expenses for respiratory diseases ranged from 500 to over 1000 yuan per person in 1990. However, the price level in the 1980s was much lower than during the 1990s. We, suppose therefore that 150 yuan was spent per year on respiratory diseases caused by PM_{10}. The expenses on morbidity from 1981 to 1990 are derived by multiplying the proportion of respiratory diseases of the population by 150 yuan. RHA and ERV are calculated at 150 yuan per person per year. The expenditure on restricted activity days is derived by multiplying the daily output value of the respective years. The expenditures on asthma attacks and respiratory symptoms are calculated by multiplying 1/2 and 1/4 of the daily output value since 1/2 and 1/4 of expenditures are assumed to be spent per person. CB is calculated using the average medicine expenditures, 897 yuan per person yearly (the Ministry of Public Health 1990).

Table 8.11 summarises each type of morbidity by TSP at the lower, central and upper bounds; estimates of expenditure on health damage at the lower, central and upper bounds are also presented in the table.

Table 8.11 Estimation of Damage of Morbidity (TSP)
(billion yuan) (1980 prices)

year	health damage (lower bound) (a)	health damage (central bound) (b)	health damage (upper bound) (c)	deflator (1980=1) (d)	real value of damage (lower bound) (e)=(a)/(d)	real value of damage (central bound) (f)=(b)/(d)	real value of damage (upper bound) (g)=(c)/(d)
1981	5.9	11.5	22.3	1.019	5.8	11.3	22.8
1982	6.5	12.5	24.4	1.028	6.3	12.2	23.8
1983	7.2	13.9	27.5	1.039	6.9	13.4	26.5
1984	8.5	16.4	33.9	1.094	7.7	14.9	31.0
1985	9.5	18.4	41.7	1.203	7.9	15.3	34.6
1986	10.5	20.2	47.6	1.251	8.4	16.2	38.1
1987	11.9	22.9	57.9	1.341	8.9	17.1	43.2
1988	14.2	27.4	75.1	1.452	9.8	18.9	51.7
1989	16.1	31.0	92.8	1.582	10.2	19.6	58.7
1990	16.5	31.8	100.7	1.683	9.8	18.9	59.9

Source: calculated by the author.

In Table 8.11 the total economic losses from morbidity at the lower, central and upper bounds during 1981-1990 are exhibited. A very clear profile is obtained by the estimation for morbidity. The economic damages from morbidity in real values are respectively 5.8, 11.3 and 21.8 billion yuan from the lower, central and upper bounds in 1981, and respectively 9.8, 18.9 and 59.9 billion yuan from the lower, central and upper bounds in 1990. All the values are deflated (1980 = 1). From the table it is clear that health damages increased year by year. In 1990 the damage in the upper bound was 270 percent more than in 1981.

8.4 Estimation of Health Damage from SO_2

8.4.1 Calculation of Mortality

Although it is commonly believed that emissions of SO_2 cause little health damage to human beings, we intend to test if there is damage from SO_2, given the assumption: hypothesis = 0 if there is no damage and hypothesis = 1 if there is damage. Florig (1993) calculates the ambient concentrations of SO_2 in China, but he does not mention the health damage from SO_2. Xu *et al* (1994) do mention health damage in their study. In contrast to most of the other studies on daily mortality, SO_2 was the more significant pollutant in Xu *et al*'s studies, even when regressed jointly with TSP. Thus it seems necessary to estimate the health damage from SO_2.

Estimation of mortality damage from SO_2 follows the same methodology as illustrated above by using the same dose-response function. The same dose-responses function for PM_{10} should also be applicable for SO_2 since the concentration can be adjusted as:

sulphates = 0.14 TSP

sulphates = 0.25 PM_{10}

In the paper by Xu *et al* (1994), the concentration of SO_2 is 102$\mu g/m^3$. This figure is lower than the figure mentioned by the World Bank[9], but since the figure is used in Xu *et al*'s study, it has been chosen as our calculation base. The same output value per capita is used here as in calculating the mortality due to TSP. The coefficients listed in Table 8.11 are used for calculating each type of morbidity for the lower, central and upper bounds. Again, the dose response functions are 'transferred' to the Chinese situation for the estimation of mortality effects from SO_2 emissions.

According to the conversion factor, the concentration of SO_2 is adjusted to calculate the damage. The concentration used in this study is chosen from the concentration in Xu *et al* 's study (1994), which is 102 $\mu g/m^3$. Since it is understood that sulphates = 0.25 PM_{10}, by choosing the concentration level of 102 $\mu g/m^3$ SO_2 for average urban PM_{10} concentration, the figure is multiplied by 0.25 to reach the concentration for deriving the correct mortality. The concentration in such an adjustment is 26 $\mu g/m_3$. 26 $\mu g/m^3$ times 0.7 'anthropogenic' percentage of emissions equals 18 $\mu g/m^3$. 18 $\mu g/m^3$ is used as the emission concentration of PM_{10} in this study. In Table 8.12, total death is multiplied by the lower, central and upper bounds to get death at 1 $\mu g/m^3$ of PM_{10}. We then used the same procedures as in the calculation of TSP mortality damage to derive deaths and economic damage from the lower, central and upper bounds of dose response functions. The same population size is used to obtain the number of deaths. The mortality damage in 1981 from the lower, central and upper bounds is 0.4, 0.6 and 0.9 billion yuan respectively. The deaths from SO_2 are derived and listed in Table 8.13.

In calculating health damage from mortality by emission of SO_2, we directly use the benefit transfer VOSL in estimating of health damage. It should be clear that the adjusted VOSL can only be indicative, but it provides at least some insight into underlying health damage from SO_2.

[9] According to the World Bank (1991), the concentration of SO_2 was 220 $\mu g/m^3$ in seven cities in China.

Table 8.12 Mortality from Emissions of SO_2

year	URBPOP (mi people) (a)	deaths 1256/mi (people) (b)	total death 0.203 (people) (c)=(b)/0.203	lower (people) (d)=(c)x0.00062	central (people) (e)=(c)x0.00096	upper (people) (f)=(c)x0.00130	lower 18 μg/m³ (people) (g)=(d)x18	central 18 μg/m³ (people) (h)=(e)x18	upper 18 μg/m³ (people) (i)=(f)x18
1981	200	251200	1237438	767	1188	1609	13810	21383	28956
1982	210	263700	1299310	806	1247	1689	14500	22452	30404
1983	220	276320	1361182	844	1307	1770	15191	23521	31852
1984	240	301440	1484926	921	1426	1930	16572	25660	34747
1985	250	314000	1546798	959	1485	2011	17262	26729	36195
1986	260	326560	1608670	997	1544	2091	17953	27798	37643
1987	270	339120	1670542	1036	1604	2172	18643	28867	39091
1988	280	351680	1732414	1074	1663	2252	19334	29936	40538
1989	290	364240	1794286	1112	1723	2333	20024	31005	41986
1990	300	376800	1856158	1151	1782	2413	20715	32074	43434

Source:calculated by the author.

Table 8.13 Health damage from SO_2 (mortality)

year	mortality (lower bound) (people) (a)	mortality (central bound) (people) (b)	mortality (upper bound) (people) (c)	VOSL (yuan) (1980 price) (d)	damage (lower bound) (billion yuan) (e)=(a)x(d)	damage (central bound) (billion yuan) (f)=(b)x(d)	damage (upper bound) (billion yuan) (g)=(c)x(e)
1981	13810	21383	28956	76420	1.1	1.6	2.2
1982	14500	22452	30404	76682	1.1	1.7	2.3
1983	15191	23521	31852	78580	1.2	1.8	2.5
1984	16572	25660	34747	61888	1.0	1.6	2.2
1985	17262	26729	36195	58943	1.0	1.6	2.1
1986	17953	27798	37643	54585	1.0	1.5	2.1
1987	18643	28867	39091	56830	1.1	1.6	2.2
1988	19334	29936	40538	61724	1.2	1.8	2.5
1989	20024	31005	41986	61618	1.2	1.9	2.6
1990	20715	32074	43434	51124	1.1	1.6	2.2

Source: calculated by the author.

In Table 8.13, estimates of total economic damage from SO_2 emissions are derived. What is very surprising is the figure from the central bound of the dose response function. In 1990, this figure was 1.6 billion yuan for health damage from mortality. This further sunstantiates Xu *et al's* (1994) statement that the air pollution from SO_2 has brought about damage not only to buildings and ecosystems, but also to human health.

8.4.2 Calculation of Morbidity

Xu *et al* (1994) did not conduct an estimation of the health damage of morbidity caused by emissions of SO_2. If there is a mortality damage, there should also be a morbidity damage to human health from emissions of SO_2. Therefore, it is necessary to examine the results of morbidity from emissions of SO_2. We use the same categories used in the estimation of the health damage from morbidity of TSP, that is "respiratory hospital admissions (RHA)", "emergency room visits (ERV)", "restricted activity days (RAD)", "asthma attacks (AA)", "respiratory symptoms (RS)" and "chronic bronchitis (CB)". These terms represent ill health conditions. We follow the same methodology as Rowe *et al* (1995) in applying the relevant dose-response functions for morbidity. Their methodology is again used in our study of China, after some necessary adjustments for the number of people infected according to the concentration of emissions of SO_2.

Given 18 $\mu g/m^3$ of anthropogenic emissions, the number of people who suffer from respiratory disease from the lower, central and upper bounds is derived using the coefficients from Rowe *et al*'s (1995) paper. The numbers of respiratory hospital admissions, emergency room visits, restricted activity days, asthma attacks, respiratory symptoms and chronic bronchitis are computed based upon the previously listed coefficients and the urban population size in China. These numbers are multiplied by the anthropogenic concentration of SO_2 emissions to get the total numbers of morbidity from air pollution in China.

The same level of expenditures as in the calculation of TSP morbidity damage is used in calculating morbidity from emission of SO_2. 150 yuan per year is assumed to have been spent for RHA and ERV. Health damage of RADs is derived by multiplying RADs with the daily output value. 1/2 of the day value is assumed to have been spent for asthma attacks, and 1/4 of the daily output value is assumed to have been spent for respiratory symptoms. Since we have the actual expenditures for chronic bronchitis (the Ministry of Public Health 1990), the real expenditure was used in calculating health damage from this category. Table 7.14 summarises the total economic damage from emission of SO_2 from both mortality and morbidity.

Table 8.14 Estimation of Health Damage from Emission of SO_2
(billion yuan) (1980 prices)

year	mortality			morbidity			total		
	lower	central	upper	lower	central	upper	lower	central	upper
1981	1.1	1.6	2.2	0.7	1.4	2.7	1.8	3.1	4.9
1982	1.1	1.7	2.3	0.8	1.6	3.0	1.9	3.3	5.3
1983	1.2	1.8	2.5	0.9	1.7	3.3	2.1	3.6	5.8
1984	1.0	1.6	2.2	1.0	2.0	3.9	2.1	3.6	6.0
1985	1.0	1.6	2.1	1.2	2.2	4.3	2.2	3.8	6.5
1986	1.0	1.5	2.1	1.3	2.4	4.8	2.2	4.0	6.8
1987	1.1	1.6	2.2	1.4	2.8	5.4	2.5	4.4	7.6
1988	1.2	1.8	2.5	1.7	3.3	6.5	2.9	5.1	9.0
1989	1.2	1.9	2.6	1.9	3.7	7.3	3.2	5.6	9.9
1990	1.1	1.6	2.2	2.0	3.8	7.5	3.0	5.4	9.7

Source: Calculated by the author.

Thus, the results of our calculation turn out to be consistent with our prior hypothesis, showing that emissions of SO_2 do indeed cause health damage to human beings, and that this damage is significant compared to China's GNP level in the corresponding years.

8.5 Total Economic Damage to Health from TSP and SO_2 and Further Discussion

8.5.1 Calculation of Overlapping Part of Health Damage

In order to avoid double accounting, we calculated the overlap between TSP and SO_2. From Xu *et al*'s (1994) study, we acquired the concentrations of emissions of TSP and SO_2 from January to December in Beijing. Then we ran a regression to see the correlation between the two. The correlated R squared in our regression is 0.66. We assume that there are three types of victims of pollution. N1 is the number of people affected by TSP, N2 is the number of people affected by SO_2 and N3 is the overlap of people affected by both TSP and SO_2.

If SO_2 and TSP had independent effects on respiratory diseases, the overlap would be estimated by N1 x N2/Pop. If we assume, as a first approximation, that the correlation between diseases attributable to TSP and diseases attributable to SO_2 is 0.66, the same as the correlation between TSP and SO_2 concentration levels, then an extra term must be added to N1 x N2/Pop as follows:

$$N3 = N1xN2/Pop + 0.66x(\sqrt{N1xN2(1-P(S)x((1-P(T))} \qquad (14)$$

where

N1 = the number of people that suffer respiratory diseases due to emissions of TSP relative to the total population

N2 = the number of people that suffer respiratory diseases due to emissions of SO_2 relative to the total population

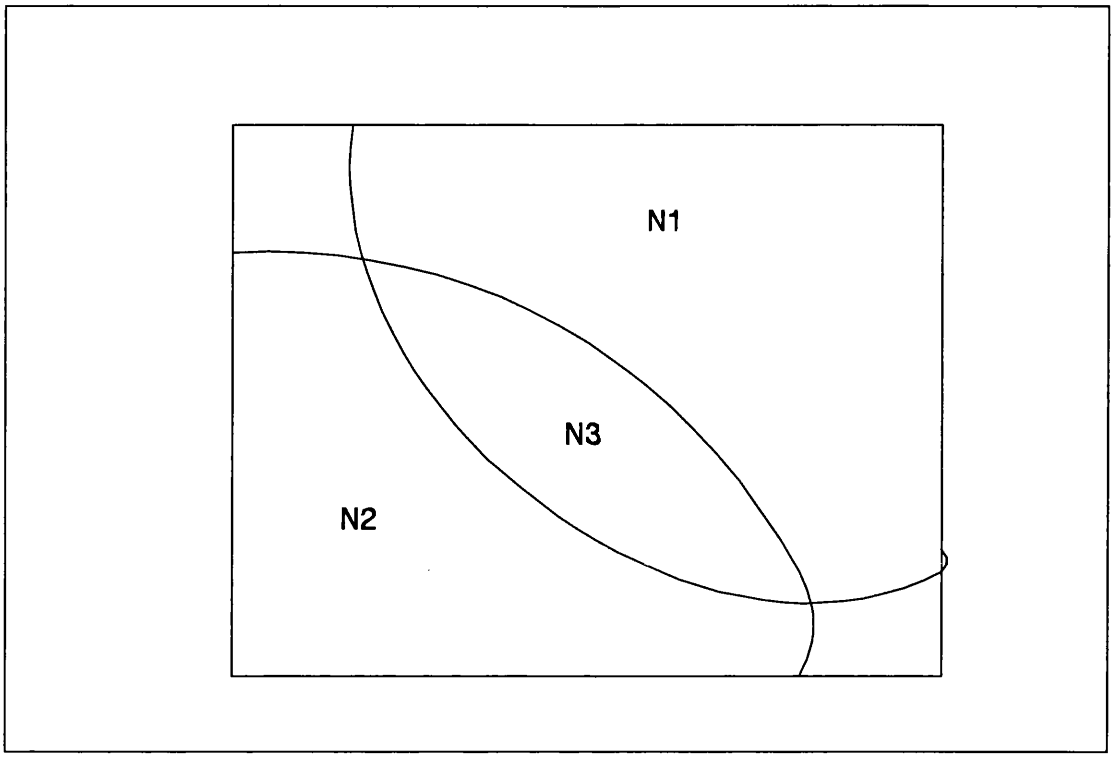
N3 = the overlap of the affected population

