Population and Labor Movement between Urban and Rural Areas of China

by

William Kei Leung, Lee

Submitted to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degree of

Master of Engineering in Electrical Engineering and Computer Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 1995

Author ....
Department of Electrical Engineering and Computer Science
January 18, 1995

Certified by ....
Eckaus, Richard S
Professor
Thesis Supervisor

Accepted by ....
F. R. Morgenthaler
Chairman, Department Committee on Graduate Theses

Population and Labor Movement between Urban and Rural Areas of China

by

William Kei Leung, Lee

Submitted to the Department of Electrical Engineering and Computer Science
on January 18, 1995, in partial fulfillment of the
requirements for the degree of
Master of Engineering in Electrical Engineering and Computer Science

Abstract

In this thesis, I have modified an existing economic model program and use it to predict the patterns of population and labor movements in China as well as analyse the effect of different population and labor movement policies on the Chinese economy. The economic model is a general equilibrium model which has a 60 years time horizon. The model is implemented with a high level language - gams. From the results of the simulations, we notice that the Chinese economy cannot sustain as high economic growth rates in the future as in the past fifteen years after the market reform was in place. It, however, can still maintain an average of nearly 4.5 percent per year growth for the next forty years. We also notice that there may exist excess labor in the Chinese economy. If the Chinese authority, however, applies stricter controls on the population growth, the economy may have a short term gain but will suffer in the long run. Therefore, the Chinese government needs to plan carefully and make a balanced choice between economic prosperity and smaller population size. In addition, if the Chinese authority has to restrict the labor movement, a restriction on the rural labor movement will result a less distorted econony than a restriction on the urban labor movement.

Thesis Supervisor: Eckaus, Richard S
Title: Professor

Acknowledgments

I would like to take this opportunity to thank Professor Eckaus for helping me to finish the thesis, and Professor Zhang and Lixin Lu, who came from China, to supply me with the Chinese data. I guess, the most important people are my family members. Thank you for providing me all kinds of supports.

In addition, I would like to thank Ken and Vivian for always staying in Athena with me so that I can keep bothering them, and mostly vice versa. To Danny, Terry, Preston, Zhou Yu, Thomas and Connie, thanks for keep asking me out and delaying my progress. Also, thanks Yitwah, Calvin, HoBun and Dewang for asking me to play basketball and volleyball so that I always felt extremely tired when I worked. And thanks Ling, Jenny, Jocelyn, Jessica and Walter for keep chating to me when I worked. Alexandra and Vinci, thanks for the headache and white hair. And also thanks Jerome, Esther and Nicholas for competing with me in the job search. Oliver, Andy and Felix, thanks for keep asking me questions on problem sets, and made me nearly do all the problem sets for you guys.

Well, I hope that you guys won't get mad at me and know that I was just joking, if you guys ever read my thesis. :P I really appreciate your helps and and I am so glad to know you guys in my MIT life. Last but not least, I would like to specifically thank Daricha, my dearest friend and my best partner, for going through the MIT process and all the difficulties with me.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

This thesis addresses the trends and patterns of the population and labor movements within the rural and urban areas of China. The analysis is based on computer simulations of a general equilibrium model of the Chinese economy which has a time horizon sixty years. We model the Chinese economy into twenty three sectors. Based on the 1990 Chinese economy activity levels, we predict the future values of different macroeconomics variables and study how the various economic forces affect the population and labor movements and vice versa. The economic model was developed by the Center for Energy and Environmental Policy Research at M.I.T. in 1989 in a study of the Egyptian economy. A program has already been written for the Egyptian economy. The model and the program were used later in a study of the Indian economy. New constraints and equations have been added to the new Chinese model to allow detail analysis on the population and labor movement in China. The 1990 base year data are mostly provided by Professor Zhang, a Professor at Tsing Hua University. Some of the data, however, may be incomplete.

Chapter 2 presents the motivation to do the thesis. We discuss the interesting "floating" population phenomenon in China, and how it arises. We also go over a brief history of the recent population and labor movements and see how those movements affected the economy.

Chapter 3 begins with a discussion on the "miracle" that the Chinese economy has had for the past fifteen years. The Chinese economy attained a nearly double digit per year growth rate on average since the market reform was set forth in 1978. We will also look at the underlying reasons that made the reform so successful.

Chapter 4 reviews the technical aspect of the thesis. We will take a look at the underlying linear-programming model and discuss the general techniques and procedures in solving a linear-programming problem. We will also explain how our non-linear programming economic model fits into the discussed linear-programming content.

Chapter 5 is a detail discussion of the economic model. The settings of the model is described. The macro-economic variables which are determined by the economic model are presented. And the details of different equations and constraints within the model are explained.

Chapter 6 shows the approach to analyze the effects of different population and labor movement policies. Chapter 7 presents and analyses the results of the simulations, and draws conclusions on the different policies. Chapter 8 is the final conclusion and provides suggestions for future works.

Chapter 2

Motivation

The population and labor movement phenomenon has been an important issue in China. Because of the recently rapid growth in the coastal urban areas, there are huge number of people moving from the less prosperous interior parts of the mainland to those economic vigorous coastal cities. The total number of the so called "floating" population - population floating from rural areas to urban areas, is estimated to reach 100 million. Such rapid growth in urban population raises certain social problems. It creates huge pressure for the government to provide housing, jobs, medical facilities, public transports, educations, and other services; it increases the crime rate; and it also retards the development of economic and social infrastructures. As a result, a rapid improvement in the people's standard of living becomes harder to achieve and the economic growth of the urban areas are likely to impede.

Recent history of population movements in China is very interesting. Figure 2-1 shows the total population growth, as well as the urban and rural population growth for the past 43 years after liberation in 1949. The total population has grown at a rate of 1.81 percent per year on average for the last 43 years. The total population size has increased more than double during the period from 541.67 millions people in 1949 to 1171.71 millions in 1992. The rapid population growth period has brought China to become the most populated country. We can also note from the graph that the urban population growth rate fluctuated a lot and we are going to take a closer look in later sections.

Figure 2-1: Population Growths for the period 1950 to 1992

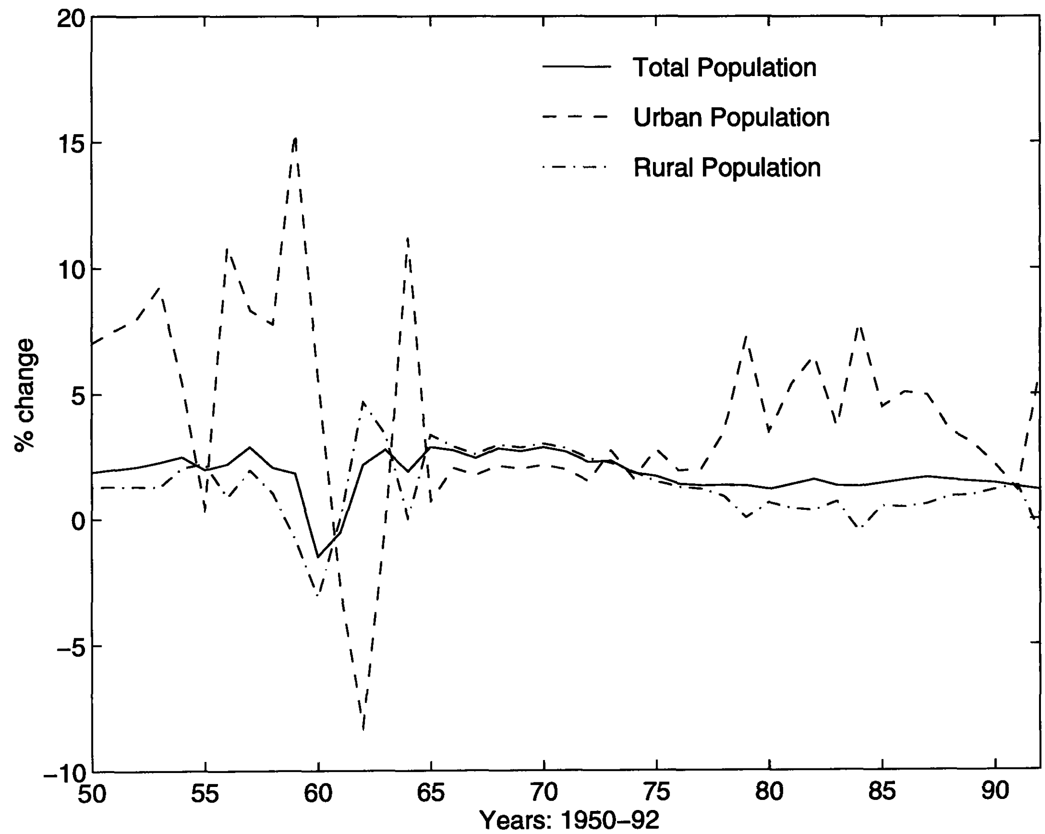
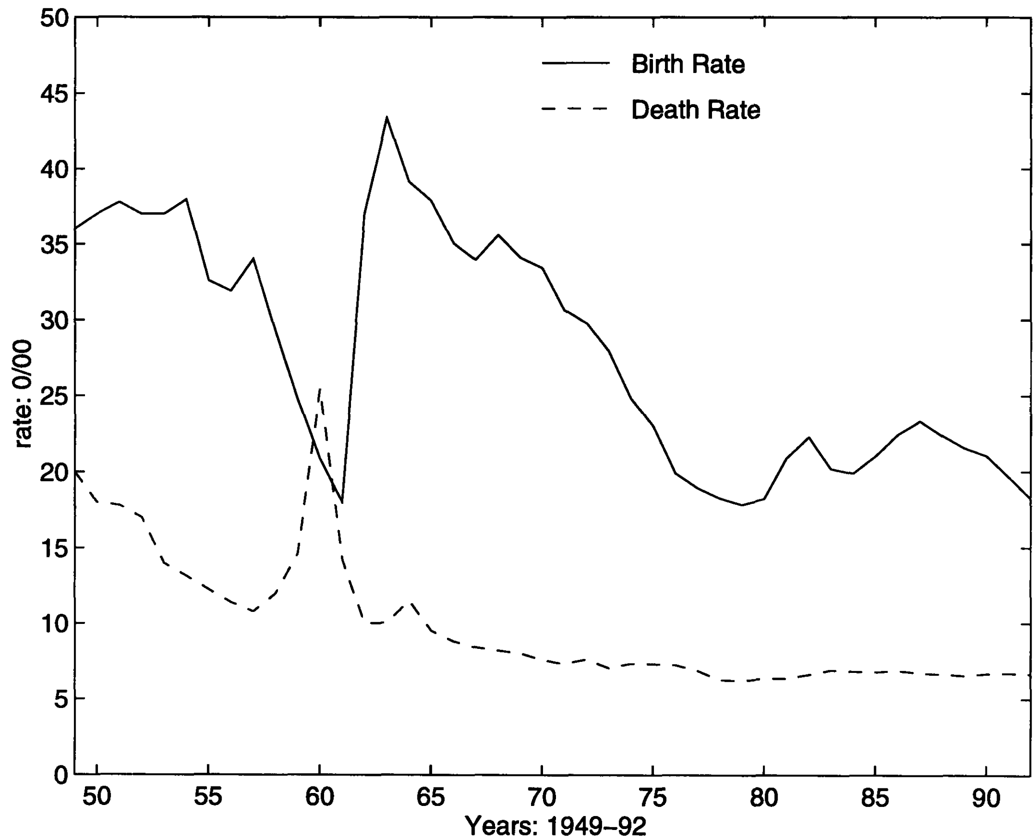


Figure 2-2: Birth and Death Rate for the period 1950 to 1992



The nationwide birth and death rate per thousand heads of China for the 1949 to 1992 period is shown in figure 2-2. Both the birth and death rates are decreasing in general as a function of time. The birth rate, however, has always been greater than the death rate except in the year 1960. Since the immigration and emigration rate of China are not significant, the natural increase accounted for most of the population increase in the past 43 years.

It is generally agreed that the population growth rate in China was too high and the continuation of the rapid growth is going to threaten the success of the economy. The Chinese authority recognized the problem as early as in 1961. In the meantime, it has adopted certain policies to reduce the overall growth rate. The most well known policy is the so called "one-child" policy in June 1979. Besides encouraging one child per family, the Chinese authority also provided the public with extensive family planning education and services. In addition, it also advocated late marriage and improved education opportunities in rural areas.

The improvement in death rate can be attributed to the improvement in living standard and better medical provision for the public. In addition, the stable environment after liberation except the Great Leap Forward and Cultural Revolution period also reduced the chance of early age and middle age death. As recent research pointed out, the main reason for death in modern China is old age diseases [12]. The life expectancy has increased from 33.3 years in 1936 to 64.9 years in 1973-1975, and reached 67.9 in 1982. It is expected to reach 75.7 in 2020-2025 [15].

The natural growth rates per thousand people in China is shown in Figure 2-3. They are presented in National, City, and County levels instead of urban and rural levels. Therefore, the urban and rural areas natural growth rates can only be approximated by the City and County natural growth rates. In addition, the discontinuities in the City and County natural growth curves are due to the incomplete set of data available. The general trends and relationships, however, can be inferred from the graph. It can be seen that the natural growth rate in urban areas was always higher than that of the rural areas in the early period before 1963. After 1963, the trend, however, reversed. The phenomenon is strange and is going to be explained in

Figure 2-3: Natural Growth Rate for the period 1950 to 1992

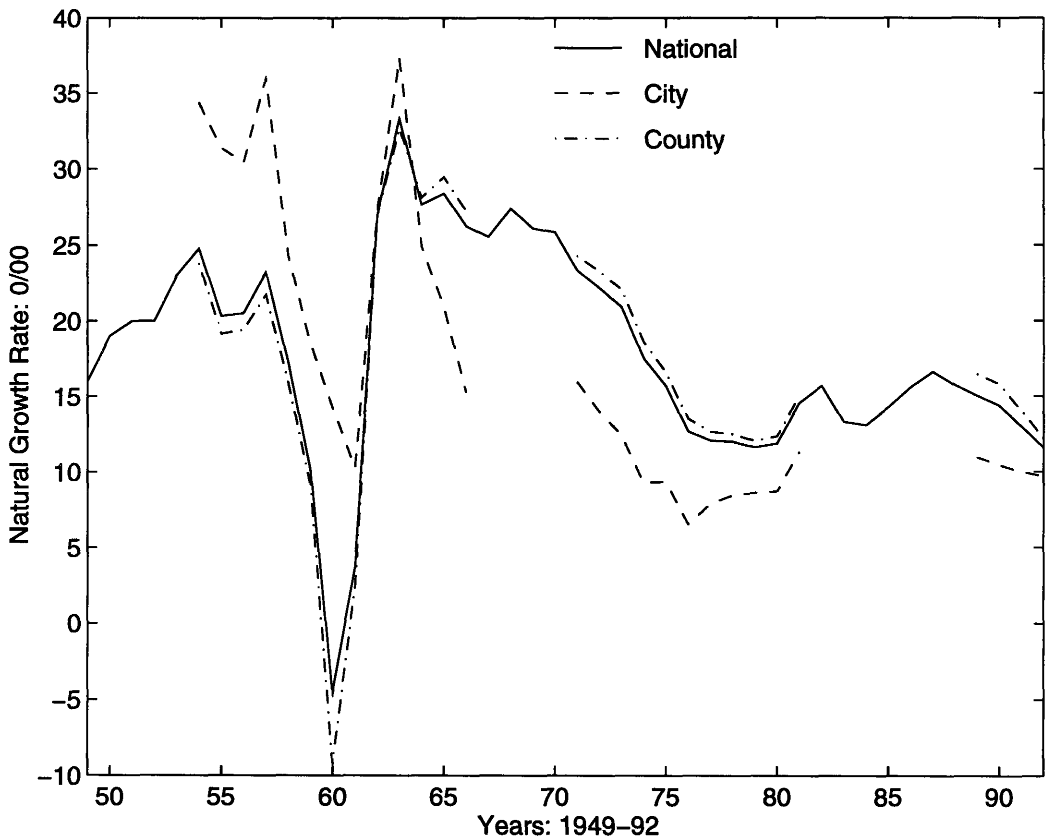


Table 2.1: Summary of Defining Population Characteristics for Different Periods

	Total Population[a]			Urban Population			Rural Population			National Income		
Period	1[b]	2[c]	3[d]	1	2	3	1	2	3	1	2	3
52-57	574.8	646.5	2.38	71.6	99.5	6.79	503.2	547.0	1.69	100.0	153.0	8.89
58-62	659.9	673.0	0.49	107.2	116.6	2.12	552.7	556.4	0.16	186.7	130.9	-8.49
63-66	691.7	745.4	2.52	116.5	133.1	4.56	575.3	612.3	2.10	144.9	231.0	16.82
67-77	763.7	949.7	2.20	135.5	166.7	2.09	628.2	783.1	2.23	214.3	403.7	6.54
78-91	962.6	1158.2	1.43	172.5	305.4	4.50	790.1	852.8	0.59	453.4	1287.8	8.36
92	1171.7	-	-	323.7	-	-	848.0	-	-	1473.2	-	-

[a]Total population, urban population, and rural population are in million people, while national income is in billion Yuan

[b]Beginning Figure

[c]End Figure

[d]Per Year Average Percentage

the subsequent sections.

In order to understand the population movements between urban and rural areas, we are going to divide the whole 43 years period into several sub-periods: 1952-57, 1958-62, 1963-66, 1967-77, 1978-91, and 1992 onward, and look at them separately. A summary of the data defining the population characteristics of these periods is shown in table 2.1.

1952-1957

After the establishment of the People's Republic of China in 1949, the government has provided a more stable environment for its citizen to live. There were vast improvements in nutrition and public health in the urban areas. As a result, the mortality rate started to decline and the birth rate was picking up. The total population was growing at a 2.38 percent rate on average during the period. The growth in China's urban size was even more extraordinary. It averaged a 6.79 percent annual growth rate. The main component of the rapid increase was the migration of rural people to the urban areas. It was the time that substantial number of people who had taken refuge in the countryside during the war period to return to the urban areas. Net migration accounted for more than 70 percent of total urban growth [14], while natural growth had only a minor effect. The natural growth rate of urban areas, however, also reached its height, mainly because of the stable environment.

1958-1962

This period corresponded to the Mao Zedong's Great Leap Forward campaign. The Great Leap Forward hurt the economy and cost million of lives. The economy became stunted. The national income dropped 8.49 percent a year on average in this five years period. The mortality rate went up and the birth rate went down. The total population grew only .49 percent a year, the lowest throughout the whole period after liberation. There was a decrease of total 13.5 million of people in the years 1960 and 1961.

The urban population increased about 8 millions in 1958 with a further increase of 16.5 millions in 1959. The huge sudden increase in urban population at the early phase of the Great Leap Forward was a result of vast migration of peasants from rural areas into the towns and cities for the over-ambitious Great Leap Forward campaign. It is believed that the campaign sucked in more than 20 millions of peasants. Starting from 1960, there was a sharp down turn of urban population size, see figure 2-1. With Zhou Enlai called for a correction for the over-ambitious campaign, and a mass deportation of urban people, the urban population decreased sharply.

1963-1966

This period was basically a recuperation period after the failure of the Great Leap Forward campaign. The economy resumed its growth. It corrected the inefficient production methods that adopted during the Great Leap Forward, and the economy as a whole achieved a 16.82 average growth in national income during this period. The population increased rapidly with a 2.52 percent rate of growth per year. The urban population grew rapidly.

The rural area natural growth rate became higher than that of the urban area in 1963 for the first time since liberation. Although the urban birth rates were higher than the rural birth rates until then is puzzling, the change might be due to the previous massive movements of urban people which gave them uncertainty about their future and caused them not to set up families. Studies have shown that permanent migrants have a higher rate of fertility [13]. At a result, the birth rate in the city areas has dropped from 44.5 per thousand people in 1963 to 32.17 in 1964 and further decreased to 26.59 in 1965. The rural birth rate, however, maintained at a high level with 43.19 in 1963, 40.27 in 1964 and 39.53 in 1965. The contemporary agricultural farmland policy also indirectly encouraged peasants to have more children to serve as a source of resources. Therefore, the rural areas maintained a higher natural growth rate.

1967-1977

The early phase of this period is the Cultural Revolution. There were massive movements of population in this early phase. The official net migration data, however, showed no indication of such huge population flows. The reasoning behind is the massive outflow of urban youngsters was practically offset by the substantial recruitments of rural peasant labors by urban units. In 1966 and 1967 alone, about 17 million young people have sent out to the villages and small towns "to support border constructions"[14], at the same time, about 13-14 millions of peasants have been drawn into the urban workforce. The reasoning for bringing in less productive rural forces into urban areas and simultaneously sent out more efficient young urban labor force was a calculated political move to give urban workers rural experiences.

After the Cultural Revolution, the total population as well as the urban and rural population grew steadily at high rates. The youngsters who were sent out during the Cultural Revolution were mostly back after 1977. The total population reached 949.74 million in 1977 and China became the most populated country since then.

1978-1991

This period is featured by the rapid economic growth. The market reform was set in in 1978, and the economy has averaged nearly double digit growth rate per year. A detailed discussion will be postponed until section 3.2. The characteristics of the population movement are firstly, much slower total population growth than the previous Cultural Revolution period, and secondly, a huge increase in urban population. The whole economy averaged 1.43 percent in annual total population growth, which was by no means high but was comparatively much smaller than those in previous periods. The urban population, on the other hand, has maintained an average 4.5 percent per year of growth during the period.

The slow growth of the total population is best attributed to the "one-child" policy introduced in 1979. The "one-child" per family policy made having an addition child extremely costly and hence reduced the incentive to have more than one child. Although the "one-child" policy has created certain social problems, such as killing newly born baby girls and illegally having another baby and giving it to other people, the "one-child" policy was basically very successful in constraining the population size.

During the reform period, there was a surge in urban areas size. More areas were defined as urban areas. This partly explained the huge increase in the urban population size. The great bulk of the urban population increase was accounted for by the officially-sanctioned return to the urban areas of millions of people who were sent away during previous period [14]. Figures showed that net immigration to the towns and cities between 1977 and 1982 was almost 33 million. Immigration became the single most important factor behind the rapid increase in urban population.

1992 onward

Due to the insufficient data available, the following discussion can only be treated as speculation. It is generally believe that because of the rapid economic growth and vast improvement in living standard in the urban areas, a huge number of rural people have moved to the urban areas legally or illegally to search for higher paid jobs and better living. In 1992 alone, there was a 18.29 million net increase in urban population from 1991. It is believed that about 100 million of rural people have been moving to the urban areas in recent years and caused a number of social problems.

In conclusion, the population movement between the urban and rural areas of China is important to its economic growth. A sudden increase in the urban population is going to cause economic and social instabilities. It is important for the Chinese authority to recognize the problem and be capable to predict the future population movement. It is also important for the Chinese government to understand how certain population movement policies affect its economy. The current research work is based on this spirit, and it is hoped to understand the interactions between the economy and population movement, as well as between the economy and different population policies.

Chapter 3

The Chinese Economy

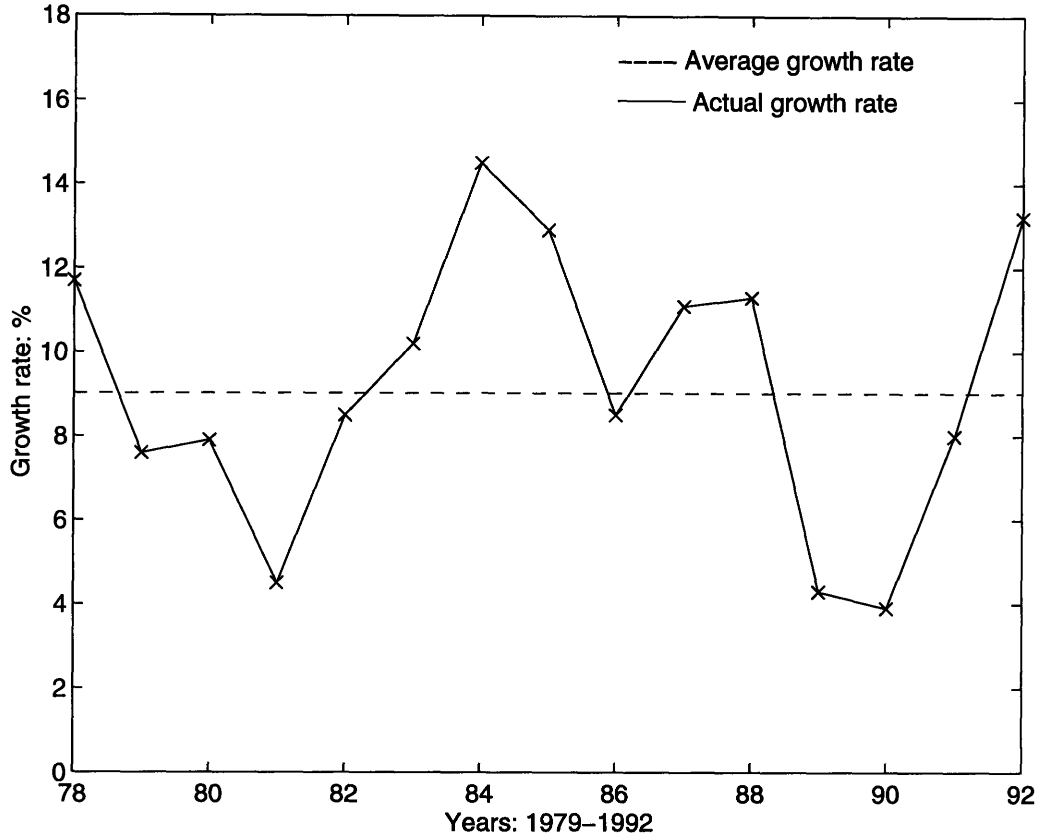
3.1 The Settings

China is the world largest country; it has more than one fifth of the world population. After the revolution at the end of 1940's, China was completely ruled under the Communist Party. Her economy was practically closed to all western countries before 1978. The economic activities were hardly known by western foreigners. Only after the reform in 1978, the activities in China began to unfold to foreigners.

Even with the short history after the revolution in late 1940's, China has already experienced several severe economic cycles. The Great Leap Forward in 1958 and the Cultural Revolution in 1966 caused major slowdowns, if not setback, in the Chinese economy. After 1978, the economic policy was revised, and market reforms were set at a clear and compelling manner by the central government. The Chinese economy then experienced the most rapid growth period in her history.

In contrast with the former Soviet Union and some Eastern Europe countries, China did not attempt to change her economy in a "Big Bang". She instead has transformed herself in a step by step, controlled manner. She encouraged small-scale, experimental type transformation throughout the country. Once the small-scale reform became successful, the central government then spreaded the practice to the whole country. At present, China is in a state of transition, gradually turning into a more efficient economy.