Pop = the total population of China

P(S) = N2/Pop

P(T) = N1/Pop (see Appendix 2 for detailed calculations)

Figure 8.1 Overlapping Part of Health Damage



N1 = people affected by TSP

N2 = people affected by SO_2

N3 = overlapping part

According to our calculations, 20 percent of people are affected by emissions of both TSP and SO_2. This 20 percent must be deducted from the total number of people in both mortality and morbidity. The following calculation shows our accordingly adjusted results:

Scenario 1 Calculation of the overlap of mortality (in the year of 1990)

1990	TSP	SO_2	Total	Overlap	percent
lower	165718	20715	186433	38669	20
central	256595	32074	288669	59874	20
upper	347473	43434	390907	81078	20

Scenario 2 Calculation of the overlap of morbidity (in the year of 1990)

Here some adjustment was also made. For example, for RAD the total days is the total population times 365 days. Here we selected 1990 to show respiratory hospital admissions (RHA):

1990	TSP	SO_2	Total	Overlap	percent
lower	285120	35640	320760	66496	20
central	518400	64800	583200	120960	20
upper	747360	93420	840780	174381	20

We calculated the ratio of the overlap to the total number of people suffering from emissions of TSP and SO_2. A 20 percent overlap between TSP and SO_2 is estimated, that is, 20 percent of the people who suffered from respiratory diseases related to emissions of TSP and SO_2 should be deducted. Thus the total overlap damage should also be 20 percent of the total health damage. This 20 percent of damage should be deducted from the total damage in order to avoid double accounting. Table 8.15 shows the health damage from TSP and SO_2 without deduction of the overlapping part of the damage. Table 8.16 shows the adjusted damage after deduction of the overlapping part.

Total 8.15 Health Damage from TSP and SO2 in terms of PM_{10}
(billion yuan) (in 1980 prices)

year	TSP			SO_2			total		
	lower	central	upper	lower	central	upper	lower	central	upper
1981	14.3	24.4	39.5	1.8	3.1	4.9	16.1	27.4	44.5
1982	15.2	25.9	42.4	1.9	3.3	5.3	17.1	29.2	47.7
1983	616.5	28.2	46.5	2.1	3.6	5.8	18.5	31.7	52.3
1984	15.9	27.7	48.2	2.1	3.6	6.0	18.0	31.3	54.3
1985	16.0	27.9	51.7	2.2	3.8	6.5	18.2	31.7	58.2
1986	16.2	28.3	54.5	2.2	4.0	6.8	18.4	32.2	61.3
1987	17.3	30.2	61.0	2.5	4.4	7.6	19.8	34.6	68.6
1988	19.3	33.6	71.8	2.9	5.1	9.0	22.2	38.8	80.7
1989	20.1	34.9	79.4	3.2	5.6	9.9	23.2	40.5	89.3
1990	18.3	32.0	77.6	3.0	5.4	9.7	21.3	37.4	87.3

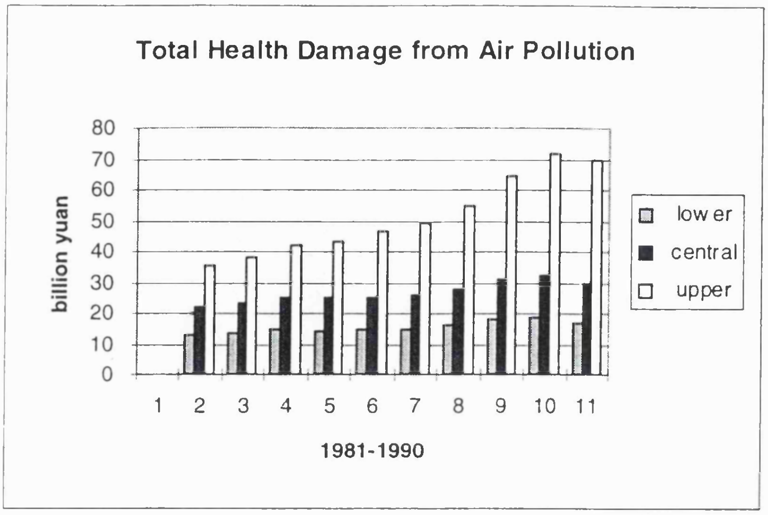
Source: calculated by the author.

Table 8.16 Overlapping Damage and Adjusted Total Damage
(billion yuan) (1980 prices)

year	Overlaping damage			Total Health Damage from TSP and SO_2 (after deduction of overlapping part)		
	lower	central	upper	lower	central	upper
1981	3.2	5.5	8.9	12.8	21.9	35.6
1982	3.4	5.8	9.5	13.7	23.4	38.2
1983	3.7	6.3	10.5	14.8	25.4	41.8
1984	3.6	6.3	10.9	14.4	25.0	43.4
1985	3.6	6.3	11.6	14.6	25.3	46.5
1986	3.7	6.4	12.3	14.8	25.8	49.0
1987	4.0	6.9	13.7	15.9	27.7	54.9
1988	4.4	7.8	16.1	17.8	31.0	64.6
1989	4.6	8.1	17.9	18.6	32.4	71.4
1990	4.3	7.5	17.5	17.0	29.9	69.9

Source: Calculated by the author.

Figure 8.2 Total Health Damage after Deduction of the Overlapping Part



8.5.2 Total Health Damage

The total health damage after deduction of the overlapping part is still quite high as shown in Table 8.16. In valuing risks to life, our calculation accounts for a large proportion of the GNP. Table 8.17 shows the total economic damages from mortality and morbidity after deduction of the overlapping damage. By adding the economic damage from mortality and morbidity from TSP and SO_2 together, the damages reach 12.8, 21.9 and 35.6 billion yuan in 1981 and 17.0, 29.9 and 69.9 billion yuan in 1990. The adjusted GNP is derived in Table 18 and the ratios of health damage to the GNP are calculated. The ratios in the lower bound are around 2-3 percent of the GNP, in the central bound they are 3-5 percent of the GNP, and in the upper bound they reach 7-8 percent of the GNP in 1990. These ratios are high and indicate that health damage is the most serious damage caused by air pollution in China.

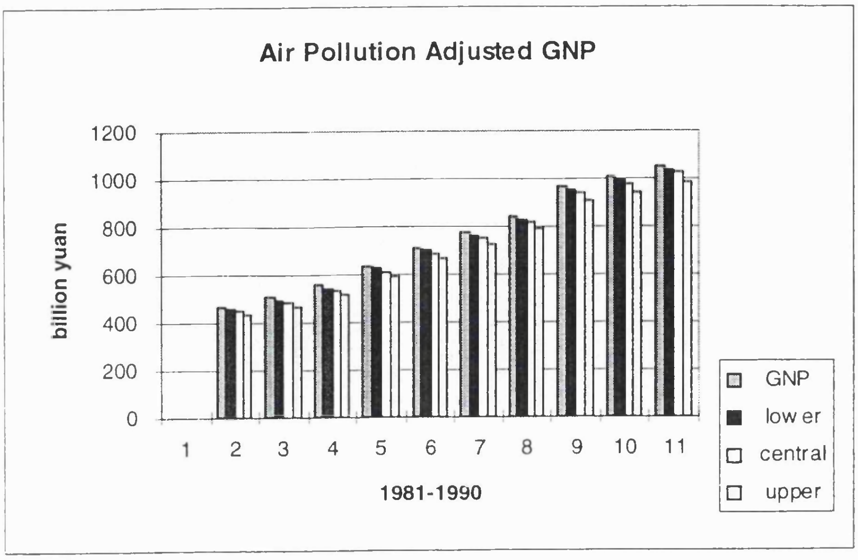
Human health damage is undeniably the most important aspect of air pollution damage to be accounted for. From our discussion above it is known that health damages account for 2 percent of the GNP in the lower bound, for 3-5 percent in the central bound and for 7-8 percent in the upper bound. The significance of calculating health damage is that it directly exposes the harm caused by air pollution to the well-beings of humans on this planet. The estimation of the monetised social costs of exposure to TSP and SO_2 may also help to demonstrate the benefits to be obtained by reduction in TSP and SO_2 emissions. The results of our application of the methodology to China are worthy of consideration, if only as a first approximation and basis for future refinements. It is hardly surprising that a country whose main energy source is coal sustains a high level of air pollution damage. The damage from air pollution in China is very high by western standards, as illustrated by the high percentages of the GNP found in our study to be accounted for by air pollution over the period 1981 to 1990. Although China spends about 0.6 percent of its budget on pollution control (including air, water, solid waste and others), our research shows that for air pollution control alone, China should be spending at least 2 percent of its GNP to maintain sustainable development (weak).

Table 8.17 Health Damage and Its Percentage of the GNP
(billion yuan) (1980 price)

year	lower estimate (a)	central estimate (b)	upper estimate (c)	GNP (d)	adjusted GNP (lower) (e)=(d)-(a)	adjusted GNP (central) (f)=(d)-(b)	adjusted GNP (upper) (g)=(d)-(c)	Damage/GNP (lower) (h)	Damage/GNP (central) (i)	Damage/GNP (upper) (j)
1981	12.8	21.9	35.6	468.4	455.6	446.5	432.8	0.03	0.05	0.08
1982	13.7	23.4	38.2	505.2	491.5	481.8	467.0	0.03	0.05	0.08
1983	14.8	25.4	41.8	559.1	544.3	533.7	517.3	0.03	0.05	0.07
1984	14.4	25.0	43.4	636.4	622.0	611.4	593.0	0.02	0.04	0.07
1985	14.6	25.3	46.5	711.4	696.8	686.1	664.9	0.02	0.04	0.07
1986	14.8	25.8	49.0	775.1	760.3	749.3	726.1	0.02	0.03	0.06
1987	15.9	27.7	54.9	842.7	826.8	815.0	787.8	0.02	0.03	0.07
1988	17.8	31.0	64.6	968.9	951.1	937.9	904.3	0.02	0.03	0.07
1989	18.6	32.4	71.4	1011.0	992.4	978.6	939.6	0.02	0.03	0.07
1990	17.0	29.9	69.9	1051.4	1034.4	1021.5	981.5	0.02	0.03	0.07

Source: calculated by the author.

Figure 8.3 Air Pollution Adjusted GNP



Florig (1993) argues that international comparisons of mortality rates provide a means for placing an upper bound on the health effects of particulate matter. Respiratory disease is a leading cause of death in China, accounting for about 26 percent of the 6.6 million deaths in 1988. Florig declares that the standardized death rate from respiratory diseases in China is 5.5 times higher than in the USA. TSP levels in US cities average less than 100 $\mu g/m^3$ compared to 400 $\mu g/m^3$ for the typical Chinese city. In Hall *et al*'s (1992) study, the average annual risk of death is 1/10000 persons as a test of elevated PM_{10} exposure in the South Coast Air Basin of California. In our study, the death rates from exposure to PM_{10} in 1990 from the lower, central and upper bounds are 0.055, 0.085 and 0.116 percent. The death rates imply that in every 10000 people there are 5.5, 8.5 and 11.6 deaths from exposure of PM_{10}. Our lower bound figure coincides with the declaration from Florig, that the death rate from respiratory disease is 5.5 times that of the USA. Pope III *et al* (1992) suggest that an increase in 5 deaths moves the average PM_{10} level to 100 $\mu g/m^3$ of the 260,000 population in the Utah Valley. By contrast, the death rates estimated here for China are far higher than those in the Utah Valley. This implies that the actual concentration of PM_{10} in China is probably higher than 144 μg/m^3.

Hall *et al* (1992) estimated that the annual number of restricted activity days (RAD) per person resulting from these conditions rises by about 5.5 days/year for each 100μg/m^3 increase in average ambient PM_{10} concentration. By using the estimate of 5.5 days off-work per 100 μg/m^3 increase in PM_{10}, for 144 μg/m^3, the restricted activity days should come to 7.9 days. But this figure does not match up with some statistics issued by the Ministry of Public Health. According to their statistics, the days of staying in hospital are 19.4 on an average. By applying Rowe *et al*'s coefficients of the dose-response function, the restricted activity days in China are 4.2, 8.4 and 11.2 days for the lower, central and upper bounds. Taking the figure from the central bound as a standardised RAD, it appears close to the estimation of Hall *et al,* but is lower than the figure from the Ministry of Public Health. The figure from the Ministry of Public Health should include deaths by other causes, thus our estimation shows results which are satisfactory with respect to reality.

Whilst health damage is an important aspect of total damage, it is essential to evaluate overall air pollution damages. Xu *et al* (1994) calculated the damage caused by air pollution in residential areas of Beijing. In their study, the distribution of air pollution caused mortality daily in 1989 in the Dongcheng and Xicheng districts. TSP concentrations (375 μg/m^3) in these districts are far above WHO recommended criteria. In their study TSP is associated negatively with temperature, indicating that coal combustion for heating was an important source. High monthly mean mortality rates were observed in winter months when TSP and SO_2 were high, and temperature and humidity were low. In our study it is also confirmed that health damage correlates with air pollution: the higher the concentration, the higher the health damage incurred.

In our study we applied procedures for placing economic values on losses of statistical lives. The approach used here should be an effective means of estimating health damage because: a) it includes emission factors, health factors and social factors together to measure pollution damage; b) it factors in changes in the level of PM_{10} into changes in health. The dose-response function is a useful function in empirical studies and economic valuation is the most important aspect of the assessment of the effects of air pollution on human health damage.

In Xu *et al*'s (1994) study, SO_2 was the more significant pollutant. In our study we tested their statement and found that SO_2 is indeed correlated with health damage. Although the damage is not as large as the damage from TSP, there is certainly some damage caused by SO_2. Our study further underlines Xu *et al*'s statement that there is human health damage due to emissions of SO_2.

8.6 Conclusion

The air pollution situation in China was discussed in this chapter. From our overview it is clear that China is a country with serious air pollution problem. Although China spends a certain amount of money on environmental protection, this still falls far below the amount required for sustainable air pollution control.

In this chapter the economic damages and social costs of air pollution were calculated. A dose-response function (DRF) was employed in order to derive the monetary values of air pollution damage. The DRF was used to derive health damage in terms of mortality and morbidity from TSP and SO_2. The method is applicable to the estimation of mortality from air pollution. Because of data shortage, for morbidity, we applied Rowe *et al*'s coefficients of DRFs for estimating morbidity cases as a first approximation.

Finally we estimated the total losses due to air pollution damage. The air pollution damages account for 2-3 percent in the lower bound, 3-5 percent in the central bound and around 7-8 in the upper bound of the GNP per year from 1981 to 1990. This is not a surprising result for a country which uses coal as its main energy source, losing most of its vegetation and spending little on pollution control. If China intends to maintain sustainable development, it should invest at least 2 percent (the lower bound, Table 8.17) of its GNP in air pollution control. A more detailed discussion of specific policies will be presented in a later evaluation.

Appendix 8.1 Calculation of Value of Social Life

year	US GNP (US$)	deflator 1980=100	CH GNP (yuan)	deflators 1980=100	US GNP (yuan)	ex rate	CH GNP
1981	13340	1.113	480	1.019	20975	1.75	471
1982	13690	1.183	515	1.028	22219	1.92	501
1983	14580	1.225	568	1.039	23566	1.98	547
1984	15980	1.282	671	1.094	34902	2.80	613
1985	16860	1.324	814	1.203	40749	3.20	677
1986	17570	1.366	909	1.251	47848	3.72	727
1987	18480	1.408	1042	1.341	48825	3.72	777
1988	19770	1.465	1277	1.452	50201	3.72	879
1989	21050	1.535	1430	1.582	51699	3.77	904
1990	21910	1.591	1559	1.683	65826	4.78	926

Appendix 8.2 Calculation of the Overlapping Part of Health Damage

let N1 = 1 if the person is ill due to SO^2
= 0 if the person is not ill due to SO_2

N2 = 1 if the person is ill due to TSP
= 0 if the person is not ill due to TSP

P(S) = P (N1 = 1)
P(T) = P (N2 =1)

P(S,T) = P(N1 =1 and N2 =1)
= P(the person is ill due to TSP and SO_2)

Thus

$$correlation(N1,N2)=\frac{Cov(N1,N2)}{\sqrt{Var(N1)V(N2)}} \quad (1)$$

$$Cov\ (N1, N2) = P(S,T) - P(S)P(T) \quad (2)$$

and $Var\ (N1) = P(S)(1-P(S)) = (N1/M)(1-P(S))$
$Var\ (N2) = P(T)(1-P(T)) = (N2/M)(1-P(T))$ (3)

(1), (2) and (3) yield:

$$N3/Pop=(N1/Pop)(N2/Pop)+corre(\sqrt{(N1/Pop)(N2/Pop)(1-P(S))(1-P(T))}) \quad (4)$$

Thus,

$$N3=N1xN2/Pop+0.66(\sqrt{N1xN2(1-P(S)(1-P(T)})) \quad (5)$$

Appendix 8.3 Correlation of TSP and SO2

month	TSP	SO2	XY		
Jan	550	390	214500	4770	164482
Feb	430	225	96750	1510	46732
Mar	480	115	55200	397.50	5182
Apr	420	45	18900	125.83	-31118
May	310	40	12400	50018.75	-37618
Jun	300	25	7500		-42518
Jul	240	25	6000		-44018
Aug	250	25	6250		-43768
Sep	230	40	9200		-40818
Oct	450	55	24750		-25268
Nov	540	225	121500		71482
Dec	570	300	171000		120982
		Regression Output:			
	Constant			-198.358	
	Std Err of Y Est			77.11868	
	R Squared			0.663409	
	No. of Observations			12	
	Degrees of Freedom			10	
	X Coefficient(s)		0.815577		
	Std Err of Coef.		0.183707		

Appendix 8.4 Morbidity Dose Response Functions for PM_{10}
(effect per 10 $\mu g/m^3$ change in PM_{10})

morbidity effect	low estimate	central estimate	upper estimate
RHA/100,000	6.6	12.0	17.3
ERV/100,000	116.0	237.0	354.0
RAD/person	0.29	0.58	0.78
Asthma attacks	0.33	0.58	1.96
respiratory symptoms/person	0.80	1.68	2.56
chronic bronchitis/100,000	30.0	61.2	93.0

Source: Rowe *et al* (1995).
Notes: RHA is respiratory hospital admissions; ERV is emergency room visits; RAD is restricted activity days.

Chapter 9

Quantifying the Overall Extent of Unsustainability

This chapter is divided into three parts. First, we report our figures for adjusted gNNP and we measure the extent of (weak) sustainability for China. By 'net' investment we mean actual gross investment minus depreciation of man-made capital and natural capital. Gross investment is inclusive of any resource discoveries and any stock appreciation. For weak sustainability net investment must be positive over time. Secondly, we assess the factors responsible for the large gNNP adjustment and high unsustainability levels. Having quantified environmental changes and their effects on GNP, we then survey the specific causes of the environmental degradation which have led to such large figures. Thirdly, we suggest a framework for the policy changes needed to tackle these causes and to restore sustainable development. We also employ this framework to assess the policy changes already taking place.

9.1 The Overall Extent of Unsustainability

9.1.1 Overview

In the previous four chapters 'green' national accounts for the evaluation of forests, coal, oil and air pollution have been derived. In the present chapter, we provide an overall evaluation of depreciation against GNP, and analyze the causes of environmental degradation. Finally, we discuss policy for sustainable development.

In the previous calculations, a reduction in forest, coal and oil stocks is regarded as depreciation. Monetary depreciation of these natural resources is displayed as a percentage of GNP as a convenient benchmark.

The Forest Sector. In calculating the depreciation of forest resources, two approaches were used:

the user cost approach and the net price approach. The depreciation of forest resources using user cost approach is less than the depreciation under the net price approach. Both approaches seem reasonable for calculating forest depreciation. The negative net investment of the forest sector by both the user cost and the net price approach implies that the forestry sector is not sustainable in the sense that continues to exploit this resource at its present rate will lead to eventual extinction of some species. Forest depreciation accounts for more than percent of total GNP under the net price approach and accounts for less than 1 percent under the user cost approach.

The Coal Sector. Three approaches were used in deriving the depreciation of coal. The depreciation of coal under the net price approach simply equals the value of the change of coal stocks and shows erratic results. The total rent approach indicates quite stable results for depreciation in the sense of a fairly constant level of depreciation over time. Under the user cost approach, only zero percent of depreciation is significant, because the depreciation at 5 and 10 percent discount rates is zero. The reason for this is simply that coal stocks in China are very large and could last for several hundred years given the current rate of mining. The net investment of the sector under the total rent and user cost approaches is consistently negative from 1976 to 1992. The depreciation of the coal sector accounts for about 10 percent of total GNP under the total rent approach and the user cost approach.

The Oil Sector. The calculation using the net price approach again shows erratic results over time but in this case the range of change is smaller than for coal because oil resources are less than coal resources. The total rent approach displays quite rational results for depreciation, while the user cost approach shows that the depreciations for zero, 5 and 10 percent are all meaningful. It indicates that the higher the discount rates, the lower the depreciation. The net investments by the total rent and the user cost approach are shown to have been negative. The net investments by the net price approach are negative throughout the period 1976-1992. The depreciation of the oil sector accounts for 3-8 percent of total GNP under the total rent approach and 1-8 percent under the user cost approach.

Air Pollution. The depreciation related to air pollution equals the health damage caused by that pollution. Health damage due to air pollution from TSP and SO_2 is very high. China's investment in the relevant sectors is low, relative to the depreciation of the resources. Some general conclusions for these sectors are specified below. In the evaluation of air pollution damage, we evaluated mainly health damage from both emissions of TSP and SO_2 in terms of PM_{10}. A dose response function was used to derive the health damage from mortality and morbidity due to emissions of TSP and SO_2. For reasons of simplicity, we select only the results from the central bound for our overall evaluation. Investment in air pollution control is extremely small and the net investment remains negative over time. Air pollution damage accounts for 5 percent of total GNP.

9.1.2 The Adjusted Net National Product (gNNP)

As discussed before, the net price approach is not particularly reliable (see Chapters 5 & 6). In this chapter, we mainly use the user cost and the total rent approaches for our analysis. Here GNP was adjusted according to the world price when we calculated depreciation for coal and oil resources. In Table 9.1 the relationship between depreciation of each sector and total depreciation is derived using the user cost approach. From 1976 to 1992, the total depreciation from forest, coal, oil and air pollution rises from 57.9 billion yuan to 228.8 billion yuan by the user cost approach. Coal depreciation accounts for the main part of this value. Using the total rent approach the total depreciation from the 4 sectors is from 64.6 to 214.9 billion yuan.

Figure 9.1 Depreciation of 4 Sectors (the user cost approach)

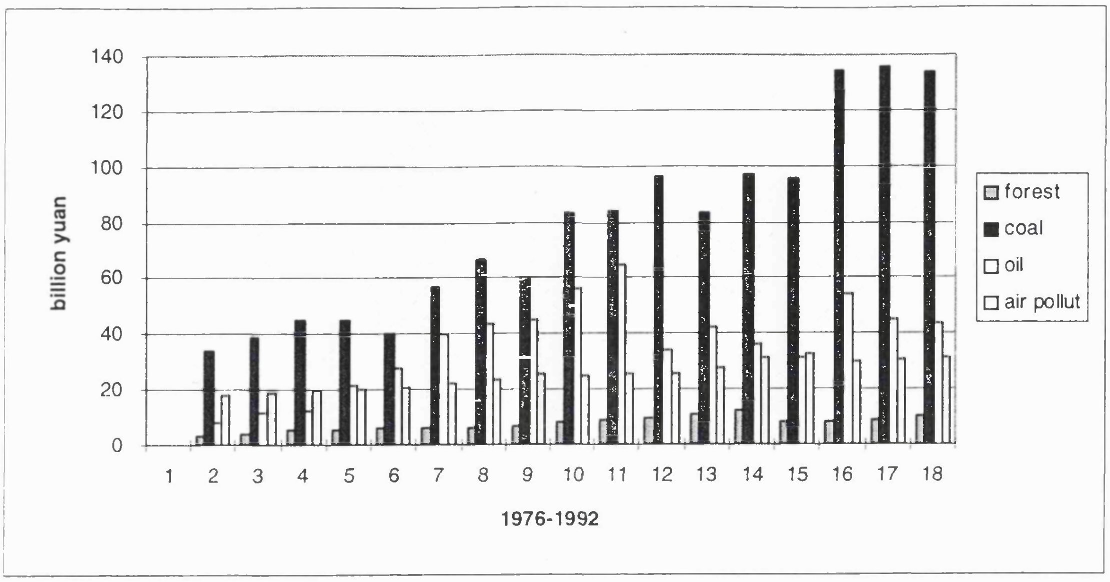
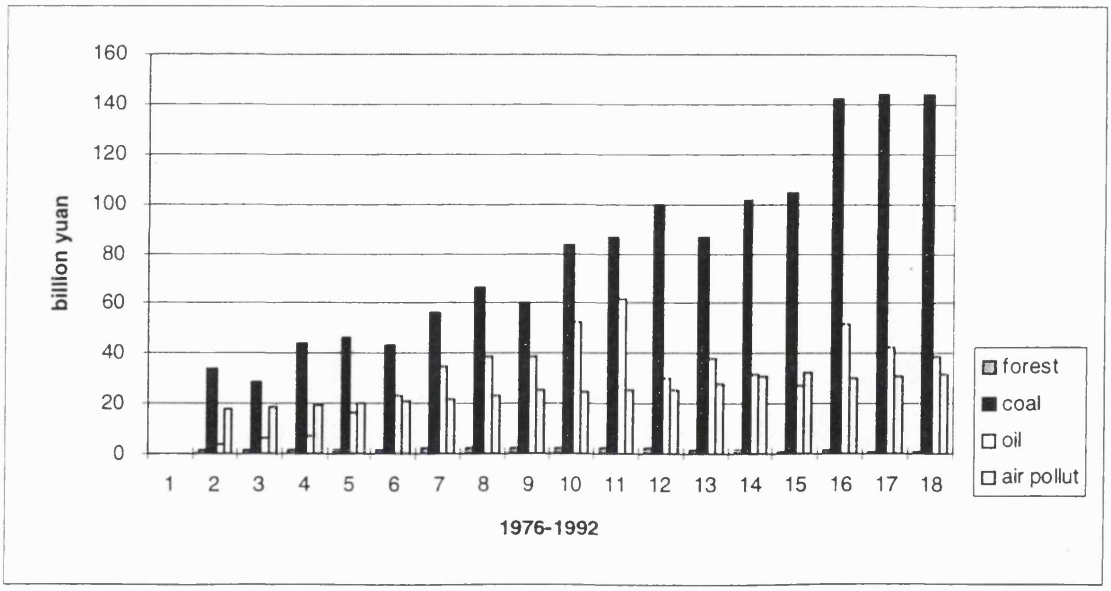


Figure 9.2 Depreciation of 4 Sectors (the total rent approach)



The formula of deriving 'green' NNP is: gNNP = GNP - depreciation of man-made capital - depreciation of natural capital. GNP minus depreciation of man-made capital equals NNP and NNP minus depreciation of natural capital equals 'green' NNP. According to this notion, 'green' NNP has been derived in our research. The total depreciation of natural capital from the four sectors lies between 15 and 22 percent of GNP. 'Green' NNP is around 60 to 70 percent of GNP under both the total rent approach and the user cost approach. For example, in 1991 the GNP was 1318.3 billion yuan, depreciation was 227.8 billion yuan by the total rent approach, NNP was 1142.0 billion yuan, hence 'green' NNP was 924.1 billion yuan. Depreciation in that year was 17 percent of the original GNP. Thus, the 'green' NNP was about 69 percent of the original GNP under the user cost approach. Using the total rent approach, the total depreciation is close to the user cost approach. Taking 1991 as an example, the original GNP in that year was 1318.3 billion yuan, the depreciation was 217.8 billion yuan, the NNP was 1142.0 billion yuan and the 'green' NNP was 921.0 billion yuan. The 'Green' NNP was 70 percent of the original GNP. The depreciation in that year was 16.5 percent of GNP.