Figure 3-1: GDP Growth Rate for the period 1978 to 1992

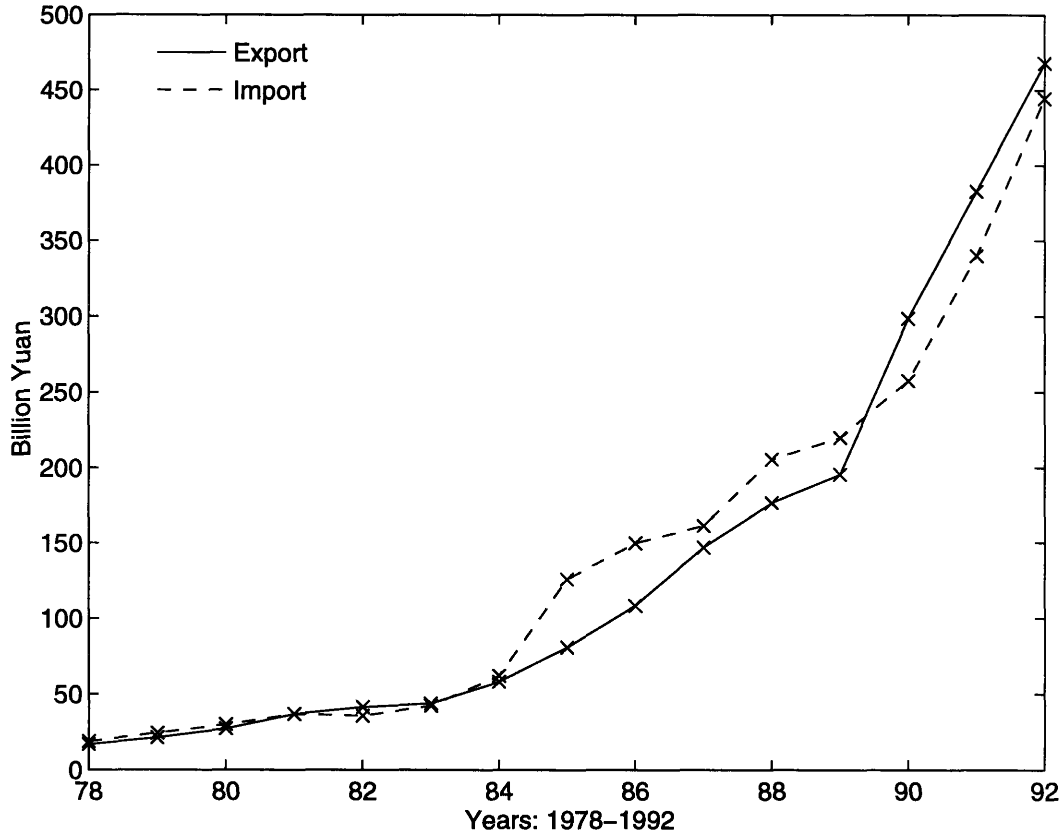


China is transforming herself into both a political and an economic superpower in the world. With the atrophy of the former Soviet Union, her role on international issues is becoming more important than before. The activities going on within China are becoming more and more important to the global environment.

3.2 The Success

The Chinese economy has averaged 9.2 percent per year growth rate since the reform in 1978, figure 3-1. The GDP growth rate even reached more than 13 percent in 1993 and it is widely expected that the growth rate will be even higher in 1994. This fast growth rate is impressive and is comparable to Japan during 1960-74 and South Korea from 1965-78. When economies are compared using purchasing power parity exchange rates, China is already the third largest economy after the U.S. and

Figure 3-2: Import and Export for the period 1978 to 1992

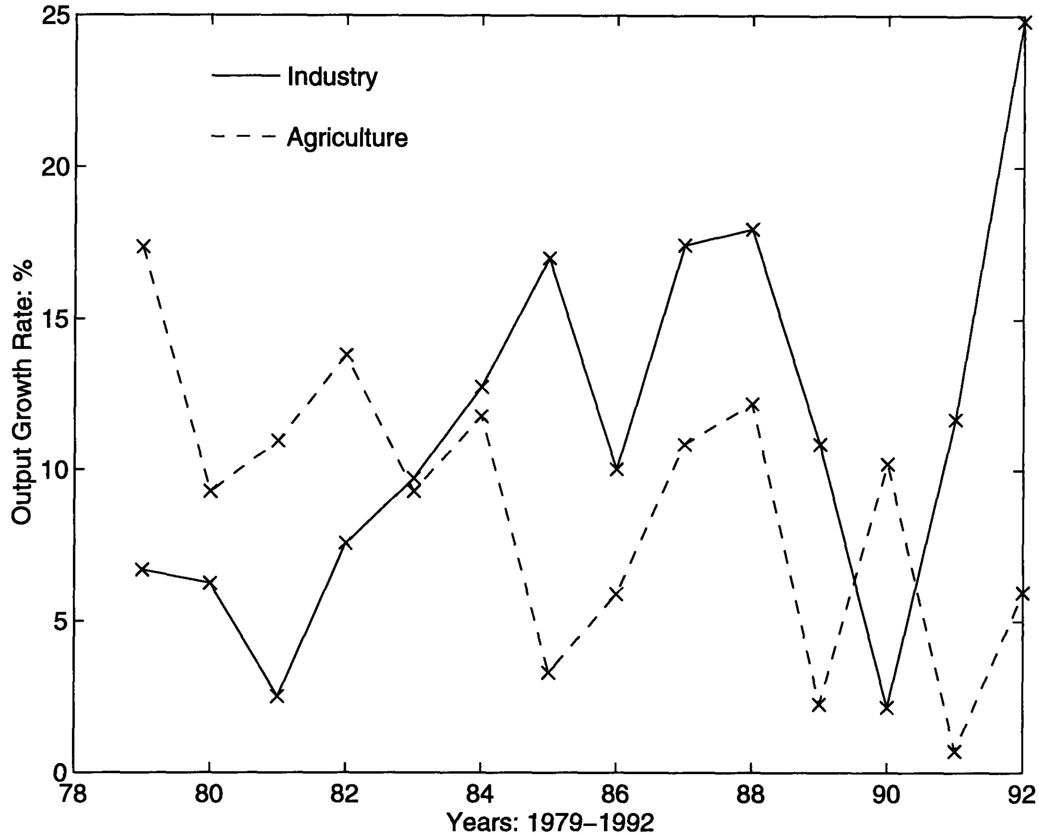


Japan [17]. Although the government has imposed tightening policies four times in the past fifteen years, 1981, 1985, 1988-89, and currently, the reform momentum did not halt. It, on the other hand, resumed quickly and generated even faster growth after the slow down.

The growth in trade is also impressive, see figure 3-2. It grows from less than ten percent of GDP in 1978 to 38 percent of GDP in 1992. The growth in the price adjusted values of import and export reached more than 20 percent per year on average. It is not hard to imagine that China will become the biggest trade partner of U.S. by the end of the century.

The main reason behind the high GDP growth rate is the rapid growth in the agricultural sector and in the industrial sector, figure 3-3. The agricultural sector attained an average 8.8 percent growth in the past fifteen years, while the industrial

Figure 3-3: Adjusted Output Value of Agriculture and Industry Growth Rate



sector has an average 11.2 percent growth. Both average growth rates have already been adjusted for inflation. As a result, per capita annual income has grown rapidly since 1978 with an average growth rate almost eight percent per year. The living standard of Chinese people is greatly improved in the past fifteen years.

It is unquestionably that the economic reform in China since 1978 was very successful. The success not only improves the living standard for Chinese people, but also can serve as a model for other developing countries which are going through the same development process as China. There is no miracle behind the success. Next section will discuss some of the reasons for the success in the reform.

3.3 The Reasons

The key determinants for the success of the economic reform in China are: (1) appropriate choice of strategy for economic reform; (2) commitment of the central government in reform; (3) high level of domestic saving; (4) high level of foreign investment; (5) correction of accumulation of the gross inefficiencies; and (6) the reform in State Owned Enterprises (SOEs) and the success of Township and Village Enterprises (TVEs).

Appropriate choice of strategy for economic reform:

Instead of using a "big bang" in the reform, Chinese government chose to carry out the reform in a step-by-step, completely controlled manner. The reform can be divided into two phases: 1978-84, and 1985 onward. In the first phase, most of the economic growth was due to the success in the agricultural sector; while the industrial sector contributed for most of the growth in the later phase. See figure 3-3.

The Chinese government started an experiment on agricultural reform in Sze Chuan Province in 1978. The reform caused a shift from collective farming to household farming. As a result, farmers' compensation were directly related to the outcome of their works. The change provided the incentive for farmers to work harder, and at the same time, invest heavily in their farmlands to increase productivity. The agricultural reform was a complete success in the Sze Chuan Province. The central government then applied the methodology to the whole country. As a result, the agricultural sector as a whole was growing at a rate of 12 percent per year between 1978 to 1984.

Entering the second phase of the reform, the rapid expansion in the industrial sector was the locomotive of the economy. During the 1985-92 period, the average industrial growth rate reached almost 14 percent per year.

The choice of having agricultural reform as the first step has a couple advantages. The agricultural sector is historically the most important sector in the Chinese economy. It has the largest number of workers. Reallocation of labor in the agricultural sector and redistribution of land would certainly improve efficiency, thus provided a firm base for future economic reform. After the successful reform in the agricultural sector, the Chinese government then shifted the attention to industrialize the country, which, from previous western experiences, is the most important step and a necessarily path towards modernization.

Another important constituent of the reform is the decentralization. Decentralization has occurred at two different levels: administrative decentralization, and fiscal decentralization. Administration decentralization has allowed provincial and local authorities to make routine decisions, and allowed them to have more flexible and adaptive administrations. In addition, the decentralization also affected the state owned enterprises (SOEs), allowing them to enjoy a greater production automony. The effect of this changes in the SOEs will be discussed later.

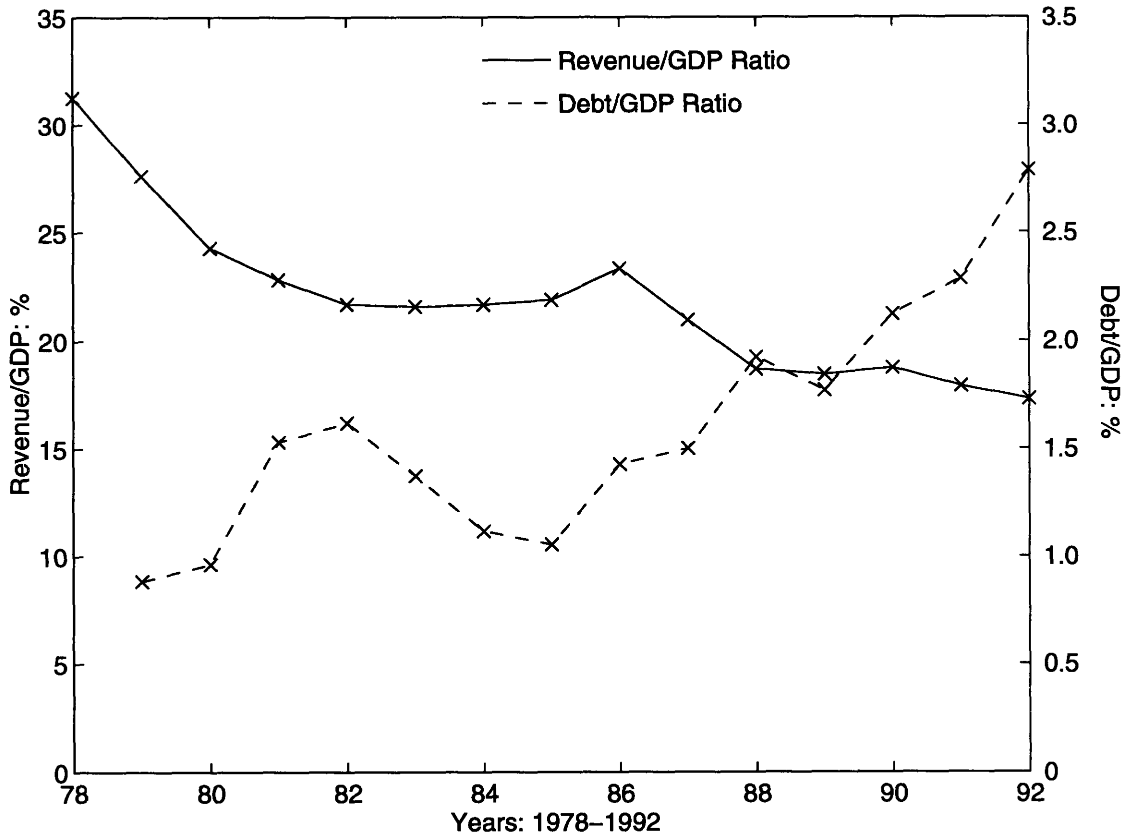
Fiscal decentralization was introduced incrementally after 1981. It allowed subnational governments to share fiscal revenues. In addition, the local governments can levy subcharges and fees, which provide additional revenue. They are also responsible for controlling the budgets of the provincially owned state enterprises [17].

As a result of both types of decentralization, the local governments gained more power and more automony. This created the incentive for provinces to find ways to boost their local economies, at the same time, compete with other provinces for capital investment. Each local government was eager to experiment new market reform in its own area. In addition, each local government has invested heavily to improve local transportation and expand its own infrastructure through the revenue it collected. This is evident in the ability of the local governments to finance nine-tenths of the intraprovincial road network locally [5]. Due to the keen competitions among the provinces, most of the provinces attained tremendous growth during the last fifteen years.

Commitment of the central government in reform:

The Chinese central authority has been very supportive of the economic adjustment. The commitment of the central government to the reform has been very clear and

Figure 3-4: Government Revenue/GDP and Debt/GDP ratio from 1978 to 1992



compelling. As a result, the government provides confidence for both domestic and foreign investors to make commitments to invest in China.