The calculations reveal that environmental damage and natural resource depletion are very high in China. If the depreciation is calculated for all the environmental and natural resource sectors, including grassland, soil, natural gas, all minerals, water, wetland, fisheries and so on, the total depreciation could be higher still and this situation is a threat to overall sustainability.

Although inefficient management of environmental and natural resource base has resulted in less present and future welfare, appropriate policy reforms can substantially improve the way we use these resources in the future and thus keep economic development sustainable. Sustainable development is about ensuring that some measure of human wellbeing is sustained over time. Fundamental to this standard of economic development is the requirement that any actions now which are likely significantly to impair the wellbeing of the future must be associated with actual compensation of the future. Otherwise the future is worse off compared with the present.

Table 9.1 Adjusted Net National Product (gNNP) (billion yuan) (1980 prices)

year	GNP	NNP	gNNP (total rent)	gNNP (user cost)	ratio: gNNP/GNP (total rent)	ratio: gNNP/GNP (user cost)	total depreciation (total rent)	total depreciation (user cost)
1976	298.1	266.9	202.3	209.0	0.68	0.70	64.6	57.9
1977	325.6	301.9	227.5	244.6	0.70	0.75	74.4	57.3
1978	429.9	387.9	309.0	312.2	0.72	0.73	78.9	75.7
1979	475.1	430.5	340.8	338.4	0.72	0.71	89.7	92.1
1980	504.1	457.7	365.9	359.5	0.73	0.71	91.8	98.2
1981	552.3	517.1	395.6	396.3	0.72	0.72	121.5	120.8
1982	603.1	558.1	419.5	423.6	0.70	0.70	138.6	134.5
1983	651.3	593.6	458.1	464.8	0.70	0.71	135.5	128.8
1984	763.7	684.0	514.5	512.4	0.67	0.67	169.5	171.6
1985	851.8	760.4	582.1	576.2	0.68	0.68	178.3	184.2
1986	897.8	784.1	623.1	615.0	0.69	0.69	161.0	169.1
1987	958.3	850.6	688.0	688.6	0.72	0.72	162.6	162.0
1988	1095.7	929.5	760.3	759.2	0.69	0.69	169.2	170.3
1989	1136.5	1032.7	865.2	863.6	0.76	0.76	167.5	169.1
1990	1238.9	1128.2	904.0	891.4	0.73	0.72	224.2	236.8
1991	1318.3	1142.0	924.2	914.2	0.70	0.69	217.8	227.8
1992	1460.8	1460.8	*	*	*	*	214.9	228.8

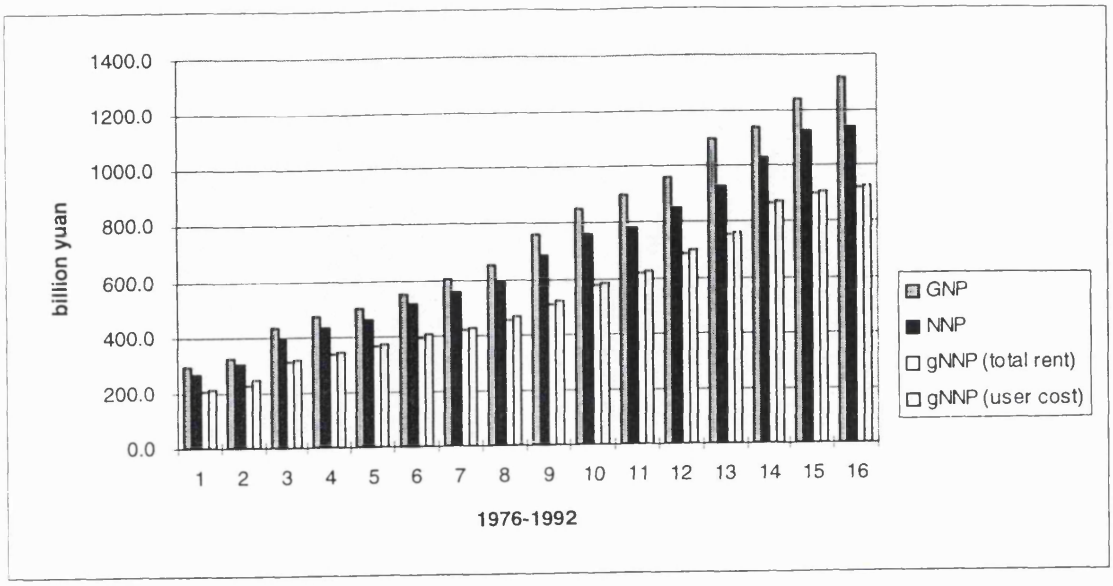
*Data are not available. Source: Calculated by the author.

Table 9.2 Depreciation and GNP (billion yuan)
(1980 prices)

year	total depreciation (total rent)	total depreciation (user cost)	GNP	depreciation/GNP (total rent)	depreciation/GNP (user cost)
1976	64.6	57.9	298.1	0.22	0.19
1977	74.4	57.3	325.6	0.23	0.18
1978	78.9	75.7	429.9	0.18	0.18
1979	89.7	92.1	475.1	0.19	0.19
1980	91.8	98.2	504.1	0.18	0.19
1981	121.5	120.8	552.3	0.22	0.22
1982	138.6	134.5	603.1	0.23	0.22
1983	135.5	128.8	651.3	0.21	0.20
1984	169.5	171.6	763.7	0.22	0.22
1985	178.3	184.2	851.8	0.21	0.22
1986	161.0	169.1	897.8	0.18	0.19
1987	162.6	162.0	958.3	0.17	0.17
1988	169.2	170.3	1095.7	0.15	0.16
1989	167.5	169.1	1136.5	0.15	0.15
1990	224.2	236.8	1238.9	0.18	0.19
1991	217.8	227.8	1318.3	0.17	0.17
1992	214.9	228.8	1460.8	0.15	0.16

Source: Calculated by the author.

Figure 9.3 GNP, NNP and gNNP



9.1.3 Net Investment and Sustainability

Net investment is the critical measure of weak sustainability for a country. Development is sustainable when the net investment is positive, otherwise it is unsustainable. Net investment is gross investment minus depreciation of man-made capital and natural capital. Weak sustainability is the criterion used in our study. Weak sustainability requires that the present generation passes on to the next generation an aggregate capital stock no less than the one that exists now. The measurements of sustainability using the user cost approach and the total rent approach are all negative. However, the figure of the negative net investment under the user cost approach is similar to that under the total rent approach. For example, in 1976, the total gross investment in the four sectors was 12.3 billion yuan, the total depreciation was 57.9 billion yuan by the user cost approach and the total depreciation was 64.6 billion yuan by the total rent approach. Thus, the net investment was -45.6 billion yuan by the user cost approach and -52.3 billion yuan by the total rent approach.

Table 9.3 Measuring Sustainability (billion yuan)

(1980 prices)

year	total depreciation (total rent)	total depreciation (user cost)	total investment	net investment (total rent)	net investment (user cost)
1976	64.6	57.9	12.3	-52.3	-45.6
1977	74.4	57.3	11.5	-62.9	-45.8
1978	78.9	75.7	17.7	-61.2	-58.0
1979	89.7	92.1	19.7	-70.0	-72.4
1980	91.8	98.2	21.1	-70.7	-77.1
1981	121.5	120.8	20.3	-101.2	-100.5
1982	138.6	134.5	20.9	-117.7	-113.6
1983	135.5	128.8	23.0	-112.5	-105.8
1984	169.5	171.6	26.7	-142.8	-144.9
1985	178.3	184.2	28.0	-150.3	-156.2
1986	161.0	169.1	27.9	-133.1	-141.2
1987	162.6	162.0	29.8	-132.8	-132.2
1988	169.2	170.3	31.8	-137.4	-138.5
1989	167.5	169.1	30.0	-137.5	-139.1
1990	224.2	236.8	29.5	-194.7	-207.3
1991	217.8	227.8	31.7	-186.1	-196.1
1992	214.9	228.8	35.0	-179.9	-193.8

Source: Calculated by the author.

Figure 9.4 Net Investment under Two Approaches

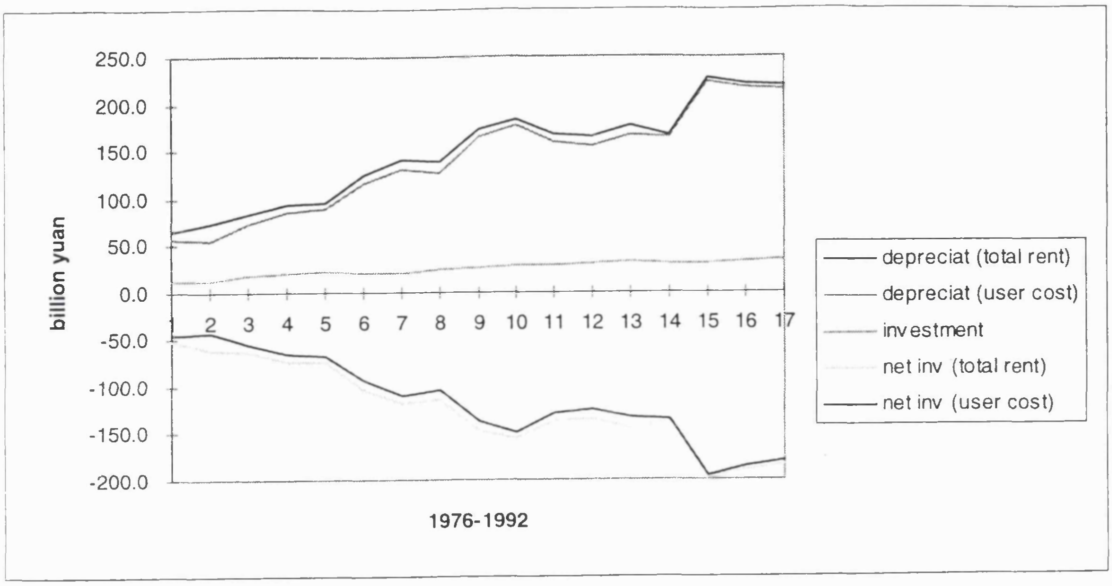


Table 9.3 shows that the country was not sustainable from 1976 to 1992 with respect to the calculation of the four sectors' depreciation. It is clear that the modern development process fails to meet human needs and often destroys or degrades the resource base. A pattern of human development that favours the rich and those of the current generation at the expense of the poor and those yet to be born is, by definition, unsustainable with respect to future generations. China is no exception to this. The high percentage of depreciation indicates that if China does invest enough to compensate for environmental consumption. The economic development will also be endangered by the severe degradation of the environment and the depletion of natural resources.

9.2 Analysis of the Forestry Sector

9.2.1 The Reason of Deforestation in China

The situation of deforestation have already been discussed in Chapter 3. Basically the reasons are population growth, market failure and intervention failure. These led to failure of sustainable management of the forestry sector, overexploitation of timber, poor investment in reforestation and plantation, agricultural reclamation, price distortion and population growth. We will discuss these reasons in the following sections.

Population Growth

In his famous paper "The Tragedy of the Commons", Hardin (1968) mentions that as the human population has increased, the commons have had to be abandoned in one aspect after another. Here "commons" represent nature and natural resources. He considers the emergence of the tragedy to be a consequence of increasing resource scarcity due to unrestrained population growth. Although we know that population growth is not the sole cause, it is linked with the degradation of the environment. Hardin recognises that air, water and many other environmental resources, unlike the traditional commons, cannot readily be fenced and parcelled out to private owners who would be motivated to preserve them.

The notion that a society's population growth progresses in three stages of the 'demographic transition' is well known. Phase I is primitive phase, marked by high mortality and short life expectancy. During Phase II the situation improves with high fertility and low mortality and eventually the fertility declines with economic growth. Phase III should be a stable population at a high living standard, which is supported by low birth and death rates, and a high life expectancy at birth.

If we check the world population situation, we find that more than half of the world's population has a real per capita income of less than $2000 (Baldwin 1994). The birth rate decreases with the increase of income. This means that further economic growth helps to reduce the birth rate. China's population accounts for 22 percent of the global population while its share of arable land is only 7 percent. The heavy burden of the population has not only brought food, housing and clothing pressure to the economy, but also serious environmental degradation. The growth of population has increased rapidly although China adopted the "one child" policy some fifteen years ago. In 1992, the total population in China was 1.2 billion. The huge population has consumed large quantities of natural resources and at the same time caused deterioration of the environment. More agricultural reclamation from forests and grasslands leads to desertification and soil erosion; desertification and soil erosion cause more natural disasters and a lower yield of crops; population growth is also the reason for the expanded consumption of timber in China.

Because 800 million people live in the rural areas, the growth of population and increase of density per square kilometre necessarily affects the environment negatively by transferring lands of natural vegetation, forest land, grass land, wet land and so on into agricultural land. This kind of reclamation is still going on. Furthermore, natural forests decrease year by year, grassland is destroyed by overgrazing, wetland disappears and many species become extinct. These phenomena have already occurred or are happening right now. The ecological environment has deteriorated sharply, soil erosion occurs all over the country, and draughts and floods arise frequently.

Population size and growth, therefore, is one of the main causes of deforestation in China. While control of the increase in population is necessary and vital to the survival of Chinese society, adequate polices and strategies should be adopted instead of the rigid 'one child' policy. These policies and strategies should include: raising the quality of the population by eliminating illiteracy, creating a sound pension system in the rural areas so as to encourage population control and developing highly efficient machinery for agriculture.

Pricing Problem - a Problem of Market Failure

Being an economy in transition, the pricing system in China is still not completely market-based. Prices of some goods have been liberalised while others are still under control. Some inputs to production are liberalised, but the prices of the final products are still controlled. This kind of price structure will not help to conserve forest resources. It is very difficult for loss-making enterprises to change the situation in the short-run. Timber produced within the government quota is still under price control, while timber outside of the quota is sold at market prices which are several times higher than the planned price. Thus, all forest bureaus try to log more in order to generate ex-quota income and illegal logging is also encouraged, this has been happening frequently in the Daxinganling forests.

The gap between the domestic prices and international prices would encourage people to continue logging forest resources because it is cheaper to get timber supply than import from the international market. Comparing the international prices and domestic prices, the domestic price level has been evidently too low. The following table shows the difference between the international prices and domestic prices.