The central government has been pushing a rapid economics reform even through it is jeopardizing its political stability. The central government has imposed tightening policies in 1981, 1985, 1988-89, and now to reduce inflation. None of them, however, has stopped the growth of the economy. The GDP growth rate never drop below 3.5 percent per year, figure 3-1. Once the tightening policy was relaxed, the economic momentum resumed quickly by the push from local governments and individuals. There never existed a recession period in the past fifteen years. For example, even though the 1989 Tienanmen Square issue challenged the political system and created instability within the Communist Party, the economic progress, however, quickly resumed its momentum in 1991 and attained a double digit growth rate in 1992.

The central government also carried out the tax reform which allowed local governments to retain a large portion of the fiscal income. The revenue sharing system provided incentives to local governments to push the local economies. The result of such revenue sharing system was a steep fall of the central government's revenue/GNP ratio and a rise of the debt/GDP ratio since 1978, figure 3-4. The China's revenue/GNP ratio fell from 31.2 percent in 1978 to 17.3 percent in 1992. And the government debt has risen from 0.9 percent of GDP in 1979 to 2.8 percent of GDP in 1992. Such system put the central government at the risk of running continuous huge budgetary deficits. Although there was a new tax reform recently intended to increase the share of revenue to the central government, it is still believed that the central government is committed to the tax reform and the local government financial liberation policy.

In addition to the tax reform, the Chinese government indirectly provided easy credits for SOEs through the People' Bank of China to encourage improvement in SOEs' productivity . The budget deficit was basically financed through seignorage. If the situation continues, the central government is again risking itself in having a hyperinflation situation in the future.

The Chinese authority maintained an open door policy since reform in 1978. It encouraged the coastal provinces to develop rapidly by attracting resources from Hong Kong and other countries. It encouraged foreign investments and trade with these coastal provinces by offering preferential tax rates, guarantee profit and royalty repatriation, and two month clearance for foreign investment [8] In addition, the Chinese authority was quick to adjust the nominal exchange rate. The currency was devaluated several times during the reform. It not only boosted exports, but also made investment in China seem more worthwhile. As a result of the open door policy, the trade sector grew rapidly. The volume of trade as a percentage of GDP grew at an average rate of 9.4 percent per year.

High level of domestic saving

In marco-economic terms, saving is necessary for investments, and in turn, make the country possible to have high growth rates. It is believed that the Chinese economic growth for the last fifteen years was investment driven. More than one third of the growth is due to the capital investment [17]. For the last fifteen years, high level of domestic saving in China provided sufficient capitals to maintain high level of investment. Gross national savings rose from an already high average of about 33 percent of GNP during 1978-84 to 38 percent in the 1985-92 period [17]. This high saving rate phenomenon justifies the more than 30 percent of GNP investment during the reform period.

As Hussain pointed out, a large part of the domestic saving in China is the result of "involuntary savings". Involuntary savings arising from unsatisfied demand for consumer goods increases the volume of liquid assets in possession of households [11]. As we know, the living standard of the Chinese households has increased dramatically for the last fifteen years. The average income per capita was growing at eight percent per year, it is not surprising to see that there existed excess demand in the market even though both outputs of the society and imports from foreign countries were growing rapidly. As a result, the excess money was put into the saving accounts.

In addition, for historical or cultural reason, it is believed that Chinese people are more oriented towards production rather than consumption [8]. Saving is treated as a virtue and is encouraged in the Chinese society. The lack of a complete social security system also encourages saving. As the fertility rate went down drastically for the last fifteen years, old people can expect to depend on their next generations less, and hence the saving for retirement becomes more important. Furthermore, the absence of a mature financial or credit market also makes household save for durable goods.

With the above reasons, the saving rate in China remains high or even higher than before. Sufficient funds from saving are available to fund the investment projects in order to boost the economy throughout the market reform period. The ratio of household bank deposits to national income is 58 percent in 1992 rising from 7 percent in 1978.

High level of foreign investment

One of the stimulants to the rapid growth in the Chinese economy is the large amount of foreign investment. Different from the investment through domestic savings, foreign investment adds extra values to the Chinese economy. Foreign investment normally brings in skills that Chinese people will take time to learn. Direct foreign investment has already brought in advanced electronic technology, advanced transportation, etc. Joint venture, for example, brings in valuable intangible skills such as financial analysis, quality control, production management, and project evaluation skills.

The huge inflow of capital investment into China is best attributed to the success of the central government's commitment to the reform. As mentioned before, the central government's commitment to reform has provided the desirable stable environment for long term investment. The initial success of the foreign investment projects bred further foreign investments in China. In addition, with the push from the Chinese authority to rapidly develop the coastal provinces and the implementation of certain advantageous investment policies, huge amount of foreign capital is attracted into China.

Besides the special efforts from the Chinese authority, China is naturally a good place to invest. China has large resource base, and it also has the largest portion of world population. The potential of domestic market is huge when compared to any other single country in the world. In addition, the labor cost in China is cheap. All these factors make China an attractive place to invest.

Hong Kong, Taiwan, Singapore and other Chinese communities have been investing a lot in China. One of the main reason is the special attachment to the same origins; language proficiency is also another important reason. The geographical closeness to China also allows these countries to invest in China at lower overheads, at the same time, allows more dynamic business decisions to be made in a shorter time frame. China has been most benefited from these non-local Chinese communities, since these communities are more willing to transfer their knowledge and technologies to the people in China due to, maybe, the special attachment. Other foreign countries, for example Japan, are less willing to transfer their technologies out to other countries [10].

Correction of accumulation of the gross inefficiencies

It is believed that one-third of the growth in the reform period is due to the increase in capital investment; one-third of the growth is due to the improvement in total factor productivity; and the remaining one-third is linked to an expansion of labor usage which includes the increase in labor force participation and the absorption of the unemployed [17].

Eckaus argues that the comparative success of the economic reforms in China is, to a large extent, simply the result of the elimination of some of the old mistakes and inefficiencies of planning [8]. This argument is especially true to the Chinese economy. The communal system imposed on the Chinese economy before the reform can be treated as a grossly inefficient system. The communal scheme encouraged cooperative production. The return of the workers had no direct relationship with how they perform. The central government had the responsibility to bear all the losses from the SOEs, as well as to provide basic necessities for all the people. People's lives in China were well protected, even though the living standard was poor, or they did not have a choice to improve it. As a result, no incentive for any improvement. The economy stalled and the inefficiency accumulated.

Besides the lack of improvement situation before the reform, the economy actually had its setback during the Great Leap Forward and Cultural Revolution period in late 1950's and late 1960's respectively. The over ambitious Great Leap Forward economic reform actually caused million of factories to produce useless products because of the insufficient skills and technologies and also cost million of lives. The economy was badly hurt. After a decade of steady recovery, the Cultural Revolution gave the economy another big hit. During the Cultural Revolution, production slowed drastically and the economy turned into a mess.

With the above incidents, the reform in 1978 was started at a time that the economy was suffering from serious deficiencies. Once the communal constraint has been removed in 1978, the agricultural sector changed from ineffective collective structure to high incentive household responsibilities system, the output grew rapidly. After the success in the agricultural sector, reform in the industrial sector then began at the SOEs level. Inefficiencies in SOEs were partly removed. Together with the establishment of more efficient TVEs system, the economy was benefited and operated under a more efficient environment. More detailed discussion about the SOEs and TVEs will be postponed until next section.

As a result of the elimination of the inefficiencies, the labor productivity growth rate was nearly double in the reform period compared to the period between revolution and reform. The average overall labor productivity increased at a rate 6.0 percent per year for 1978-89 compared to 3.6 percent for 1953-77. Since the SOEs are still inefficient in general, and the TVEs do not have the benefit of the economy of scale, it is expected that there still have rooms for further correcting inefficiency and hence the China's growth is expected to sustain.

The reform in State Owned Enterprises (SOEs) and the success of Township and Village Enterprises (TVEs)

After the success of the agricultural sector reform, the reform spread to the industrial sector in the middle of 1980s, which include the reform in SOEs and the establishment of TVEs. The reform in the SOEs have several important characteristics: delegation of decision-making on investment, financial liberalization, vertical disintegration, and the possibility of closing due to continuous losses. The TVEs are in a much smaller scale than SOEs. They, however, are more efficient than SOEs in general.

Delegation of decision-making on investment to enterprises was simply a result of the decentralization of government and reaction of the ability to retain profit. The independence in decision-making allowed SOEs' managers to be more flexible and efficient in making business decisions in response to the changes in business environment. Also, they are in a better position to allocate the resources for more efficient use.

Following the 1984 enterprise reforms, most SOEs have become financially independent. The percentage of government financed investment in SOE fell drastically in the 1980's. The SOEs financed their investments through borrowing from the People's Bank of China, and had to pay a positive interest charge on the loans. In parallel with the less funding from the central government, the SOEs were allowed to retain a portion of the revenue. The SOEs could use the retained revenue to finance investment projects as well as increase the wages for their employees or even introduce performance related bonus systems.

Before the reform, SOEs were never subject to shut down of production even they are suffered from severe losses. The central government had the responsibility to subsidize these loss-making enterprises. This proved to be a very heavy burden to the Chinese government. Since the start of the reform, the central government has been encouraging the loss-making SOEs to close and redistribute their workers, or to restructure and disintegrate the enterprises if not closure. Although not much of this has been done, the "iron bowl" image of SOEs has been changed. In addition, the vertically disintegration of the SOEs allowed them to focus on a narrower range of production activities and hence be more efficient in production.

The main reason for the rapid industrial growth lays in the success of the Township and Village Enterprise (TVEs). TVEs are small scale enterprises. They are "owned" by each of the villages collectively, instead of by the central government. The rapid growth of TVEs accounted for nearly one-half of the industrial growth in China, and the gross output of these enterprises averaged a growth rate of 22 percent per year between 1984 to 1992.

The success of the TVEs may due to the fuzzy property rights of the enterprises. In one sense, the TVEs were belonged to the village as a whole, in the other sense, they are the country's properties. The local residents have the right to share the profits, but at the same time, share the responsibility in operating the collectives. This fuzzy property right again created incentive for individuals to put in efforts in return for greater profits.

The small scale of the TVEs allowed flexibility in decision making. It allows the TVEs to respond to the change in demand rapidly. One of the comment to the success of TVEs is that the TVEs are providing goods that are neglected from the central government planning [8]. Because they are smaller than SOEs and subjected less control from the central government, they have the ability to move to the business areas that have high demand but not enough supply from the society.

TVEs, however, do not enjoy economy of scale because of their small sizes. The success of the TVEs in the reform period was mainly the result of the inefficiency of the SOEs, and the highly imperfect competition of the market. Once the SOEs gain efficiencies and enjoy economy of scale, and the market turns into a more mature phase, the market competition is likely to drive the TVEs out from the market.

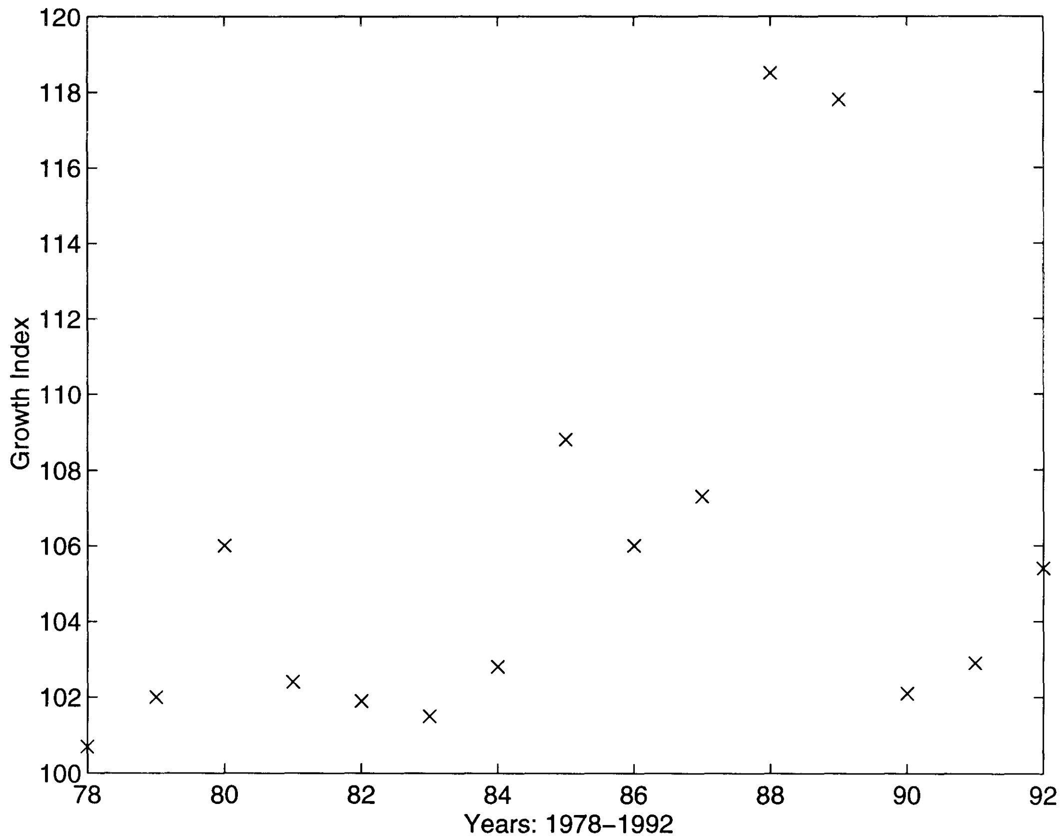
3.4 The Inflation

The inflation phenomenon in China is quite interesting and worth to take a closer look. Figure 3-5 shows the overall retail price growth rate for the period 1978 to 1992. Inflation was basically absent during the early phase of the reform. During the reform period, the central government has been financing its budget deficit through seignorage. Moreover, the demand for goods has risen rapidly and the wages of labor have been increasing. The absence of inflation in the early phase seemed to be quite contradictory to the conventional wisdom of fast economic growth, high inflation.

The government has been running budget deficit since 1979 as a result of the shrinking in tax base. The fiscal imbalances were financed by lending from the central bank, the People's Bank of China. At the same time, the central bank also provided easy credits to the SOEs. As a result, the monetary base increased drastically. Furthermore, a large portion of the loan to the Ministry of Finance was canceled at a later time. Therefore, the government was basically financing its deficit by printing money. The seignorage has reached 6.3 percent of GDP on average for the period 1986 to 1992.

As mentioned before, the average income per capita has been rising rapid through-

Figure 3-5: Overall Retail Price Index for the period 1978 to 1992



out the reform period. The consumption of the household, as a result, has also risen rapidly, and averaged 6.7 percent growth per year throughout the reform period. This is resulted in a rapid increase of the demand for both domestic commodities and imported goods.

With the rapidly expansion of the monetary base and the rise in wages and demand for final goods, the prices of the commodities should have risen rapidly, and huge inflation should have expected. The economy, however, showed no sign of high inflation in the early phase of the reform. The absence of such phenomenon may be best explained by the rapidly increase in money demand from the public.

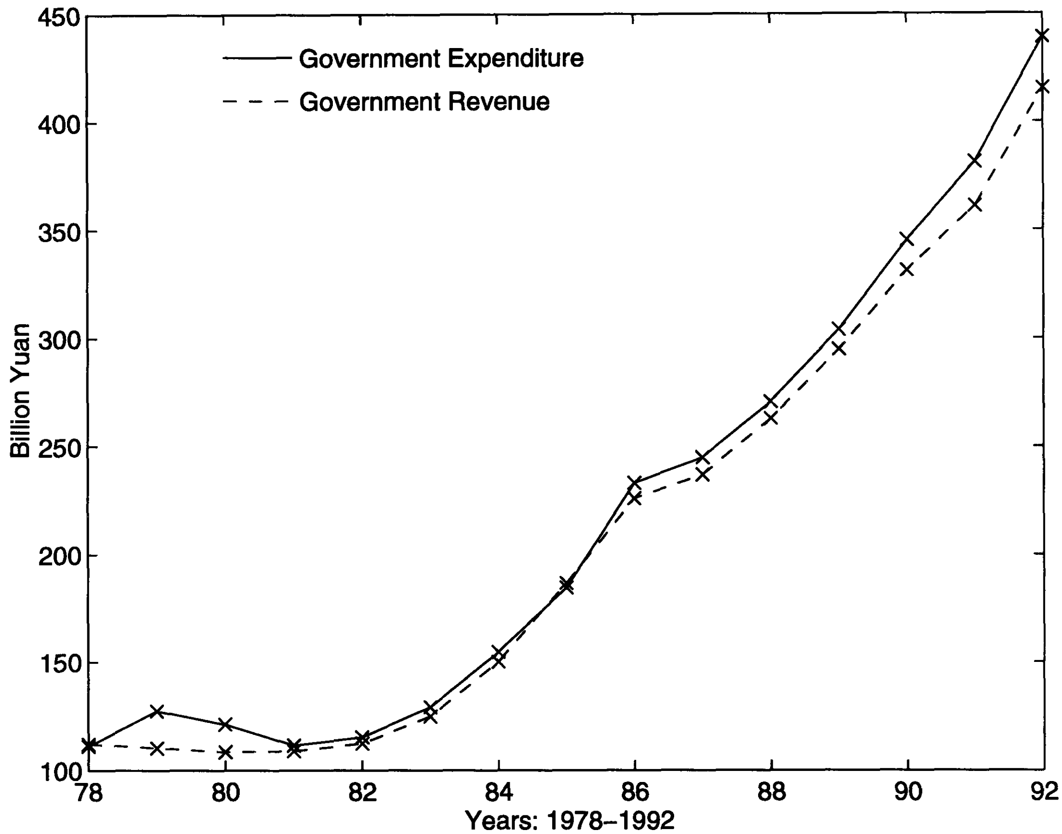
The increase in the money demand is the result of a small monetary base to start with and the absence of a liquid financial market. Before the reform, the money supply and demand were relatively small. As the reform went on, households' income went up. And since there was absent of a financial market, most saving was done in cash instead of other financial assets. As a result, the money demand went up. The increase in money demand matched the increase in money supply, and hence this greatly lessened the inflation pressure.

Starting from 1985, the inflation rate started to increase. It might be due to the excess supply of money through seignorage and the economic overheating in China. The inflation rate in 1988 has reached 18.5 percent and 15 percent in 1993. The Chinese government had to act decisively to put down the rapid growth in inflation in several occasions. The continuous economic growth in China will continuously generate inflation pressure to the society. This inflation pressure is going to be one of the toughest tasks that the Chinese government has to deal with in the future. The extent of the success of the Chinese economy is greatly depend on how much the Chinese government can keep the inflation at an acceptable low level.

3.5 The Problems

Although China has achieved tremendous success in the past fifteen years, a lot of problems still need to be overcome to maintain the growth opportunity. The

Figure 3-6: Government Revenue and Expenditure for the period 1978 to 1992



inflation problem mentioned in the previous section remains as one of the toughest problems. Growth without inflation seems impossible. The extent that the Chinese authority compromises inflation and economic growth will be of critical to her future. The outlook, however, is promising. We saw that the industrial output share of SOEs dropped from 75 percent in 1980 to 48 percent in 1992. If the trend continues and if the Chinese authority keeps encouraging and allowing more bankruptcies, or restructuring loss-making enterprises, the financial burden for the central government on supporting SOEs will be lessened. The need to finance through seignorage will then be less. It will surely help to reduce the inflationary pressure.

Another problem is the shrinking in tax base, as a result of decentralization and allowing local governments to retain part of the tax income, which forces the central government to continue running budget deficit. As mentioned before, the government revenue/GNP ratio fell sharply during the reform period and the Chinese government has been running budget deficit since 1979, see figure 3-6. Although the debt/GDP ratio was only 2.79 percent in 1992, which by international standard is comparatively small, it is going to be problematic in the long run if the situation has shown no progress.

The partial tax reform is also problematic. It encourages local governments to challenge the tax system both legally and illegally by exploiting extra-budgetary sources. The local governments can derive revenues from surcharges on various taxes and from fees levied on enterprises and particular activities, which are not incorporated in the unified budget [17].

The easy credits given by the People's Bank of China have caused the inflationary pressure. The easy credits also provided a distorted incentive for SOEs to invest. Even though the loans to SOEs are now carrying interest, the SOEs still do not have to bear huge financial responsibilities about the borrowings. Therefore, it may encourage the SOEs to invest in unprofitable investments. One thing worth to mention is the People's Bank of China's lack of independence from the government authorities. The monetary management of the bank is mainly driven by the political forces from both the local governments and political officials. In order to have efficient monetary policies, the central bank should have the ability to act independently irrespect to the political forces.

With the decentralization reform, the provincial authorities gained power and were filled with ambitious plans to boost the local economies. They do not bear macroeconomics responsibilities. It becomes extremely hard for the central government to persuade all the provinces to adapt common contractionary policies. This is especially true when the senior leaders do not have a common view point on how the economy should perform.

The gap of the economic performance between the coastal provinces and the interior provinces keeps widening. The difference in living standard of the people in these areas are kept increasing. This not only creates inequality among people, which contradict the communist ideology, but also causes millions of people moving from interior parts of the continent to the coastal areas. This "floating" population problem is going to cause social problem in the country, such as the job pressure in the coastal areas, the crime problem and the housing problem.

Whilst the income of the self-employed or those engaged in the production process increases rapidly during the last fifteen year, the growth in income for those engaged in the non-marketed services, such as education and health, is far lagged behind. In the long run, this phenomenon is going to cost the country since from the past experience, a country's prosperity is highly correlated to its technology level, which in turn, largely depends on the education level of its citizen. Ignoring the importance of education is going to slow down the development of the country into a powerful economy.

The road for the Chinese government will not be easy. How well the Chinese economy will be depends on how well the Chinese government can handle the above problems. It is not uncommon for a developing country to overcome many problems in order to success. With the history serving as the educational materials, China is likely to continue to success in her reform.

Chapter 4

Technical Background

The programming problem in the current context is concerned with the efficient allocation of limited resources, according to a certain objective. The aim of programming is to find a solution which optimizes the desired objective, and at the same time, satisfies all the conditions of the problem.

4.1 Linear Programming Model

The general form of a linear-programming problem is to find a set of independent variables' values x_{ij}'s which minimizes the objective function:

$$c_1x_1 + c_2x_2 + \cdots + c_jx_j + \cdots + c_nx_n \tag{4.1}$$

subject to the following linear constraints:

$$\begin{array}{ccccccccccc} a_{11}x_1 & + & \cdots & + & a_{1j}x_j & + & \cdots & + & a_{1n}x_n & + & z_1 & = & b_1 \\ a_{21}x_1 & + & \cdots & + & a_{2j}x_j & + & \cdots & + & a_{2n}x_n & + & z_2 & = & b_2 \\ \vdots & & & & \vdots & & & & \vdots & & \vdots & & \vdots \\ a_{i1}x_1 & + & \cdots & + & a_{ij}x_j & + & \cdots & + & a_{in}x_n & + & z_i & = & b_i \\ \vdots & & & & \vdots & & & & \vdots & & \vdots & & \vdots \\ a_{m1}x_1 & + & \cdots & + & a_{mj}x_j & + & \cdots & + & a_{mn}x_n & + & z_m & = & b_m \end{array} \tag{4.2}$$

and

$$x_j \geq 0 \qquad j = 1, 2, \ldots, n, n+1 \tag{4.3}$$

where a_{ij}, b_i, and c_j are given constants and $m < n$. And z_i is a slack variable when the constraints are inequalities and equal to 0 when the constraint is an equation. In the case where x can be negative, we can always write $x = x^+ + x^-$, $x^+ \geq 0$ and $-x^- \geq 0$. For a maximizing objective function, the settings are exactly the same except multiplying -1 to the objective function.

In vector form, the problem is to minimize:

$$f(\mathbf{X}) = \mathbf{cX} \tag{4.4}$$

subject to:

$$\mathbf{AX} + \mathbf{Z} = \mathbf{b} \tag{4.5}$$

or:

$$x_1\mathbf{P}_1 + x_2\mathbf{P}_2 + \cdots + x_n\mathbf{P}_n + \mathbf{Z} = \mathbf{P}_0 \tag{4.6}$$

and

$$\mathbf{X} \geq \mathbf{0} \tag{4.7}$$

where $\mathbf{c} = (c_1, c_2, \ldots, c_n)$ is a row vector, $\mathbf{X} = (x_1, x_2, \ldots, x_n)$ is a column vector, $\mathbf{A} = (a_{ij})$, $\mathbf{P}_j$, for $j = 1, 2, \ldots, n$, is the jth column of the matrix $\mathbf{A}$, $\mathbf{Z} = (z_1, z_2, \ldots, z_m)$ is a column vector, $\mathbf{b} = (b_1, b_2, \ldots, b_m)$ is a column vector, $\mathbf{P}_0 = \mathbf{b}$, and $\mathbf{0}$ is an n-dimensional null column vector.

4.2 Terminologies, Definitions and Theorems

Equation (4.1) is termed the objective function which is being minimized its value in the linear-programming process. Equation (4.2) and (4.3) are conditions that avoid making the value of the objective function infinitely small.

There are a couple standard definitions that describe the characteristics of a solution to the linear-programming problem:

Definition 1. A *feasible solution* to the linear-programming problem stated above is a vector $\mathbf{X} = (x_1, x_2, \ldots, x_n)$ which satisfies conditions (4.1) and (4.2).

Definition 2a. A *basic solution* to (4.2) is a solution obtained by setting $n - m$ variables equal to zero and solving for the remaining m variables, provided that the determinant of the coefficients of these m variables is nonzero. The m variables are called *basic variables.*

Definition 2b. A *basic feasible solution* is a basic solution which also satisfies (4.3).

Definition 3. A *minimum feasible solution* is a feasible solution which also minimizes (4.1).

Definition 4. An *optimal basic feasible solution* is a basic feasible solution which satisfies conditions (4.1), (4.2), and (4.3).

The method of finding the optimal basic feasible solution is based on five basic theorems in linear-programming. The theorems are stated without proof. The proofs can be find in [9].

Theorem 1. The set of all feasible solutions to the linear-programming problem is a convex set.

Theorem 2. The objective function (4.1) assumes its minimum at an extreme point of the convex set $\mathbf{K}$, where $\mathbf{K}$ is a bounded convex polyhedron, generated by the set of feasible solutions to the linear-programming problem. If it assumes its minimum at more than one extreme point, then it takes on the same value for every convex combination of those particular points.

Theorem 3. If a set of $k \leq m$ vectors $\mathbf{P}_1, \mathbf{P}_2, \ldots, \mathbf{P}_k$ can be found that is linearly independent and such that

$$x_1\mathbf{P}_1 + x_2\mathbf{P}_2 + \cdots + x_k\mathbf{P}_k + \mathbf{Z} = \mathbf{P}_0$$

and all $x_i \geq 0$, then the point $\mathbf{X} = (x_1, x_2, \ldots, x_k, 0, \ldots, 0)$ is an extreme point of the convex set of feasible solutions. Here $\mathbf{X}$ is an n-dimensional vector whose last $n - k$ elements are zero.