Table 9.4 Comparison of Domestic and International Prices for Timber (yuan/m^3) (1980 prices)

year	domestic price (1)	international price (2)	price difference (3)	ratio (4)=(3)/(2)
1976	75.2	86.3	11.1	12.9
1977	74.4	96.8	22.4	23.1
1978	73.3	101.9	28.6	28.1
1979	71.9	133.2	61.3	46.0
1980	68.0	137.7	69.7	50.6
1981	91.7	139.1	37.4	26.9
1982	100.1	136.3	36.2	26.5
1983	102.1	120.1	18.0	15.0
1984	97.9	161.2	63.3	39.2
1985	94.7	162.3	67.6	41.6
1986	95.9	193.3	97.4	50.4
1987	115.8	205.3	89.5	43.6
1988	159.8	225.5	65.7	29.1
1989	146.0	219.2	73.2	33.4
1990	131.6	289.7	158.1	54.6

1991	142.3	284.1	141.8	49.9
1992	144.2	332.1	187.9	56.6

Source: calculated by the author.

Poor Management of Forest Resources - Governmental Failure

A sustainable management should allow the quantity of logging less than or equal to the growth rate of forest resources. China's reforestation and output of timber is as follows.

Table 9.5 Reduction of Timber Volume
(million cubic metres)

year	growth	reduction	net reduction
1976	275.3	390.4	115.1
1977	275.3	413.1	137.8
1978	275.3	330.6	55.3
1979	275.3	358.0	82.7
1980	275.3	342.4	67.1
1981	275.3	347.9	72.6
1982	329.5	432.5	103.0
1983	329.5	423.8	94.3
1984	329.5	421.6	92.2
1985	329.5	424.7	95.2
1986	329.5	439.5	110.1
1987	329.5	484.3	154.8
1988	329.5	421.4	50.9
1989	329.5	433.2	103.7
1990	329.5	417.2	87.7
1991	329.5	408.5	79.0
1992	329.5	405.6	76.1

Sources: adapted by the author from data in *Statistics of Forestry 1987-1992*, Beijing.

Although great efforts have been made for reforestation, according to the table above, there is still a net reduction of forest resources every year. This is mainly due to the management system of reforestation. According to Zhang (1993), the limited investment in reforestation, high timber output targets and profit targets force all forest farms in Xiaoxinganling to log more trees than are planted. In the area of Xiaoxinganling, the area of plantation is only 0.8 percent of the total forest area. In addition, all the good quality trees were logged out and some species vanished. In the previous section we showed that the net investment level measures the sustainability of the sector. In the forest sector 95 percent of the investment went to logging, only 5 percent went to plantation and reforestation (Yang *et al* 1993). Since 1979 the investment level reduced year by year. The investment in reforestation from 1985-1989 is shown below:

Table 9.6 Investment in Reforestation and Plantation

(million yuan)

year	investment in reforestation (current prices)	deflator (1980 price)	real investment (1980 prices)
1985	189.2	1.203	157.3
1986	171.3	1.251	136.9
1987	188.6	1.341	140.6
1988	195.6	1.452	134.7
1989	186.9	1.582	118.1

Source: Calculated by the author based on Yang *et al* (1993).

The management system is another problem. Economic reform in China has been carrying on for almost 20 years. However, the management of forestry is still under the old Soviet management regime. Plantation and reforestation should be considered as investment in forest management, but so far they are under the category of administration fees. Since they are administration fees, no one considers the costs and benefits of such an investment. So far there is no definite statistics to calculate investment results, such as, the area of plantation and reforestation per year and percentage of forest formation from plantation and reforestation. The forest farms are also faced with overemployment problems. According to Tao (1993), in Heilongjiang forest sector the employment quota should be 43512 people, but actual employment was 49353 people, 5841 people were "overemployed".

Property rights problems also lead to inefficient management. In principle all the forests belong to the state, thus there is no incentive for afforestation and reforestation. Forests which should be managed in a highly efficient way in order to maintain sustainable harvesting, are suffering from serious deforestation, and natural forests in China are disappearing. Property rights problems make the management consider only present income and present generations, leaving future generations to suffer from forest resource depletion.

9.2.2 Policy Implications

Population Control

The relationships between per capita income and demographics are not immutable. They may be affected by policy. The goal of policy should be twofold: firstly, to get the fertility curve down to a level closer to the death curve, and secondly, to get net investment surpassing the consumption of natural resources and the pollution abatement curve up to the incipient pollution curve.

Population growth is broadly considered to be the dominant cause of environmental degradation and overuse of natural resources. Rapid population growth is a formidable threat to sustainable development. Since a deteriorating environment induces poverty, population growth is linked to poverty through the environment. Reducing population growth will certainly reduce the environmental degradation and ease the consumption burden on natural resources. In the past two decades, China has adopted a compulsory 'one family, one child' policy. This policy functioned effectively at first, with the population growth rate falling from 2.5 percent in the early 1970s to 1.9 in the 1990s (*Statistical Yearbook of China 1993*). However, this policy does have some negative effects:

1) It puts the emphasis purely on the reduction of population growth, rather than educating people to bring about awareness of the importance of population control. 2) The compulsory population policy violates human willingness when people do not realise the importance of population control. 3) It is not effective in the rural areas, where people try all ways possible to have more than one child, and especially to have more male children[1]. From a long-term point of view, it is not a feasible policy for population control. The suggested alternative population policy has some negative aspects.

The right population policy should emphasise: a) raising educational level of the public, through better education, the old tradition of having more children can easily be broken down and women will have more freedom regarding birth control. b) reforming land tenure system and giving better agricultural policy establishing a secured social welfare system. c) establishing a secured social welfare system can help greatly in reducing population growth. There is no pension and retirement system, no health insurance, no work injury compensation and other social welfare in the rural area.

Sustainable Management for Forest Resources

Sustainable development for forests requires the harvesting of trees at a rate less than or equal to the growth rate of the biomass. What is being sustained is both the output and the resource in this instance. Failure to plan for sustainability results in disappearance of the resources in

[1]In China, traditionally only males are considered for inheritance of the family title, wealth and other properties. Males are also regarded as the main labour force for farming in the rural areas, where most people cannot afford to buy machines.

question, perhaps for some period while stocks are given a chance to regrow, or perhaps permanently if that chance is not given and stocks fall below the crucial threshold.

The management of forest resources involves several aspects: forest rotation, spacing and thinning, crop improvement, silviculture, mixed land use, taxes and subsidies from the government and forest valuation. This requires a comprehensive management strategy in operation. To assess timber values under sustainable production, the model described above was applied to the average forest class, assuming a certain period of years of minimum cutting cycle. The value of the harvest from the logged-over forests was calculated by discounting the relevant stumpage values by the factor $1/[(1 + r)^{cc-1}]$ to reflect the fact that the revenue would not be realised until the end of the cutting cycle. Here cc is the cutting cycle in years. A similar method was suggested by Solorzano *et al* (1992).

Here we discuss a quite useful formula for forest management. The sustainable value of an irregularly managed forest may be determined mathematically as an extension of the Faustmann formula of forest expectation value:

$$V_{SM} = CVO_1 \cdot SV + \frac{MAI \cdot cc \cdot SV - \sum C_j (1+i)^{(cc-j)}}{(1+i)^{cc} - 1} \tag{1}$$

where:

V_{SM} = value of forest under sustainable management

CVO_1 = marketable volume cut in first year of intervention

SV = stumpage value in year of harvest, which also equals stumpage value at time of future harvests if prices are constant

MAI = mean annual increment under intensive management

cc = cutting cycle in years

C_j = costs of forestry management in year j of the cutting cycle

i = interest rate

This formula implies that cycles start with a timber harvest and are repeated indefinitely. The formula represents the potential timber value of a natural forest. When a forest is cleared, national forest assets are decreased by depletion of both standing commercial timber and future harvests of valuable wood. The natural forest is generally capable of producing tradable products. Harvests do not mean to draw down forest capital in sustainable forest management. Ideally, only the annual growth should be harvested. On lands best suited to continuing forestry use, the stream of benefits would exceed that generated by any other use. Consequently, the total value of forest assets is best represented by the discounted net benefits obtained by managing the forest in a sustainable manner.

In China most forests are temperate forests with fewer species and longer growth periods than the tropical forests. Forests are usually best exploited by harvesting only when trees grow over a certain diameter, leaving the best of the rest as growth capital. This capital increases in volume at an annual rate (the mean annual increment), that depends on the site and the type of forest. Forest management generally involves reducing competition from other trees, liana, and epiphytes to give more valuable species room to grow.

For a sustainable management of a natural forest, starting with a previously unharvested forest, all trees larger than 50 cm (in China logging at 40 cm or below) could be logged in a harvest year, extracting those with commercial value. In the process, some damage is inevitable to the logged-over. Harvesting would be followed by forestry operations to increase the growth of the logged-over forest during a cutting cycle, whose length equals the ratio of the extracted volume plus damages to the average annual increment. During this interval, the forest regains its original volume and can once again be harvested. This pattern can be repeated indefinitely.

Over the next several decades China should not depend on domestic forests for its timber consumption since its timber resource is decreasing over time. A suitable timber policy consists of (a) a timber import strategy at least in the next decade; (b) timber substitution and saving policies; (c) more investment in reforestation and plantation. The present forest management institutions (mostly timber logging institutions) should turn to reforestation and afforestation. Some experience from other countries, such as Finland, can be used for forest management. Furthermore, reclamation in grasslands should be severely prohibited in order to at least keep the current areas of grasslands.

9.3 The Coal and Oil Sectors

9.3.1 Problems in the Coal and Oil Sectors

Energy Pricing Problem - Market Failure

We have discussed the problems of coal and oil in Chapters 5 and 6. Here we discuss reasons of these problems in the following sections.

The low prices of coal and oil in China encourage overconsumption of fossil resources since it is cheap to get these resources. Table 9.7 compares between the domestic prices and international prices for coal:

Table 9.7 Comparison of Domestic and International Prices of Coal (1980 prices)

year	Domestic price (yuan/tonne)	International price (yuan)	Price ratio % (DD/ID)
1976	18.6	88.9	20.9
1977	18.1	89.0	20.3
1978	17.8	90.2	19.7
1979	20.4	89.6	22.8
1980	21.3	85.2	25.0

1981	21.0	112.0	18.7
1982	21.0	121.3	17.3
1983	21.1	105.8	19.9
1984	20.8	127.1	16.3
1985	21.7	120.5	18.0
1986	21.2	133.4	15.9
1987	19.6	115.1	17.0
1988	28.9	126.8	22.8
1989	32.9	124.5	26.4
1990	32.4	159.5	20.3
1991	32.6	161.5	20.2
1992	33.7	159.9	21.1

Source: Author's calculations based on data from the Financial and Accounting Department of the Ministry of Coal Industry, Beijing.

The under valuation of fossil fuels in China and the subsidy system encourage massive exploitation of both high quality coal and oil resources. Under the dual pricing system, the prices for fossil fuels are below the opportunity cost and, thus there is a market failure. The correct fossil pricing policy in China should be to abolish the dual pricing system completely and let the market determine the price level. The difference between the domestic and international prices suggests that prices of coal and oil should be raised to the international level to avoid price distortion in the market.

Low Investment Level - Governmental Failure

Our analysis reveals that the coal and crude oil sectors have negative net 'genuine' investment. The negative net investment results in a decline of fossil fuel resources uncompensated for by investment in other resources. A population of 1.2 billion people requires enormous amounts of energy for heat and lighting. Coal in particular has been extracted widely. Although China has large reserves of coal, easily-mineable and good quality of coal has already been widely mined and investments do not keep up with the decline of coal stocks. And in the western part of China, where a large reserve of coal exists, coal has also been wasted because of transportation and pricing problems. China has very limited oil stocks. Most of the rich oil fields which are favourable to drilling, such as the Daqing and Keramy, have already been almost depleted. The rest of the limited oil fields are either difficult or very costly to drill. As investments do not keep up with consumption of natural resources, this will eventually lead to exhaustion of some natural resources and provide no compensation for future generations.

Property Rights

From an economic point of view, natural resource depletion in China is also closely linked with the common property problem. Some minerals in China are also considered as common property, thus, overextraction and low levels of investment have become common practice. Successful common property regimes are characterized by the existence of individual rights or well-defined local community rights. What varies among different types of property regimes is the scope of the primary decision-making unit. Control over natural resources consists of socially recognised and sanctioned rules and conventions that make it clear who is the 'owner' of the resource. Each owner will have certain interests in the management of that resource. The failure of environmental protection can also be traced to the property rights issue, in accordance with the points below:

1) Public property. The environment and natural resources are treated as public property, that is, anyone can use them and there is no licence on control. An example in China is coal. By definition, coal belongs to the state. However, with no specific management or controls on it and the lack of license system, anybody can access to mine and sell it, from individuals, town and villegeship enterprises to large and medium coal mines. In this sense, coal is treated as common property. This leads to a situation where natural resources are wasted, creating environmental problems.

2) Lack of Private Property Issue. In China's case all natural resources belong to the state or are common property. The lack of private property is also closely related to the environmental degradation problem. In a private property regime, owners choose to manage property well and to produce things which are valued by society. Private property is socially compelling as long as the general interests of the owner are in accordance with the interests of society. In the management of natural resources, private property regimes are recommended while some strengthening of the management of common property may also be a strategy worth considering.

9.3.2 Policy Implications

Price Reform

Ideally, pricing should include environmental costs. At least, prices could be raised to eliminate implicit subsidies. A policy of higher energy prices would be more effective in terms of reducing environmental pollution in China. Raising energy prices is likely to be superior to air pollution control.

Elimination of the dual pricing system is an important step in the reduction of natural resource consumption. As with certain other natural resources, timber prices are still not fully liberalised. For timber production within the quota, the price is fixed, otherwise, prices are determined by market demand. This kind of dual pricing system leads to timber consumption higher than the amount of forest growth each year and overconsumption of coal and oil. Reforming the pricing system or liberalisation of prices for timber, coal and oil will help to control the decline of natural forests and the overconsumption of fossil fuels. The concept of border prices should be used to judge whether prices of natural resources reflect their real value or not. This price policy combined with extensive establishment of market mechanisms can play an important role in environmental protection and natural resource conservation.

As China is not an oil-rich country, in the future coal will still be its main energy source. Given the large reservations of coal and an increasing demand for energy, coal cannot be replaced by any other energy resources. Comparing coal with oil stocks, in 1992 the proven stocks of coal are 366.7 billion tonnes and the oil reserves are only 3.2 billion tonnes. Coal reserves are over 100 times larger than oil reserves. Secondly, although theoretically there are 3.2 billion tonnes of oil reserves, these reserves are still to be proven and they are mostly located in the remote desert or ocean areas which are difficult to explore. Energy demand increases rapidly with the growth of the economy and the fast growth of the economy also requires high speed growth of energy production to meet its energy demand.

Management of The Coal and Oil Sectors

An approximation to the opportunity cost of coal is given by the unit price for the proportion of coal traded in the free domestic market. As pointed out earlier, energy subsidies are responsible for a significant part of the budget deficit. Insofar as this deficit means that coal and oil resources are limited and reduced, we can say that energy pricing has had a direct impact on the depletion of nonrenewable resources. Since air pollution from combustion of coal is a serious problem in China, energy pricing should at least set the price above the marginal cost of coal production.

Energy taxes may be another solution. The advantages of energy taxation are: reducing consumption of fossil fuels, increasing the value of fossil fuel and raising money for energy conservation and air pollution control.

Supporting technical innovation, technology transfer and adaptation can raise the quality of domestic equipment and processes and provide opportunities for adopting more advanced technology. Measures to conserve coal and improve its use are essential in order to reduce the energy intensity of the economy and the concomitant environmental impact. There are many technological solutions for improving coal utilisation, including: improving the transportation of coal, assuring the operating efficiency and technical quality of conventional industrial and utility boilers, upgrading domestic industrial plants and rationalising processes and energy use in existing industrial plants. Further exploration needs to be conducted to see which solutions are more feasible technically.

Finally, the coordination of energy and environmental policies and investment policies is an essential step for the coal and oil sectors in terms of reducing financial losses, improving efficiency of coal and oil production and consumption and reducing emissions of air pollution from coal combustion.

Privatisation

From the governmental side it is necessary: to raise the efficiency of energy production and consumption, to improve the environmental implications of forestry, grassland and agriculture; to constrain energy output in the face of expensive capital inputs; to modulate swings in forestry, husbandry and agricultural income, to reduce subsidies to the energy sector and to make pollution control more effective.

In the industrial sector, privatisation will help to reduce pollutants and to determine the level of environmental quality which is regarded as 'optimal'. A collective production or corporation share approach can be adopted initially. 'Share contracting' is the best way for privatisation. The gradual shift of fundamental rights would continue to favour individual ownership. Laws and regulations would extend to building, engineering, mining and other operations. Currently, over 50 percent of the state-owned enterprises in China have financial losses. Privatisation is the best solution for these enterprises both in terms of improving financial efficiency and in terms of the environment.

The process of shifting entitlements is consistent with the view of fairness. Constraints are initially introduced over actions where, because of shifting values, social costs are regarded as exceeding private benefits. However, compensation will be paid in the process of shifting property rights.

9.4 Air pollution

9.4.1 Reasons for Air Pollution

Market Failure

We have discussed the air pollution problem in China in Chapter 8. Basically air pollution comes from emissions of coal combustion. The implementation of pollution control is very poor in China.

Over the last 15 years China has developed a comprehensive set of environmental policies and laws, but the weakest part of the system is the implementation and enforcement of laws and regulations, slow price reform and the shortcomings of the current generation of environmental control mechanisms in coping with the rapid economic reform process. Among the trends that point towards a general strengthening of environmental laws and policies are the 1993 establishment of the Environment and Resources Protection Committee of National People's Congress, the current reformation of laws and policies initiated by this committee, the strong political commitment to the Agenda 21 process, price reforms which are gradually more far-reaching, particularly in the energy sector, and a growing acknowledgement of the need to strengthen enforcement routines.

Intervention Failure

The Environmental Protection Law (EPL 1989) is a basic law on environmental protection. Specific laws, such as the Law on Air Pollution and Prevention (1987), the Water Pollution Prevention and Control Law (1984), deal with specific subjects that are addressed more generally in the EPL. Other relevant statutes, such as those governing forestry, fisheries, grasslands, water and so on, are basic laws within their own spheres, but in terms of environmental protection they are specific laws subject to the EPL.

At the next level of authority come regulations, which are generally more technical and specific, and as such, more compelling to the individual actor than the statutes. Specific regulations for air pollution control are: The Detailed Enforcement Procedure of Air Pollution Prevention and Control (1991), The Provisional Method on Levy of Pollution Charges (1982), The Provisional Method on Special Funding Payable for Pollution Control (1988), The Provisional Method for Development of Briquettes for Household (1987), and the Management Regulation for TSP Control District in Urban Areas (1987).

With all of these environmental laws and regulations, the fundamental problem is enforcing them in practice. Because of the low pollution charges, enterprises have no incentive to control pollution. China published the Forest Law in 1984, which includes particular provisions for the control of forest logging. However, actually implementing these provisions is another matter. Local governments, especially those below county level, sometimes encourage logging in order to increase their income. A license for logging must be obtained before logging, nevertheless illegal logging and stealing from logged timber are quite frequent occurrences. The government encourages the use of briquettes for heating and cooking, yet loose coal is quite often used, especially in areas near coal mines. Thus weak enforcement is the basic problem here. This weakness manifests itself in the following areas: 1) there is no institution which can comprehensively supervise and control implementation of the regulations; 2) there is no serious penalty for violation of environmental regulations; 3) environmental laws and regulations resemble "paper tigers" and environmental degradation continues to take place even after laws and regulations are stipulated. Weak implementation and enforcement is one of the reasons for the environmental crisis in China.

9.4.2 Suggested Policies

Strengthening the implementation and enforcement of environmental laws and regulations is the most critical objective for air pollution control. The suggested policies on implementation include the following aspects:

1) Integration of environmental concerns into basic economic and industrial planning and activities, which is an overriding goal of the Agenda 21[2] process. An increasing awareness of the detrimental effects of the current underpricing of natural resources, and a beginning process of price reform, may also be seen as a reflection of efforts to take this principle on board.

2) Pollution prevention. Under this principle, facilities must meet minimum pollution prevention standards, comply with environmental impact assessments, and heavy polluters may be subject to forced relocation of industries.

3) Polluter responsibility. Under this principle, the government is authorised to collect pollution discharge fees for emissions violating standards, to require control or elimination of pollution within time limits, and to collect resource taxes and fees for resource extraction.

4) The fourth principle of public participation requires government agencies to issue periodic public bulletins on the state of the environment, and to provide various channels through which citizens can express their views on environmental issues.

9.4.3 Economic Instruments

Economic instruments have a potentially wide application in the field of environmental policy.

[2]Agenda 21 is written by the Environmental Protection Committee of the State Council in 1994. It contains the most important policies and strategies for environmental protection and natural resource conservation for the next century.

With these instruments, financial burdens are put on polluters, in some cases to the extent that these costs provide an incentive to reduce pollution. Traditionally, regulatory instruments have been used as the basic equipment for carrying out environmental policy, while economic instruments remained secondary to other instruments enabling a much more direct regulatory approach towards environmental degradation. The reduction of air pollution via economic instruments is expected to be one of the important strategies for the effective reduction of emissions and development of cleaner technologies. These aspects of flexibility and efficiency have frequently been put forward as features which make economic instruments preferable to the instruments of direct regulation.

As discussed above, "command and control" regulations are likely to be the basic framework for a long time to come. This conclusion is further reinforced by the fact that adverse environmental effects increase the necessity for strong, preventive policies. Positive contributions to the achievement of policy objectives, however, may be expected from economic instruments, in particular from emission charges and product charges, if the levels of the charges are high enough.

What appears to be most important in considering the values of economic instruments is an awareness of the gap between theory and practice. In some policy fields the regulatory approach seems to have reached the end of its possibilities. The combination of direct regulations and economic instruments may provide effective and efficient policy solutions.

Pollution charges, tradeable permits, energy taxes and deposit-refund systems are the most useful economic instruments in practice. The pollution charges are currently set at the price level of 1982 when the provisional method of pollution charges was published. The aim of pollution charges is to abate pollution emissions and improve environmental situation. However, since pollution charges are set lower than the cost of pollution control, most enterprises prefer to pay charges rather than to control pollution. The current pollution charges must be raised to a sufficient level to cover pollution control costs. As discussed previously, energy taxes should be introduced to reduce the consumption of fossil fuels. Deposit-refund systems should be considered for products or substances which can be reused or which should be returned for destruction.

9.5 Sustainable Environmental Policies

As Pearce (1993), Goldin and Winters (1994) and Pezzey (1995) mention, sustainable development is often defined as development that meets the needs of present generations without compromising the ability of future generations to meet their needs. The concept of needs is one of the most complex in economics, and to impose it in the definition of sustainability is to render intractable an already complex definition. Sustainable development is concerned with the interaction of economic policies, growth and the environment. Dasgupta and Heal (1979), Pearce and Turner (1990), and others have sought to demonstrate that the development of appropriate incentives and regulatory structures is not only compatible with sustainable development, but is essential for it.

A number of studies by Krueger, Schiff and Valdes (1991), Goldin and Winters (1992) and Goldin (1994) have shown that macroeconomic policies may be more important than sectoral policies. They suggest that economy-wide policy distortions may have a significant impact on the environment. *The World Development Report* (World Bank 1992) highlights the need to pay greater attention to the economy-wide dimension and such analyses are likely to become ever more frequent as the demand for greater sustainability in economic policies increase.

A broadly defined proper environmental policy is vital to sustainable development and the conservation of the natural environment. Current activities involving the environment and natural resources are not sustainable because of their negative impact on critical natural resources. The changes in land use and management over the past decades have increased pollution and have been one of the major contributors to natural disasters, i.e. loss of biodiversity, soil erosion, desertification and so on.

The environment is much more important than any other sector in maintaining sustainable development. Efficient management of the environment requires a system consisting of proper policy mechanisms, funding and technology; as Scott (1994) notes, more investment is needed if per capita income is to grow, but the greater its efficiency, the less should be needed. Experience suggests that, for much investment, decentralised decision-making coordinated by the market, with a system of private property which allows the investor to keep an appreciable part of the gains, results in sustainable development. This has proved to be more efficient, and more sustainable, than attempts by the government to control most investment. If the policy is to reduce impact on the environment and bring about sustainability, the environmental policy signals must be revised, along with the whole emphasis of land use policy. The necessary policies on the environment and on sustainability include: increased intensity of input use for present industrial and agricultural production; price reform of inputs and outputs to increase market mechanisms; direct income support for enhanced conservation practices; and reduction of the use of fossil fuels. On the basis of our studies of China's environmental problems, we propose the following:

1. It is essential to establish a national level environmental authority, embracing all aspects of the environment. This will take on both the role of the present state environmental agency (which is only responsible for pollution control), and roles from other ministries, such as forestry, agriculture, water conservation and so on. It will control, monitor and observe all environmental problems, deforestation, destruction of grassland, soil erosion, water conservation, air and water pollution, etc..

2. A more detailed and plenary survey in addition to research should be carried out by the designated authority to study, observe and analyze environmental issues. The economic valuation of environmental losses would be an important part of all the research. From the results an appropriate plan of action can be formulated, and actions and strategies eventually put into effect.

3. China must invest more in forestry, energy and air pollution control as well as other sectors which are not evaluated in this research. The minimum investment level is to show a positive net investment if consumption and environmental damage does not decrease. On the other hand, the consumption levels of forest, coal and oil should be reduced through proper policies on pricing, management and distribution.

4. Recognising the negative effects of environmental damage is very important. The government should try to create public awareness in this area. China ought to send more students and professionals abroad to be trained in environmental fields: such as ecology, water conservation and treatment, environmental economics, etc.. It is very important for them to absorb the contemporary ideas and methodologies of environmental management. Finally, it would be helpful if international organisations and foundations were to finance more environmentally related projects in China.

9.6 Concluding Remarks

In this chapter we estimated the overall depreciation in the "green" net national accounts using the total rent approach and the user cost approach. The environmental depreciation turns out to be very high, according to the calculation of the depreciation for only 4 sectors. Environmental degradation ranges from 15 percent to over 20 percent of the GNP on both approaches. The net investment is always negative in the period 1976-1992. This situation demonstrates that China is not in a situation of sustainable development.

The causes of environmental degradation were analyzed and illustrated in the chapter. Like most centrally planned economies, China does not pay sufficient attention to environmental issues. Rapid population growth is another problem causing deterioration of the environment. Missing property rights and a distorted pricing system facilitate environmental degradation and the decline of natural resources.

A policy framework for attaining sustainable development was discussed here in terms of sectors on sustainable development, population control, privatisation, price reform and implementation of laws and regulations. Specific sectoral policies were also addressed in this chapter.

Appendix 9.1 Measuring Sustainability of China (user cost) (billion yuan)

year	investment (forest)	investment (coal)	investment (oil)	investment (air pollution)	total investment	depreciation (forest)	depreciation (coal)	depreciation (oil)	depreciation (air pollution)	total depreciation
1976	7.6	2.1	2.6	0.0	12.3	1.3	34.4	6.1	17.9	59.7
1977	6.5	2.4	2.6	0.0	11.5	1.5	39.1	6.9	18.7	66.2
1978	9.2	3.6	4.8	0.1	17.7	1.4	44.8	7.0	19.5	72.7
1979	12.4	3.4	3.8	0.2	19.7	1.7	47.0	7.3	20.3	76.3
1980	13.8	3.5	3.6	0.2	21.1	2.0	44.1	7.0	21.1	74.2
1981	13.1	2.4	4.6	0.3	20.3	2.3	57.7	6.2	21.9	88.1
1982	11.5	3.1	6.0	0.3	20.9	2.7	67.9	5.8	23.4	99.8
1983	11.5	4.1	7.1	0.4	23.0	2.8	62.2	5.8	25.4	96.2
1984	12.1	5.5	8.6	0.5	26.7	2.9	86.0	8.7	25.0	122.6
1985	11.5	5.1	10.8	0.6	28.0	2.9	89.3	9.8	25.3	127.3
1986	11.0	5.1	11.0	0.8	27.9	2.6	102.4	9.6	25.8	140.5
1987	11.6	4.9	12.4	0.9	29.8	2.2	89.4	12.4	27.7	131.7
1988	12.5	4.7	13.6	1.0	31.8	1.9	105.0	9.8	31.0	147.7
1989	9.7	4.6	14.7	1.0	30.0	1.2	107.7	8.8	32.4	150.1
1990	9.2	5.7	13.7	0.9	29.5	1.7	146.0	11.4	29.9	189.0
1991	9.8	6.5	14.5	0.9	31.7	1.5	148.4	11.4	30.7	192.0
1992	10.2	7.0	16.8	1.0	35.0	1.6	148.7	13.5	31.5	195.3

Source: Calculated by the author.