Theorem 4. If $\mathbf{X} = (x_1, x_2, \ldots, x_k)$ is an extreme point of $\mathbf{K}$, then the vectors associated with positive x_i form a linearly independent set. From this it follows that, at most, m of the x_i are positive.

Theorem 5. $\mathbf{X} = (x_1, x_2, \ldots, x_k)$ is an extreme point of $\mathbf{K}$ if and only if the positive x_j are coefficients of linearly independent vectors $\mathbf{P}_j$ in

$$\sum_{j=1}^{n} x_j \mathbf{P}_j + \mathbf{Z} = \mathbf{P}_0$$

From the theorems above, we can conclude that for each extreme point in the convex polyhedron, $\mathbf{K}$, it has m linearly independent vectors from the set $(\mathbf{P}_1, \mathbf{P}_2, \ldots, \mathbf{P}_n)$, and each extreme point corresponds to a basic feasible soluton. The objective function takes on its minimum at one of the extreme points in the polyhedron.

4.3 The Method

The procedure to solve a linear-programming problem can be divided into two stages. The first stage is to find a basic feasible solution from the given constraints, it can be done by using the artificial basis method together with the simplex method. The second stage is to use the simplex method to obtain a minimum feasible solution in a finite number of iterations, which is based on the basic feasible solution found in the first stage. Instead of getting into the mathematical details of both stages, the general ideas of finding solutions in both stages will be outlined in the following paragraphs. Interested readers can refer to [9]

The Simplex Procedure

Provided that the problem is feasible and a basic feasible solution is given, simplex procedure can find a minimum feasible solution in a finite number of steps, in which the value of the objective function decreases at each step. Suppose we have a solution vector $\mathbf{X} = (x_1, x_2, \ldots, x_m, 0, \ldots, 0)$ to start with and hence we have the following equation:

$$x_1\mathbf{P}_1 + x_2\mathbf{P}_2 + \cdots + x_m\mathbf{P}_m + \mathbf{Z} = \mathbf{P}_0 \tag{4.8}$$

where all $x_i \geq 0$. Since the vectors $\mathbf{P}_1, \mathbf{P}_2, \ldots, \mathbf{P}_m$ are linearly independent and form a basis for a m-dimensional vector space, all the n vectors $\mathbf{P}_j$'s can then be written as linear combinations of these basic vectors $\mathbf{P}_i$:

$$\sum_{i=1}^{m} x_{ij}\mathbf{P}_i = \mathbf{P}_j \qquad j = 1, \ldots, n$$

Now assume that we have

$$x_{1,m+1}\mathbf{P}_1 + x_{2,m+1}\mathbf{P}_2 + \cdots + x_{m,m+1}\mathbf{P}_m = \mathbf{P}_{m+1} \tag{4.9}$$

Then let θ be any number, and multiply (4.9) by θ and subtract the result from (4.8), we obtain

$$(x_1 - \theta x_{1,m+1})\mathbf{P}_1 + (x_2 - \theta x_{2,m+1})\mathbf{P}_2 + \cdots + (x_m - \theta x_{m,m+1})\mathbf{P}_m + \theta\mathbf{P}_{m+1} + \mathbf{Z} = \mathbf{P}_0 \tag{4.10}$$

The vector $\mathbf{X}' = (x_1 - \theta x_{1,m+1}, x_2 - \theta x_{2,m+1}, \ldots, x_m - \theta x_{m,m+1}, \theta)$ is another solution to the problem. Since it is impossible to have all the $m+1$ elements of $\mathbf{X}'$ positive at an extreme-point, from theorems (4) and (5), at least one of the elements of $\mathbf{X}'$ is zero. If we select θ_0 such that $x_1 - \theta_0 x_{1,m+1}$ equal to zero, the new feasible solution becomes

$$x_2'\mathbf{P}_2 + x_3'\mathbf{P}_3 + \cdots + x_m'\mathbf{P}_m + x_{m+1}'\mathbf{P}_{m+1} + \mathbf{Z} = \mathbf{P}_0$$

where

$$x_i^{'} = x_i - \theta_0 x_{i,m+1} \qquad i = 2, \ldots, m$$

$$\textit{and} \qquad x_{m+1}^{'} = \theta_0$$

The simplex procedure selects the appropriate value of θ at each step, which makes the value of the objective function decrease from the previous step. The process iterates itself until no more positive θ can be found. The last set of the solution vector found is the optimal feasible solution. The details of the method to choose θ and how the iteration is done without creating cycle are skipped here.

The Artificial-Basis Technique

The artificial basis method is used in the first step to find a basic feasible solution for the given constraints. This procedure can also determines whether the stated problem has any feasible solutions. The procedure starts with transforming the system stated by equations (4.1), (4.2), and (4.3) into an augmented system:

Minimizing

$$c_1 x_1 + \cdots + c_n x_n + w x_{n+1} + w x_{n+2} \cdots + w x_{n+m}$$

subject to

$$\begin{array}{ccccccccccccc} a_{11}x_1 & + & \cdots & + & a_{1n}x_n & + & z_1 & + & x_{n+1} & & & = & b_1 \\ a_{21}x_1 & + & \cdots & + & a_{2n}x_n & + & z_2 & & & + x_{n+2} & & = & b_2 \\ \vdots & & & & \vdots & & & & & \ddots & & & \vdots \\ a_{m1}x_1 & + & \cdots & + & a_{mn}x_n & + & z_m & & & & + x_{n+m} & = & b_m \end{array}$$

and

$$x_j \geq 0 \qquad j = 1, \ldots, n, n+1, \ldots, n+m$$

where w is taken to be a positive number. If the problem has a feasible solution, then the vectors, $\mathbf{P}_{n+1}, \mathbf{P}_{n+2}, \ldots, \mathbf{P}_{n+m}$, form an artificial basis for the augmented system. And the solution corresponding to this artificial basis is a feasible solution to the augmented system. Given this basic augmented feasible solution, the simplex method is then used to find a minimum feasible solution for this augmented system. All the artificial vectors are removed from this basis after the simplex procedure if the original system has a feasible solution. This condition is stated here without further proving. Hence this minimum feasible solution for the augmented system corresponds to a feaible solution to the original system. Regular simplex method is then applied to obtain the optimal solution.

4.4 Non-linear Programming

In the context of the current project, non-linear programming is basically the same as linear programming except the objective function is now a non-linear function. We can rewrite equation (4.1) as:

$$f(x_1, x_2, \ldots, x_j, \ldots, x_n) \tag{4.11}$$

The constraints of the problem in the current project are all linear. Therefore the technique described above can also be used to solve this non-linear problem without major modification. Note that the current content of non-linear programming is different from the normal non-linear programming practice. It is a special case of the general non-linear programming model. Interested reader can find more information about non-linear programming in [9].

Chapter 5

Economic Model

5.1 The Settings

The model used in the project is a multisector, intertemporal non-linear general equilibrium model. It was originally designed for investigating the energy policy in Egypt and was developed at the Center for Energy Policy and Environment Research at M.I.T. in 1989. The model was used again later, and a program was written to analyze the greenhouse gas emission phenomenon for the Indian economy. The model focuses on a single country's economic activities. It is implemented by a high level computer language - GAMS. In the current context, the model is used for predicting the economic activities in China, and at the same time, analyzing the population and labor movement trends within the urban and rural areas of China.

The model has a 60 years time horizon, which starts from 1990 to 2050. It is divided into thirteen five years simulation periods. The time horizon is chosen to 60 years to allow the effects of certain policies to be seen. The chosen five years per period is to avoid handling too much details in a year-to-year interaction during the dynamic solving process. This not only allows easier analysis, but also makes the program converge faster. The model uses 1990 data as base year data to predict the values of the Chinese macro-economic variables for the next 60 years.

The Chinese economy is divided into twenty one sectors, which is based on the official division. The sectors are Agriculture, Tree and forest, Livestock production,

Table 5.1: Sectors in China

Sectors	Symbol	Import Sectors	Export Sectors	Consumption Sectors	Investment Sectors	Production Sectors
Agriculture	agric	$\surd$	$\surd$	$\surd$	χ	$\surd$
Tree and forest	for	$\surd$	$\surd$	χ	$\surd$	$\surd$
Livestock production	liv	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
Coal mining	coal	$\surd$	$\surd$	$\surd$	χ	$\surd$
Crude petroleum	oil	$\surd$	$\surd$	χ	χ	$\surd$
Natural gas production	gas	χ	χ	$\surd$	χ	$\surd$
Other mining	min	$\surd$	$\surd$	χ	χ	$\surd$
Light industry	lighti	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
Electricity steam and hot water production	elec	$\surd$	$\surd$	$\surd$	χ	$\surd$
Petroleum refinery	ref	$\surd$	$\surd$	$\surd$	χ	$\surd$
Manufacturing of gas and coal products	coke	$\surd$	$\surd$	χ	χ	$\surd$
Chemicals industries	chem	$\surd$	$\surd$	$\surd$	χ	$\surd$
Manufacture of building materials	bldm	$\surd$	$\surd$	$\surd$	χ	$\surd$
Primary iron and steel manufacturing	fer	$\surd$	$\surd$	χ	χ	$\surd$
Primary non-ferrous metals manufacturing	nonfer	$\surd$	$\surd$	χ	χ	$\surd$
Manufacture of machinery and electronic	mach	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
Construction	con	χ	χ	χ	$\surd$	$\surd$
Rail transport	rail	χ	$\surd$	$\surd$	$\surd$	$\surd$
Other transport	othtr	χ	$\surd$	$\surd$	$\surd$	$\surd$
Services	serv	$\surd$	χ	$\surd$	$\surd$	$\surd$
Real estate	house	χ	χ	$\surd$	χ	$\surd$

Coal mining, Crude petroleum, Natural gas production, Other mining, Light industry, Electricity steam and hot water production, Petroleum refinery, Manufacturing of gas and coal products, Chemicals industries, Manufacture of building materials, Primary iron and steel manufacturing, Primary non-ferrous metals manufacturing, Manufacture of machinery and electronic, Construction, Rail transport, Other transport, Services, and Real estate. A list of the sectors in the model and their abbreviations are shown in table 5.1.

Among all the sectors, seven of them are energy sectors: forest, coal, oil, gas, electricity, refinery products and coke. Natural gas and petroleum refinery products are perfect substitutes for commercially use within the model. They are grouped into a sector called com-fuel. Each production sector can choose to use either gas or refinery products freely depending on which one is more cost efficient to that particular sector. Similarly, forest, refinery products, coal and gas are grouped into dom-fuel sector. They are perfect substitutes of each others from the households' view point.

The Chinese economy does not produce all the goods it needs. Some of them are acquired through import from other parts of the world. The goods that China imported are shown in the Import Sectors column in table 5.1. Similarly, the sectors export goods to foreign countries are shown in the Export Sector column. The households only consume some of the goods produced by certain sectors, and investment goods are produced by certain sectors only. The sectors which produce household consumption goods and investment goods are shown in table 5.1 with the column labelling Consumption Sectors and Investment Sectors respectively. The last column in table 5.1 shows that all the sectors used in the model produce goods for either final consumption or intermediate consumption, or both.

The general equilibrium model can be divided into two main modules: the economic module and the emission module. The economic module consists of equations and constraints that describe the Chinese economy as a whole. This module will predict the level of the economic activities in China for the period 1990 to 2050. The emission module, on the other hand, provides no constraint to the economy in general unless the government imposes certain emission regulations to the economy. It calculates the emission rate of different types of polluting gases based on the economic activity levels determined by the economic module. Within the scope of the current thesis, we do not use the results generated from the emission module. The module, however, is still retained as part of the model. It can be used in the future for further study on the Chinese economy.

The economic variables determined by the economic module are investment, capital capacity, urban and rural household consumptions, production by each sector, imports and exports, land availability for agricultural sector, urban and rural popu-

Table 5.2: Endogenous Variables in the Model

Variables	Abbreviation	Units
Total Discounted Utility	W	
Urban Consumption	C^U	Billion 1990 Yuan
Rural Consumption	C^R	Billion 1990 Yuan
Urban Domestic Fuel Mix	$DFUEL^U$	Billion 1990 Yuan
Rural Domestic Fuel Mix	$DFUEL^R$	Billion 1990 Yuan
Commercial Fuel Mix	$CFUEL$	Billion 1990 Yuan
Capital Stock	K	Billion 1990 Yuan
Addition to New Capital	ΔK	Billion 1990 Yuan
Production	X	Billion 1990 Yuan
Reserves	R	Natural Units
Investment	I	Billion 1990 Yuan
Imports	M	Billion 1990 US Dollars
Exports	E	Billion 1990 US Dollars
Foreign Debt Outstanding	D	Billion 1990 US Dollars
Foreign Borrowing	B	Billion 1990 US Dollars
Trade Deficit	F	Billion 1990 US Dollars
Land Availability	$LAND$	Billion 1990 Yuan
Urban Population	N^U	Million People
Rural Population	N^R	Million People
Total Urban Labor Force	UL	Million People
Total Rural Labor Force	RL	Million People
Incremental Urban Labor Force by Sector	$ULIN$	Million People
Incremental Rural Labor Force by Sector	$RLIN$	Million People
Labor Force by Sector	LAB	Million People
Labor Substitution by Sector	SUB	Million People
Unemployment Population	$UNEM$	Million People
Emissions from Fuel Use in Production	EFX	Billion Ton
Emissions from Fuel Use in Consumption	EFC	Billion Ton
Emissions from Production Processes	EX	Billion Ton
Emissions from Stocks of Animals	EK	Billion Ton
Emissions from all Sources	EM	Million Ton
Net Accumulation of Emissions	SEM	Million Ton

Table 5.3: Exogenous Variables in the Model

Exogenous Variables	Description
$\overline{FP}$	Foreign firms' profit remittances
$\overline{G}$	Government comsumption
$\overline{i}$	Interest rate on foreign debt
$\overline{I}^{1990}$	Total base year investment
$\overline{LAND}$	Total land supply for agricultural sector
$\overline{N}$	Total population
$\overline{P}^{e}$	World price of exports
$\overline{P}^{m}$	World price of imports
$\overline{T}$	Other foreign transfer to China
$\overline{W}$	Workers' remittances from foreign countries

lations, urban and rural labor forces, energy demand and supply, and relative prices. The emission module determines the carbon dioxide and methane emission level from fuel used in production and consumption, from the production processes, and from the stocks of animals. Table 5.2 shows a list of the endogenous variables in the model.