Appendix 9.2 Measuring Sustainability of China (total rent) (billion yuan)

year	forest	coal	oil	air poll	total investment	forest	coal	oil	air pollution	total depreciation
1976	7.6	2.1	2.6	0.0	12.3	4.3	33.9	8.5	17.9	64.6
1977	6.5	2.4	2.6	0.0	11.5	5.1	39.0	11.6	18.7	74.4
1978	9.2	3.6	4.8	0.1	17.7	2.0	44.9	12.5	19.5	78.9
1979	12.4	3.4	3.8	0.2	19.7	3.0	44.9	21.5	20.3	89.7
1980	13.8	3.5	3.6	0.2	21.1	2.3	40.4	28.0	21.1	91.8
1981	13.1	2.4	4.6	0.3	20.3	3.3	56.5	39.8	21.9	121.5
1982	11.5	3.1	6.0	0.3	20.9	5.2	66.5	43.5	23.4	138.6
1983	11.5	4.1	7.1	0.4	23.0	5.0	60.3	44.8	25.4	135.5
1984	12.1	5.5	8.6	0.5	26.7	4.6	83.5	56.4	25.0	169.5
1985	11.5	5.1	10.8	0.6	28.0	4.8	83.9	64.3	25.3	178.3
1986	11.0	5.1	11.0	0.8	27.9	5.3	96.1	33.8	25.8	161.0
1987	11.6	4.9	12.4	0.9	29.8	9.6	83.3	42.0	27.7	162.6
1988	12.5	4.7	13.6	1.0	31.8	5.0	97.3	35.9	31.0	169.2
1989	9.7	4.6	14.7	1.0	30.0	8.3	95.6	31.2	32.4	167.5
1990	9.2	5.7	13.7	0.9	29.5	5.8	134.5	54.0	29.9	224.2
1991	9.8	6.5	14.5	0.9	31.7	6.1	135.9	45.1	30.7	217.8
1992	10.2	7.0	16.8	1.0	35.0	5.7	133.8	43.9	31.5	214.9

Source: Calculated by the author.

Appendix 9.3 Depreciation of 4 Sectors
(user cost)
(billion yuan) (1980 prices)

year	depreciation				total depreciation
	forest	coal	oil	air pollution	
1976	2.3	34.2	3.5	17.9	57.9
1977	3.7	28.8	6.1	18.7	57.3
1978	4.6	44.3	7.3	19.5	75.7
1979	9.2	46.3	16.3	20.3	92.1
1980	10.7	43.3	23.1	21.1	98.2
1981	7.5	56.6	34.8	21.9	120.8
1982	6.4	66.4	38.3	23.4	134.5
1983	4.5	60.3	38.6	25.4	128.8
1984	10.1	83.6	52.9	25.0	171.6
1985	10.4	86.7	61.8	25.3	184.2
1986	13.8	99.4	30.1	25.8	169.1
1987	10.0	86.2	38.1	27.7	162.0
1988	6.3	101.5	31.5	31.0	170.3
1989	5.9	104.1	26.7	32.4	169.1
1990	13.5	141.9	51.5	29.9	236.8
1991	10.8	143.8	42.5	30.7	227.8
1992	14.8	143.5	39.0	31.5	228.8

Source: Calculated by the author.

Appendix 9.4 Depreciation of 4 Sectors
(total rent)*
(billion yuan) (1980 prices)

year	depreciation				total depreciation
	forest	coal	oil	air pollution	
1976	4.3	33.9	8.5	17.9	64.6
1977	5.1	39.0	11.6	18.7	74.4
1978	2.0	44.9	12.5	19.5	78.9
1979	3.0	44.9	21.5	20.3	89.7
1980	2.3	40.4	28.0	21.1	91.8

1981	3.3	56.5	39.8	21.9	121.5
1982	5.2	66.5	43.5	23.4	138.6
1983	5.0	60.3	44.8	25.4	135.5
1984	4.6	83.5	56.4	25.0	169.5
1985	4.8	83.9	64.3	25.3	178.3
1986	5.3	96.1	33.8	25.8	161.0
1987	9.6	83.3	42.0	27.7	162.6
1988	5.0	97.3	35.9	31.0	169.2
1989	8.3	95.6	31.2	32.4	167.5
1990	5.8	134.5	54.0	29.9	224.2
1991	6.1	135.9	45.1	30.7	217.8
1992	5.7	133.8	43.9	31.5	214.9

* Depreciation from the net price approach for forest is used here.

Appendix 9.5 Depreciation and GNP (at 1992 prices)
(user cost)(billionyuan)

year	GNP	forest	coal	oil	air pollution	total depreciation	gNNP	depreciation/GNP	deflator
1976	159.5	1.1	18.4	3.3	9.6	30.9	128.5	0.19	0.484
1977	174.2	1.8	20.9	3.7	10.0	30.5	143.5	0.18	0.489
1978	230.0	2.3	24.0	3.7	10.4	40.3	189.5	0.18	0.496
1979	254.2	4.7	25.1	3.9	10.9	49.0	204.9	0.19	0.506
1980	269.7	5.7	23.6	3.7	11.3	52.5	217.2	0.19	0.535
1981	295.5	4.1	30.9	3.3	11.7	64.7	230.9	0.22	0.546
1982	322.6	3.5	36.3	3.1	12.5	72.1	250.7	0.22	0.550
1983	348.4	2.5	33.3	3.1	13.6	69.0	279.5	0.20	0.556
1984	408.6	5.9	46.0	4.7	13.4	92.3	316.8	0.23	0.586
1985	455.7	6.7	47.8	5.3	13.5	99.7	357.1	0.22	0.644
1986	480.3	9.2	54.8	5.1	13.8	92.3	389.8	0.19	0.670
1987	512.7	7.2	47.8	6.6	14.8	88.5	426.0	0.17	0.718
1988	586.2	4.9	56.2	5.3	16.6	92.6	495.1	0.16	0.777
1989	608.0	5.0	57.6	4.7	17.3	92.3	517.5	0.15	0.847
1990	662.8	12.2	78.1	6.1	16.0	131.6	536.1	0.20	0.901
1991	705.3	10.3	79.4	6.1	16.4	126.4	583.4	0.18	0.952
1992	781.5	14.8	79.6	7.2	16.9	129.3	659.1	0.17	1.000

Source: calculated by the author.

Appendix 9.6 Depreciations and GNP (at 1992 prices)
(total rent)
(billion yuan)

year	GNP	forest	coal	oil	air pollution	total depreciation	gNNP	depreciation/GNP	deflator
1976	159.5	2.3	18.1	4.5	9.6	34.6	124.9	0.22	0.484
1977	174.2	2.7	20.9	6.2	10.0	39.8	134.4	0.23	0.489
1978	230.0	1.1	24.0	6.7	10.4	42.2	187.8	0.18	0.496
1979	254.2	1.6	24.0	11.5	10.9	48.0	206.2	0.19	0.506
1980	269.7	1.2	21.6	15.0	11.3	49.1	220.6	0.18	0.535
1981	295.5	1.8	30.2	21.3	11.7	65.0	230.5	0.22	0.546
1982	322.6	2.8	35.6	23.3	12.5	74.2	248.5	0.23	0.550
1983	348.4	2.7	32.3	24.0	13.6	72.5	276.0	0.21	0.556
1984	408.6	2.5	44.7	30.2	13.4	90.7	317.9	0.22	0.586
1985	455.7	2.6	44.9	34.4	13.5	95.4	360.3	0.21	0.644
1986	480.3	2.8	51.4	18.1	13.8	86.1	394.2	0.18	0.670
1987	512.7	5.1	44.6	22.5	14.8	87.0	425.7	0.17	0.718
1988	586.2	2.7	52.1	19.2	16.6	90.5	495.7	0.15	0.777
1989	608.0	4.4	51.1	16.7	17.3	89.6	518.4	0.15	0.847
1990	662.8	3.1	72.0	28.9	16.0	119.9	542.9	0.18	0.901
1991	705.3	3.3	72.7	24.1	16.4	116.5	588.8	0.17	0.952
1992	781.5	3.0	71.6	23.5	16.9	115.0	666.5	0.15	1.000

Source: calculated by the author.

Chapter 10

Conclusions

10.1 Summary of The Thesis

This thesis dealt with deriving the "green" net national product (gNNP) in China. In Chapter 2 we discussed the evolution of the gNNP. A summary of theoretical contributions to the gNNP was given. We focused on discussion of Hartwick's model on deriving gNNP and some other models related to Hartwick's model. We proposed three approaches to deriving the gNNP: the net price approach, the total rent approach and the user cost approach. The net price approach calculates changes in natural resources. The total rent approach is the unit cost times the total quantity extracted, and the user cost approach uses El Serafy's approach.

In Chapter 3, we started by reviewing the forest situation in China. China is a forest deficit nation in ecological, economic and social terms and currently has a serious timber shortage. The main natural forests have been greatly diminished, timber reserves have dropped, the quality of forests has decreased and forest reserves cannot withstand ten years of consumption. China has officially reported a rise in timber production over the years to just 60 million cubic metres. But its annual consumption of timber reached 344 million cubic metres. The causes of deforestation are mostly similar to the those discussed in Brown and Pearce (1994), such as agricultural conversion; another reason is the demand of timber consumption. Considering the intergenerational issue of property inheritance, including natural resources, the misuse of forest resources in China has declined natural forest resources and will be worse for the next generation if no action is taken. It is, therefore, absolutely crucial for China to determine a long-term strategy for conservation of its forest resources and proper consumption of its very limited timber reserves.

In Chapter 4 we calculated stumpage value, forest depreciation and "green" forestry output using the net price approach and the user cost approach. It is clear that the depreciation of forest resources accounts for a high percentage of the gross product of the forest sector. It also turns out to be significant to the overall GNP since the depreciation from both approaches is shown to be less than 1 or about 1 percent of GNP. The sustainability of the forestry sector was evaluated. The estimation indicated that there was a loss in forest resources, especially in timber forests. The loss was also reflected in the forest-adjusted-NNP with depreciation of forest capital. The overall investment level in the forestry sector did not come out high enough, with forest depreciation taken into account. The forestry sector must keep the present level of investment to maintain sustainable development. The depreciation in the main timber production regions confirmed our statement that there was a serious decline in timber forests in China. This analysis points to a serious situation and hence we examined the causes of declining forest resources in a later chapter, proposing certain policies to restore sustainable development to the forestry sector in China.

In Chapter 5, coal reserves, production and pricing problems were discussed. The coal industry has problems of low productivity and low efficiency. The multi-tiered pricing system has brought chaos to the Chinese coal market. Coal pricing is the main problem in the sector. Given large subsidies from the government, the sector still incurred financial losses. The chaos in prices should be eased by reforming the pricing system towards market pricing; the dual pricing system should therefore be abandoned in order to price coal in a more rational way. Coal-adjusted national accounts were calculated, using three approaches. The first of these is the net price approach, under which we find the figures of depletion unreliable because they are erratic. Secondly we applied the total rent approach. This approach is stable and its depreciation reached about 10 percent of GNP. Thirdly we tried the user cost approach. The depletion derived using this approach at zero percent discount rate is similar to the total rent approach, because theoretically they are also comparable. However, at 5 and 10 percent discount, the user cost just shows zero depreciation of coal. This indicates two things: a) for the very large stocks of natural resources, a higher discount rate cannot reflect its current depletion. b) Since higher discount rates are used only for the purposes of future investment, we suggest using zero percent of discount rate only for calculating national accounts.

The coal-adjusted accounts show that the net investment of the sector is negative at all times from 1976 to 1992 under the total rent approach and the user cost approach. This generally indicates that the sector was not in sustainable development. The net investment under the two approaches further reveals that the negative net investment. This implies that in the whole period, China was not in sustainable development with respect to the coal industry, and must invest more to keep the coal sector sustainable.

In Chapter 6, we discussed the oil situation in China. China is not an oil rich country, having limited reserves. Its production increased steadily from 1976 to 1992, however, discoveries of oil did not keep pace with production. The pricing system was set up in 1957, with little change until 1980. The centrally planned price is lower than the production cost, and each year the oil sector receives subsidies from the government. The financial and economic subsidies were calculated, the results showing that the correct pricing system should be the international price level. Starting in 1981, the government introduced the dual pricing system in order to raise oil production and investment funds. This dual pricing system probably has its historical reasons, but it seems also to have many disadvantages, providing scant incentive to raise funds, creating opportunities for speculation on the oil market, promoting corruption in dealing with oil sales, encouraging small scale refineries with low efficiencies and, as a result, wasting oil resources. The only solution is to open the market and let supply and demand guide prices.

Here we again calculated oil accounts, using three approaches: the net price approach, the total rent approach and the user cost approach. The net price approach is not stable in the calculation, although the stocks of oil are not very large and the depletion period is short. The results calculated from this approach are basically unacceptable. The results of the total rent approach are stable and show the considerable depreciation of the oil resources in China. We also calculated the user cost approach. for this approach we believe the results are also stable although less so than the total rent approach.

The depreciation of oil to GNP, NNP and the gross output value of oil was worked out using the total rent approach and the user cost approach. The results from the two approaches are stable. The user cost approach shows that the higher the discount rate, the higher the sustainable income, but the lower the depreciation to the natural capital. Sustainability of development was also measured by deriving the net investment in the oil industry. From the calculation, we see that while the net investment on the total rent approach is negative for all the years from 1976 to 1992, the net investment from the user cost approach still shows positive net investment for certain years. The ratios of depreciation to the gross national product and the gross product of the oil industry were derived. The negative net investment reveals the unsustainable development of the oil industry, and China should therefore invest more in it.

In Chapter 7 We discussed subsidies to energy sector in China. Starting from 1981 the coal sector receives subsidies from the central government and the oil sector also receives subsidies since 1987. The main reason for this kind of finanacial subsidies is due to the low planned prices, which have been set below the production costs. In this chapter we only estimated subsidies for crude oil and because of data we did estimate subsidies to petroleum products.

In Chapter 8 we discussed the air pollution situation in China. Our overview shows clearly that China is a country suffering from serious air pollution. Although China spends a certain amount of money on environmental protection, this still falls far below the amount required for sustainable air pollution control. The economic damage and social cost of air pollution were calculated. A dose-response function was employed in order to derive the monetary values of air pollution damage. The DRF was used to derive health damage in terms of mortality and morbidity from TSP and SO_2. The method is applicable to the estimation of mortality from air pollution. Because of a shortage of data on morbidity, we applied Rowe *et al*'s coefficients of DRFs for estimating morbidity cases as a first approximation.

Finally, we estimated the total losses due to air pollution damage. Air pollution damage accounts for 2-3 percent in the lower bound, 3-5 percent in the central bound and around 7-8 in the upper bound of the GNP per year from 1981 to 1990. This is not surprising in a country which uses coal as its main energy source, spending little on pollution control in case of heavy urban pollution. If China intends to maintain sustainable development, it should invest at least 2 percent (the lower bound) of its GNP in air pollution control.