Besides having the model determines the endogenous variables, some of the variables are determined exogenously. Table 5.3 shows the exogenous variables used in the model. In addition, table 5.4 shows a list of the parameters. Parameters are estimated by the Chinese statistics before 1990.

5.2 The Model

The model consists of 47 high-level equations and constraints. Out of the 47 equations and constraints, 41 of them are basic macroeconomics constraints which outline the economic conditions of China; the other 6 constraints are used to calculate the emissions rate of the polluting gases. Each of the high level equation generally consists of a number of equations, ranging from one to twenty three equations or constraints.

Objective Function:

$$W = \sum_t (\frac{1}{1+\rho})^t (N_t^U U(C_{i,t}^U) + N_t^R U(C_{i,t}^R)) \qquad (5.1)$$

Table 5.4: Parameters in the Model

Parameter	Description
a	Input coefficients
b	Fraction of investment demand to technology by sector for new capital
d^{new}	Depreciation factor for new capacity
d^{old}	Depreciation factor for old capacity
e^{fall}	Maximum export decline factor
e^{rise}	Maximum export growth factor
g^{pop}	Total population growth rate
g^{res}	Natural growth rate for certain reserves
g^{term}	Capital stock terminal growth factor
g^{RL}	Maximum rural labor force decline factor
g^{UL}	Maximum urban labor force growth factor
$ICOR$	Incremental capital-output ratio for production
m^{fall}	Maximum import decline factor
m^{rise}	Maximum import growth factor
q	Value to quantity conversion factors for reserves
β	Marginal expenditure share
$\eta^{capital}$	capital productivity rate
η^{labor}	Labor productivity rate
η^{land}	land productivity rate
γ	Subsistance consumption level
ι^{R}	Maximum portion of rural labor force to rural population
ι^{U}	Maximum portion of urban labor force to urban population
μ	Bounds on commercial fuel mix
ν	Bounds on domestic fuel mix
ϕ^{R}	Maximum portion of new urban labor force for each sector to total new urban labor
ϕ^{U}	Maximum portion of new rural labor force for each sector to total new rural labor
ϕ^{UN}	Maximum portion of unemployment labors enter each sector
τ	Maximum mobility rate
ε^{pf}	Emissions coefficients for fuel use in production
ε^{cf}	Emissions coefficients for fuel use in consumption
ε^{p}	Emissions coefficients for production process
ε^{s}	Emissions coefficients for standing reserves
ϱ^{c}	Depreciation factor for new emissions
ϱ^{s}	Depreciation factor for old emissions stock
ϱ^{r}	Maximum depletion rates of reserves

$$U(C_{x,t}) = \sum_i \beta_i ln(\frac{C^x_{i,t}}{N^x_t} - \gamma_i) \qquad where \quad x = U, R \tag{5.2}$$

The first equation in the model is the welfare function or the objective function. It is the discounted sum of aggregate urban and rural consumer utilities. The objective of the model is to maximize the total discounted utility of consumption for all the simulation periods. The total utility level is the sum of all the urban consumers' utilities together with all the rural consumers' utilities. Although the consumption patterns in the urban areas may be different from that in the rural areas, the utility level of a urban and a rural consumer are calculated with the same formulation. Each consumer's utility is a weighted logarithmic sum over all consumption goods of the difference between the consumption level of each type of goods and a parametrically fixed consumption level. Each individual utility is then multiplied by the corresponding projected population to obtain the aggregate utilities for both urban and rural areas, the total utilities for different areas add up to give the total utility.

Material Balance Equations:

$$X_{i,t} + M_{i,t} = Z_{i,t} + C^U_{i,t} + C^R_{i,t} + \overline{G}_{i,t} + I_{i,t} + E_{i,t} \tag{5.3}$$

$$X_{i,t} = \sum_k X_{i,k,t} \tag{5.4}$$

$$Z_{i,t} = \sum_j \sum_k a_{i,j,k} X_{j,k,t} \tag{5.5}$$

The material balance equation states that the sum of the production of a given commodity by all possible technologies plus the imports of that commodity will be equal to the input demand for that commodity by all producing sectors plus the private consumption and public consumption in all periods. In other words, it means that the aggregate uses of the output should be no greater than the aggregate availabilities.

Population Equation:

$$\overline{N}_t = N^U_t + N^R_t \tag{5.6}$$

The total population is determined exogenously with a 1.48 percent growth per year. The urban and rural population, however, are determined endogenously by the model. The only constraint is these populations should add up to the total population. This setting implies the urban and rural people have the choice to move between urban and rural areas to find the best living environments for themselves, which maximize their total utility. With this setting, the "floating" population problem can be addressed by looking at the patterns of population size changing in both urban and rural areas.

Bound on the Total Labor Force:

$$UL_t \leq \iota^u N_t^U \tag{5.7}$$

$$RL_t \leq \iota^r N_t^R \tag{5.8}$$

The above two constraints state that the urban and rural labor force can only be of a certain proportion of the total urban and rural population. The parameters ι^u and ι^r are estimated from past year data.

Bound on Labor Movement:

$$UL_t \leq g_t^{UL} UL_{t-1} \tag{5.9}$$

$$RL_t \geq g_t^{RL} RL_{t-1} \tag{5.10}$$

The nature of the bounds on the labor movements in the urban and rural area are different. There is an upper bound for the urban labor size to increase, but a lower bound for the rural labor size to decrease. Having these constraints in the model, government policies on the flow of rural labor to the urban areas can be easily incorporated into the model.

New Increase in Labor Force:

$$\sum_j ULIN_{j,t} \leq UL_t - UL_{t-1} \tag{5.11}$$

$$\sum_j RLIN_{j,t} \leq RL_t - RL_{t-1} \quad (5.12)$$

The newly increased urban labor is distributed to different sectors. If the demand of the urban labor is less than the supply, then part of the newly increased urban labor becomes unemployed. Therefore, the sum of all increased urban labor from all sectors should be less than or equal to the increase in urban labor force size and the difference becomes the unemployed population. This same arguement applies to the rural labor force.

Labor Force Increase by Sector Constraints:

$$ULIN_{j,t} \leq \phi^U_{j,t}(UL_t - UL_{t-1}) \quad (5.13)$$

$$RLIN_{j,t} \leq \phi^R_{j,t}(RL_t - RL_{t-1}) \quad (5.14)$$

The increase in labor force for a particular sector can be at most a preset portion, ϕ, of the newly increase in labor force for both urban and rural areas.

Labor Substitution within Group of Industries:

$$\sum_{\forall i \in Group} SUB_{i,t} \leq \sum_{\forall i \in Group,k} \tau LAB_{i,k,t-1} \quad (5.15)$$

The sectors in the Chinese economy are grouped into a couple industrial groups. Labor within the same industrial group can move from one sector to another according to certain constraints. Labor, however, cannot move between different industrial groups. The above equation states that a portion τ of the labor from each sector is set free during each period and the freed labor can freely redistribute within the same industrial group. This setting represents the labor substitution with skill constraint among sectors.

Sectoral Labor Force Growth Constraint:

$$\sum_l LAB_{j,k,t} \leq \sum_l (1-\tau) LAB_{j,k,t-l} + SUB_{j,t} + ULIN_{j,t} + RLIN_{j,t} + \phi^{UN}_j UNEM_t \quad (5.16)$$

The total sum of the labor in each sector in the current period t is equal to the total sum of the labor that remains in the same sector at the end the previous period, $t-1$, plus the newly joined labor from other sectors, together with the newly added urban and rural labor, as well as those from previously unemployed.

Total Labor Force Balances:

$$UL_t + RL_t = \sum_{j,k} LAB_{j,k,t} + UNEM_t \tag{5.17}$$

The total of urban and rural labor force should equal to the sum of all labor in each sector plus the unemployed population.

Labor Constraint on Output:

$$X_{j,k,t} \leq \eta^{labor}_{j,k,t} LAB_{j,k,t} \tag{5.18}$$

The output of a sector using a particular technology is upper bounded by the availability of labor in that segment of the sector multiplied by the productivity of labor, η^{labor}, in using that technology.

Land Supply:

$$\sum_{k} LAND_{k,t} \leq \overline{LAND}_t \tag{5.19}$$

The constraint applies only to the agricultural sector. It states that the Yuan value of the total land used by different technologies in the agricultural sector should be less than or equal to the total Yuan value of the available lands. The total value of the available lands is determined exogenously and is growing at one percent per year.

Land Constraint on Output:

$$X_{agric,k,t} \leq \eta^{land}_{l,t} LAND_{k,t} \tag{5.20}$$

The output of the agricultural sector by each technology is constrainted by the corresponding land availability. The land productivities, η^{land}, are set to be growing at a specific rate. In the current setting, the productivity for technology 3 is growing at a rate that is greater than that of technology 2, which in turn greater than that of technology 1. As a consequence, the model encourages the use of more advanced technology in producing agricultural products.

Capacity Definition:

$$K_{i,k,t} = K_{i,k,t}(1 - d_{i,k}^{old}) + d_{i,k}^{new} \Delta K_{i,k,t} \tag{5.21}$$

The above equation defines how much capital is available at each period. The production capacity in a sector in a given period is defined as the capacity in the previous period, minus the fraction that has depreciated, plus the additions to the production capacity in the present period.

Capacity Constraint:

$$X_{i,k,t} \leq \eta_{j,k,t}^{capital} K_{i,k,t} \tag{5.22}$$

The capacity constraint simply puts an upper limit of how much output that can be produced by each technology in each sector for each time period, given the available capital goods. With this capital setting, the same commodity can be produced by different technologies with different input patterns. The total output of each sector is the sum of the output from all techologies within that sector. Therefore, there is possibility of inputs substitution in the production process which depends on the relative prices of inputs and outputs for each technology. The model then chooses the most efficient input patterns to maximize the total utility.

Energy Reserves Depletion:

$$R_{i,t} = (1 + g_i^{res})^5 R_{i,t-1} - (\frac{5}{2})(\frac{1}{q_i}) \sum_k (X_{i,k,t} + X_{i,k,t-1}) \tag{5.23}$$

The energy reserves that are left at the beginning of the period are equal to the reserves in the previous period, after adjusting for the natural growth of the reserves, minus the average of the usage in the last two periods. Since the reserves and the output are in different units, the output is divided by a conversion factor, q_i, to maintain consistency. Another possilbe way to define q_i is to relate the reserve to input instead of output. This is a perfectly legitimate way. The current definition of q_i is used without specific reason.

Reserves Production Constraint:

$$\sum_k X_{i,k,t} \leq \varrho_i^r q_i R_{i,t} \tag{5.24}$$

The maximum amount in producting tree and forest products, animals, oil, natural gas and coal in any given year is constrainted, due to technical reasons, to a fraction of the total remaining reserves. The ϱ^r states the maximum portion of the total reserves that can be used in a given year, which in a sense serves as the limitation of the available technologies to extract the resources.

Production function:

$$X_{i,k,t} \leq \max[\eta_{j,k,t}^{labor} LAB_{j,k,t}, \eta_{k,t}^{land} LAND_{i,k,t}, \eta_{j,k,t}^{capital} K_{i,k,t}, \varrho_i^r q_i R_{i,t}]$$

The above capital, land and labor settings actually mean that capital, land and labor are perfectly insubstitutes of each others within the economic model. The least available factor gives the upper bound of the possible output level on a technology by technology and sector by sector basis. In addition, the availability of the reserves also constraints the possible output level. The above equation shows the actual production function. Of course, there is no land constraint on all the sectors except on agriculture, and the reserve constraint only applies to the reserve sectors which include for, liv, oil, gas and coal.

Sectoral Deliveries to Investment:

$$I_{i,t} \geq \sum_{j,k} b_{i,j,k} ICOR_{j,k} \Delta K_{j,k,t+1} \tag{5.25}$$

The above inequality states that the total consumption of a particular investment good from all production sectors should not be greater than the supply of that investment good.

Capital Terminal Growth:

$$\sum_k K_{i,k,2055} \geq (1 + g_i^{term}) \sum_k K_{i,k,2050} \tag{5.26}$$

The minimum capital stock growth rate is set at 5% in 2055, the last period in the model. The purpose of this setting is to make sure that the economy is still growing at the end of the simulation period and there has production of capital goods for future use. Otherwise, the model may choose to stop growing at the ending period which not only do not make sense at 2050, but also will affect the conclusion that can be drawn in the earlier periods.