In Chapter 9 we estimated the overall depreciation in the "green" net national accounts using the total rent approach and the user cost approach. The environmental depreciation is very high according to the calculation for only 4 sectors. Environmental degradation ranges from 15 percent to over 20 percent of GNP on both approaches. The net investment is always negative during 1976-1992. This situation demonstrates that China is not in a situation of sustainable development. The causes of environmental degradation are analyzed and illustrated in the chapter. Like most centrally planned economies, China pays little attention to environmental issues. Rapid population growth is another cause of deterioration in the environment. Missing property rights and a distorted pricing system facilitate environmental degradation and the decline of natural resources.

A policy framework for attaining sustainable development was discussed in terms of sustainable development, population control, privatisation, price reform and implementation of laws and regulations. The specific sectoral policies were also addressed in this chapter.

10.2 Contribution of This Thesis

gNNP is considered to be correct measure of environmental damage and natural resource depletion. The deduction of economic depreciation from the original GNP is the crucial step in measuring the real income of an economy. This thesis offers a number of important contribution to the field of calculating gNNP. The main contribution of this thesis is that it is the first true 'green accounts' in any form that have been estimated for China.

Data collection and compilation are also a contribution of the thesis. Although some of them are the official statistics, it is difficult to get these statistics in public libraries. In order to get these statistics, we visited many institutions repeatedly, used every channel to establish connections with people from these institutions, collected information on how and where we could get these data and spent some costs in obtaining the data. Thus, the field work was divided into four parts: 1) visiting institutions and departments concerned to get some official statistics; 2) visiting some places to get non-statistical data; 3) visiting libraries and information centres to get more references; 4) visiting various publishers and professional book stores to get published statistics. In the total 6 months data collection period, we visited two largest forests in China: Daxinganling forest and Changbaishan forest. We visited City Jinan of Shandong Province for data collection of air pollution. We also visited various government departments for data collection work.

The data have been processed and adjusted for the purpose of research. The data have been adjusted in terms of prices, costs, inflation factors and exchange rate factors. For forest resources, we calculated the stocks of natural forests, the volume of fire and insect damage based on some statistics. We also adjusted prices and costs of timer production. For coal and oil, we mainly focused on getting production costs and adjusted them. For air pollution, we found out pollution sources in Jinan city and adjusted concentration of pollutants. Thus, we have unified data for forestry, coal and oil from 1976-1992 and unified data for air pollution from 1981-1990. This first hand data are not only useful for this research but will also be useful for anybody in the future researches.

This thesis is one of the pioneering works which calculating the economic depreciation of environmental damage and natural resource depletion in four sectors in China. These four sectors represent the main environmental and natural resource sectors in China, and it is therefore significant to calculate economic depreciation for them.

The research has tested and developed a series of approaches both in theory and in empirical study. These three approaches: the net price approach, the total rent approach and the user cost approach have been all applied. We have also examined the advantages and disadvantages in applying these approaches.

The research has for the first time systematically collected and adjusted data for four sectors in China. The data are very relevant not only to this particular work but also to other research. The assessment of sustainability of four sectors in China reveals the seriousness of environmental damage and natural resource degradation in China, and indicates that China is a long way from sustainable development at present. The policy discussion provides a comprehensive framework for the sustainable development in China.

10.3 Further Research

In concluding this thesis, let us also consider further research for the future. Theoretically, we are considering the development of a social loss function between economic development and the environment. An optimal path should be found to show the trade-off between economic development and the environment. Elasticity of substitution between the man-made capital and the natural capital should also be further studied in calculating environmental damage. We also realise that measuring economic income is not equal to measuring sustainability, thus some further exploration into deriving a model for measuring sustainability must be undertaken in the future. The non-linear model and differentiation equations should be used in this further research.

Empirically, further analysis on other sectors should also be carried out. These sectors consist of water, grassland, soil, solid waste, natural hazards and so on. Further research should also measure environmental degradation to the global environment. For example, the greenhouse effect and the depletion of the ozone layer caused by China's pollution of the environment.

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Chapter 10

Conclusions

10.1 Summary of The Thesis

This thesis dealt with deriving the "green" net national product (gNNP) in China. In Chapter 2 we discussed the evolution of the gNNP. A summary of theoretical contributions to the gNNP was given. We focused on discussion of Hartwick's model on deriving gNNP and some other models related to Hartwick's model. We proposed three approaches to deriving the gNNP: the net price approach, the total rent approach and the user cost approach. The net price approach calculates changes in natural resources. The total rent approach is the unit cost times the total quantity extracted, and the user cost approach uses El Serafy's approach.

In Chapter 3, we started by reviewing the forest situation in China. China is a forest deficit nation in ecological, economic and social terms and currently has a serious timber shortage. The main natural forests have been greatly diminished, timber reserves have dropped, the quality of forests has decreased and forest reserves cannot withstand ten years of consumption. China has officially reported a rise in timber production over the years to just 60 million cubic metres. But its annual consumption of timber reached 344 million cubic metres. The causes of deforestation are mostly similar to the those discussed in Brown and Pearce (1994), such as agricultural conversion; another reason is the demand of timber consumption. Considering the intergenerational issue of property inheritance, including natural resources, the misuse of forest resources in China has declined natural forest resources and will be worse for the next generation if no action is taken. It is, therefore, absolutely crucial for China to determine a long-term strategy for conservation of its forest resources and proper consumption of its very limited timber reserves.

In Chapter 4 we calculated stumpage value, forest depreciation and "green" forestry output using the net price approach and the user cost approach. It is clear that the depreciation of forest resources accounts for a high percentage of the gross product of the forest sector. It also turns out to be significant to the overall GNP since the depreciation from both approaches is shown to be less than 1 or about 1 percent of GNP. The sustainability of the forestry sector was evaluated. The estimation indicated that there was a loss in forest resources, especially in timber forests. The loss was also reflected in the forest-adjusted-NNP with depreciation of forest capital. The overall investment level in the forestry sector did not come out high enough, with forest depreciation taken into account. The forestry sector must keep the present level of investment to maintain sustainable development. The depreciation in the main timber production regions confirmed our statement that there was a serious decline in timber forests in China. This analysis points to a serious situation and hence we examined the causes of declining forest resources in a later chapter, proposing certain policies to restore sustainable development to the forestry sector in China.

In Chapter 5, coal reserves, production and pricing problems were discussed. The coal industry has problems of low productivity and low efficiency. The multi-tiered pricing system has brought chaos to the Chinese coal market. Coal pricing is the main problem in the sector. Given large subsidies from the government, the sector still incurred financial losses. The chaos in prices should be eased by reforming the pricing system towards market pricing; the dual pricing system should therefore be abandoned in order to price coal in a more rational way. Coal-adjusted national accounts were calculated, using three approaches. The first of these is the net price approach, under which we find the figures of depletion unreliable because they are erratic. Secondly we applied the total rent approach. This approach is stable and its depreciation reached about 10 percent of GNP. Thirdly we tried the user cost approach. The depletion derived using this approach at zero percent discount rate is similar to the total rent approach, because theoretically they are also comparable. However, at 5 and 10 percent discount, the user cost just shows zero depreciation of coal. This indicates two things: a) for the very large stocks of natural resources, a higher discount rate cannot reflect its current depletion. b) Since higher discount rates are used only for the purposes of future investment, we suggest using zero percent of discount rate only for calculating national accounts.

The coal-adjusted accounts show that the net investment of the sector is negative at all times from 1976 to 1992 under the total rent approach and the user cost approach. This generally indicates that the sector was not in sustainable development. The net investment under the two approaches further reveals that the negative net investment. This implies that in the whole period, China was not in sustainable development with respect to the coal industry, and must invest more to keep the coal sector sustainable.

In Chapter 6, we discussed the oil situation in China. China is not an oil rich country, having limited reserves. Its production increased steadily from 1976 to 1992, however, discoveries of oil did not keep pace with production. The pricing system was set up in 1957, with little change until 1980. The centrally planned price is lower than the production cost, and each year the oil sector receives subsidies from the government. The financial and economic subsidies were calculated, the results showing that the correct pricing system should be the international price level. Starting in 1981, the government introduced the dual pricing system in order to raise oil production and investment funds. This dual pricing system probably has its historical reasons, but it seems also to have many disadvantages, providing scant incentive to raise funds, creating opportunities for speculation on the oil market, promoting corruption in dealing with oil sales, encouraging small scale refineries with low efficiencies and, as a result, wasting oil resources. The only solution is to open the market and let supply and demand guide prices.

Here we again calculated oil accounts, using three approaches: the net price approach, the total rent approach and the user cost approach. The net price approach is not stable in the calculation, although the stocks of oil are not very large and the depletion period is short. The results calculated from this approach are basically unacceptable. The results of the total rent approach are stable and show the considerable depreciation of the oil resources in China. We also calculated the user cost approach. for this approach we believe the results are also stable although less so than the total rent approach.

The depreciation of oil to GNP, NNP and the gross output value of oil was worked out using the total rent approach and the user cost approach. The results from the two approaches are stable. The user cost approach shows that the higher the discount rate, the higher the sustainable income, but the lower the depreciation to the natural capital. Sustainability of development was also measured by deriving the net investment in the oil industry. From the calculation, we see that while the net investment on the total rent approach is negative for all the years from 1976 to 1992, the net investment from the user cost approach still shows positive net investment for certain years. The ratios of depreciation to the gross national product and the gross product of the oil industry were derived. The negative net investment reveals the unsustainable development of the oil industry, and China should therefore invest more in it.

In Chapter 7 We discussed subsidies to energy sector in China. Starting from 1981 the coal sector receives subsidies from the central government and the oil sector also receives subsidies since 1987. The main reason for this kind of finanacial subsidies is due to the low planned prices, which have been set below the production costs. In this chapter we only estimated subsidies for crude oil and because of data we did estimate subsidies to petroleum products.

In Chapter 8 we discussed the air pollution situation in China. Our overview shows clearly that China is a country suffering from serious air pollution. Although China spends a certain amount of money on environmental protection, this still falls far below the amount required for sustainable air pollution control. The economic damage and social cost of air pollution were calculated. A dose-response function was employed in order to derive the monetary values of air pollution damage. The DRF was used to derive health damage in terms of mortality and morbidity from TSP and SO_2. The method is applicable to the estimation of mortality from air pollution. Because of a shortage of data on morbidity, we applied Rowe *et al*'s coefficients of DRFs for estimating morbidity cases as a first approximation.

Finally, we estimated the total losses due to air pollution damage. Air pollution damage accounts for 2-3 percent in the lower bound, 3-5 percent in the central bound and around 7-8 in the upper bound of the GNP per year from 1981 to 1990. This is not surprising in a country which uses coal as its main energy source, spending little on pollution control in case of heavy urban pollution. If China intends to maintain sustainable development, it should invest at least 2 percent (the lower bound) of its GNP in air pollution control.

In Chapter 9 we estimated the overall depreciation in the "green" net national accounts using the total rent approach and the user cost approach. The environmental depreciation is very high according to the calculation for only 4 sectors. Environmental degradation ranges from 15 percent to over 20 percent of GNP on both approaches. The net investment is always negative during 1976-1992. This situation demonstrates that China is not in a situation of sustainable development. The causes of environmental degradation are analyzed and illustrated in the chapter. Like most centrally planned economies, China pays little attention to environmental issues. Rapid population growth is another cause of deterioration in the environment. Missing property rights and a distorted pricing system facilitate environmental degradation and the decline of natural resources.

A policy framework for attaining sustainable development was discussed in terms of sustainable development, population control, privatisation, price reform and implementation of laws and regulations. The specific sectoral policies were also addressed in this chapter.

10.2 Contribution of This Thesis

gNNP is considered to be correct measure of environmental damage and natural resource depletion. The deduction of economic depreciation from the original GNP is the crucial step in measuring the real income of an economy. This thesis offers a number of important contribution to the field of calculating gNNP. The main contribution of this thesis is that it is the first true 'green accounts' in any form that have been estimated for China.

Data collection and compilation are also a contribution of the thesis. Although some of them are the official statistics, it is difficult to get these statistics in public libraries. In order to get these statistics, we visited many institutions repeatedly, used every channel to establish connections with people from these institutions, collected information on how and where we could get these data and spent some costs in obtaining the data. Thus, the field work was divided into four parts: 1) visiting institutions and departments concerned to get some official statistics; 2) visiting some places to get non-statistical data; 3) visiting libraries and information centres to get more references; 4) visiting various publishers and professional book stores to get published statistics. In the total 6 months data collection period, we visited two largest forests in China: Daxinganling forest and Changbaishan forest. We visited City Jinan of Shandong Province for data collection of air pollution. We also visited various government departments for data collection work.

The data have been processed and adjusted for the purpose of research. The data have been adjusted in terms of prices, costs, inflation factors and exchange rate factors. For forest resources, we calculated the stocks of natural forests, the volume of fire and insect damage based on some statistics. We also adjusted prices and costs of timer production. For coal and oil, we mainly focused on getting production costs and adjusted them. For air pollution, we found out pollution sources in Jinan city and adjusted concentration of pollutants. Thus, we have unified data for forestry, coal and oil from 1976-1992 and unified data for air pollution from 1981-1990. This first hand data are not only useful for this research but will also be useful for anybody in the future researches.

This thesis is one of the pioneering works which calculating the economic depreciation of environmental damage and natural resource depletion in four sectors in China. These four sectors represent the main environmental and natural resource sectors in China, and it is therefore significant to calculate economic depreciation for them.

The research has tested and developed a series of approaches both in theory and in empirical study. These three approaches: the net price approach, the total rent approach and the user cost approach have been all applied. We have also examined the advantages and disadvantages in applying these approaches.

The research has for the first time systematically collected and adjusted data for four sectors in China. The data are very relevant not only to this particular work but also to other research. The assessment of sustainability of four sectors in China reveals the seriousness of environmental damage and natural resource degradation in China, and indicates that China is a long way from sustainable development at present. The policy discussion provides a comprehensive framework for the sustainable development in China.

10.3 Further Research

In concluding this thesis, let us also consider further research for the future. Theoretically, we are considering the development of a social loss function between economic development and the environment. An optimal path should be found to show the trade-off between economic development and the environment. Elasticity of substitution between the man-made capital and the natural capital should also be further studied in calculating environmental damage. We also realise that measuring economic income is not equal to measuring sustainability, thus some further exploration into deriving a model for measuring sustainability must be undertaken in the future. The non-linear model and differentiation equations should be used in this further research.

Empirically, further analysis on other sectors should also be carried out. These sectors consist of water, grassland, soil, solid waste, natural hazards and so on. Further research should also measure environmental degradation to the global environment. For example, the greenhouse effect and the depletion of the ozone layer caused by China's pollution of the environment.

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