Bounds on Domestic Fuel Mixing:

$$DFUEL^U_{idf,t} \geq \mu_{min,idf} C^U_{dom\_fuel,t} \tag{5.27}$$

$$DFUEL^U_{idf,t} \leq \mu_{max,idf} C^U_{dom\_fuel,t} \tag{5.28}$$

$$DFUEL^R_{idf,t} \geq \mu_{min,idf} C^R_{dom\_fuel,t} \tag{5.29}$$

$$DFUEL^R_{idf,t} \leq \mu_{max,idf} C^R_{dom\_fuel,t} \tag{5.30}$$

As mentioned in sector 5.1, households have the abilities to substitute one fuel to the others in response to the relative costs of using different fuels. The above constraints determine the extent of such substitution possibility. Upper and lower limits are provided for both urban and rural consumption and are set exogenously. The same bounds are used for both urban and rural consumption in the current setting.

Bounds on Commerical Fuel mixing:

$$CFUEL_{icf,t} \geq \sum_{i,k} \nu_{min,icf,k} a_{com\_fuel,i,k,t} X_{i,k,t} \tag{5.31}$$

$$CFUEL_{icf,t} \leq \sum_{i,k} \nu_{max,icf,k} a_{com\_fuel,i,k,t} X_{i,k,t} \tag{5.32}$$

The above bounds are similar to the bounds on domesic fuel mixing, except that they apply to the input of the production processes instead of consumption. In addition, the types of fuel allowed to substitute are different from those used in consumption. Since the production processes do not distinguish urban and rural production, one upper bound and one lower bound are used for all sectors.

Trade Deficit:

$$F_t = \sum_i M_{i,t} - \sum_i E_{i,t} \tag{5.33}$$

Trade deficit, F_t, is just simply defined as the difference between aggregate imports and aggregate exports.

Net Borrowing Definition:

$$B_t = F_t + \bar{i}_t D_t + \overline{FP}_t - \overline{W}_t - \overline{T}_t \tag{5.34}$$

The net borrowing, B_t, of the Chinese economy in a given year is equal to the sum of the trade deficit F_t, the interest payment on the total debt $\bar{i}_t D_t$, and the foreign firms' profit repatriations out of China $\overline{FP}_t$, minus the oversea workers' remittances to China $\overline{W}_t$ and other foreign transfer to China $\overline{T}_t$. $\bar{i}_t$, $\overline{FP}_t$, $\overline{W}_t$, and $\overline{T}_t$ are determined exogenously.

The Foreign Debt Accounting Equation:

$$D_t = D_{t-1} + \frac{5}{2}(B_t + B_{t-1}) \tag{5.35}$$

The total foreign debt at year t is equal to the debt outstanding in the previous period plus the amount borrowed in the years between the previous period and the current period.

Base Year Constraint in the Demand for Investment Goods:

$$\sum_{i,t} I_{i,t} \leq \overline{I}^{1990} \tag{5.36}$$

The above equation states that the total demand for investment goods by all sectors in the base year 1990 cannot exceed the total investment goods available in the base year. The model can allocate the available investment goods to different sectors according to the economic conditions in the base year.

Import Constraint:

$$M_{i,t} \geq (1 - m_{i,t}^{fall})M_{i,t-1} \tag{5.37}$$

$$M_{i,t} \leq (1 + m_{i,t}^{rise})M_{i,t-1} \tag{5.38}$$

An upper bound and a lower bound on the changes in imports are set. The import cannot fall more than $m_{i,t}^{fall}\%$ a year from period to period and cannot rise faster than $m_{i,t}^{rise}\%$ a year. These two import constraints apply to all the Import sectors shown in Table 5.1 except for the oil and petroleum refinery sectors. These two sectors' imports are constrainted by the following constraint:

Maximum Import of Oil and Petroleum Refinery Product:

$$M_{i,t} \leq 0.1(\frac{1}{\overline{P}_{i,t}^{m}})\sum_{k} X_{i,k,t} \tag{5.39}$$

The oil and petroleum refinery sector do not have import in the base year. The oil and refinery products, however, are expected to import in the future. With the previous setting, the model will never predict there exists imports for these two sectors. Therefore, instead of linking the import levels of these two sectors to the previous period import levels, the import levels are directly related to the level of outputs with the above constraint. As a result, even though there is no import in the base year, imports in the future are possible.

Export Constraint:

$$E_{i,t} \leq (1 + e_{i,t}^{rise})E_{i,t-1} \tag{5.40}$$

$$E_{i,t} \geq (1 - e_{i,t}^{fall})E_{i,t-1} \tag{5.41}$$

Similarly, the exporting sectors are subjected to the same kind of constraints as the importing sectors. The growth in export cannot be faster than $e_{i,t}^{rise}\%$ a year, and cannot fall faster than $e_{i,t}^{fall}\%$ a year.

The above 41 equations outline the macro-economic conditions of the Chinese economy and they, as a whole, constitute the economic module of the model. The following 6 equations calculate the amount of polluting gas emitted based on the economic conditions predicted by above equations.

Emission Definitions:

$$EFX_{emi,i,t} = \sum_{j,k} \varepsilon^{pf}_{emi,i} a_{i,j,k,t} X_{j,k,t} \tag{5.42}$$

$$EFC_{emi,i,t} = \varepsilon^{cf}_{emi,i}(C^U_{i,t} + C^R_{i,t}) \tag{5.43}$$

$$EX_{emi,j,t} = \sum_{k} \varepsilon^{p}_{emi,j} X_{j,k,t} \tag{5.44}$$

$$EK_{emi,j,th} = \sum_{k} \varepsilon^{s}_{emi,j} X_{j,k,t} \tag{5.45}$$

The above four equations define how much polluting gas is emitted at a particular level of economic activites. Equation (5.42) defines the amount of emission from the fuels used in production. It is the corresponding emission coefficients multiplied by the level of fuel inputs in the production.

Equation (5.43) defines the level of the polluting gas emission from the fuels used in the consumption process. The level of emission is the corresponding emission coefficient multiplied by the total consumption, the sum of urban and rural consumption, of the corresponding fuel.

Equation (5.44) defines the amount of the polluting gas emitted from the production process. For example, the carbon dioxide generated by the paddy fields. The amount of the emitted gas is the sum of all corresponding emission coefficient multiplied by the level of output of the corresponding sector.

Equation (5.45) defines the amount of the polluting gas emitted from the standing stocks, which are expressed in terms of output. For example, methane emission from swamps. The amount of emitted gas is the corresponding emission coefficient multiplied by the corresponding output level of each sector.

Total Emissions:

$$EM_{emi,t} = \sum_{i} EFX_{emi,i,t} + \sum_{i} EFC_{emi,i,t} + \sum_{j} EX_{emi,j,t} + \sum_{j} EK_{emi,j,t} \tag{5.46}$$

Total emission is simply the sum of all the emissions from all sectors and all sources. It is the sum of the emission from fuels used in production and consumption, the emission from the production processes and the emission from standing stocks.

Accumulated Net Emissions:

$$SEM_{emi,t} = \varrho^{s}_{emi,t} SEM_{emi,t-1} + \varrho^{c}_{emi,t} (\frac{EM_{emi,t} + EM_{emi,t-1}}{2}) \tag{5.47}$$

The accumulated net emission of the polluting gas is equal to the previous period accumulated net emission multiply with the depreciation factor of the old emission stock, plus the amount of emissions between the previous and current period multiply with an adjusted depreciation factor.

Chapter 6

Methods of Approach

The aim of the current research work is to find the patterns of the population and labor movements between the urban and rural areas of China by simulating the Chinese economy with a general equilibrium model. In addition to predict the movement patterns, we can also predict how certain government policies on population and labor movements would affect the economy as a whole.

The first step is to construct a basic scenario to find out the patterns of the movements, as well as for future comparisons. The basic scenario will have no explicit control on population and labor movement. The rate of growth of the total population is set exogenously at a rate of 1.48 percent per year. The total labor force can be at most 57 percent of the total population. All the above parameter values are estimated from the data before 1990. The people and labor can move between urban and rural areas without any explicit constraint. There are labor substitutions among sectors which require similar skills. The basic scenario allows five percent of labor in each sector to switch to other sectors at the end of each five years period. And at most fifteen percent in total of the original unemployed labor can go back to the agriculture, light industry and service sector after a period, with five percent for each sector as a maximum.

In order to avoid presenting too many details, and facilitate the discussion, we will limit ourselves to concern with only a couple parameters. Table 6.1 shows the parameters that are going to be changed in different scenarios and their corresponding

Table 6.1: Changing Parameters and Their Corresponding Basic Scenario Values

Parameters	Descriptions	Values
g^{pop}	Total population growth rate	1.48
g^{RL}	Maximum rural labor force decline factor	∞
g^{UL}	Maximum urban labor force growth factor	∞
τ	Maximum mobility rate	5%

values in the basic scenario. In addition, because of the artificially setting of terminal conditions at 2050, we are only interested in the first 40 years , 1990 - 2030, economic behaviors of the Chinese economy, even though the model has a 60 years time horizon.

After constructing the basic scenario, we can then proceed to construct other scenarios to analyze the effects of different government population and labor movement policies. In general, we can divide the possible policies into the following categories:

1. Government policies on the total population growth;
2. Government policies on the urban and rural population movement;
3. Government policies on the urban labor movement;
4. Government policies on the rural labor movement;
5. Government policies on unemployment;

The government can constrain the total population growth rate by employing certain policies as discussed in Chapter 2. Since the basic setting is to have population grow at a rate of 1.48 percent per year, in order to see the effect of constraining population growth, we propose the following scenarios:

1. to encourage more population growth:
   - set the total population growth at 2 percent a year;
2. to have stricter birth control policy:
   - set the total population growth at 1 percent a year; and

- does not allow the total population grow at all;

The Chinese government can also impose restrictive policies on population movement. For example, at an extreme case, it can set up customs at all the ports of the urban areas, and only allow people who have the permits to enter to the city areas. Therefore, the Chinese government can have perfect control on the population movement between rural and urban areas. Because the total population growth rate is set exogenously, setting a limit on the increase in urban population size also simultaneously sets a limit on the increase in rural population size. We can have the following scenarios to see the effects of different population movement policies on the economy:

- limit the urban population to grow at a maximum rate of 5 percent a year, which corresponds to about a maximum of 0.2 percent increase in rural population in year 1990;

- limit the urban population to grow at a maximum rate of 3 percent a year, which corresponds to about a maximum of 1 percent increase in rural population;

- limit the urban population to grow at a maximum rate of 2 percent a year, which corresponds to about a maximum of 1.3 percent increase in rural population; and

- limit the urban population to grow at a maximum rate of 1.48 percent a year, which is equal to the natural population growth. And hence the maximum growth in rural population is also 1.48.

Instead of controlling the population movement directly, the Chinese government can also control the labor movement to affect the sizes of urban and rural population by providing more or less job opportunities in the city and countryside areas. It can also force the labor to stay in their corresponding areas. The Chinese authority can do so because there still exists large protion of labor force working in the SOEs, and it can create or destroy job opportunities by setting up or closing SOEs in the desired areas. Because of the existence of unemployment, an increase in the urban labor force does not necessarily mean a decrease in the rural labor force or vice versa. Therefore, the Chinese government has the flexibility to control the urban labor force size and the rural labor force size separately. To constrain the growth of urban areas labor force, we can have the following scenarios:

- allow the urban labor force to grow at a maximum rate of 3 percent a year;
- allow the urban labor force to grow at a maximum rate of 2 percent a year;
- allow the urban labor force to grow at a maximum rate of 1.48 percent a year, which is the natural population growth rate; and
- allow only at most 1 percent of urban labor force to grow.

To constrain the decline of the rural areas labor force, we can have the following simulations:

- allow at most 3 percent rural labor force to decline;
- allow at most 1 percent rural labor force to decline; and
- no decline in rural labor force at all.

The Chinese government can also set limits on the unemployment rate. It is a special privilege for communal countries to have a nearly direct control on the unemployment rate, although not necessary an efficient way to allocate labor. Since most labor in China depends on the government job allocation, therefore, if the government wants to increase the labor participation and reduce the unemployment rate, it can keep running the inefficient SOEs to allocate more jobs opportunities for labor. On the other hand, if the Chinese authority decides to close unprofitable SOEs, then the unemployment rate will shoot up. So in addition to the above scenarios, we can have the following:

- allow a maximum rate of 3 percent increase in unemployment rate each year; and

Table 6.2: Scenarios to be Run

Scenarios	Descriptions
1	Basic scenario
2	Total population grows at 2% a year
3	Total population grows at 1% a year
4	No growth in total population
5	Maximum 5% annual growth in urban population
6	Maximum 3% annual growth in urban population
7	Maximum 2% annual growth in urban population
8	Maximum 1.48% annual growth in urban population
9	Maximum 3% a year urban labor force growth
10	Maximum 2% a year urban labor force growth
11	Maximum 1.48% a year urban labor force growth
12	Maximum 1% a year urban labor force growth
13	Maximum 3% rural labor force decline per year
14	Maximum 1% rural labor force decline per year
15	No decline in rural labor force
16	Declining unemployment rate at 1% per year
17	Maximum 3% increase in unemployment rate per year

- force the unemployment rate to decline at a rate of 1 percent a year.

Table 6.2 presents a summary of the scenarios that are going to run in this thesis.

Chapter 7

Result and Analysis

Base case

Table 7.1 shows the values of the simulated macro economic variables for the period 1990 to 2030; table 7.2 shows the corresponding simulated annual growth rates for the same period. From the tables, we notice that there always exist initial jumps from the 1990 period to 1995 period. The existence of such jumps is unconventional in a developing economy. In here, we provide three possible explanations to the observed jumps:

1. The economic model is incorrect;

2. There simply exists such jumps in the Chinese economy; and

Table 7.1: Simulated Macro Economic Variables Values

Variables	1995	2000	2005	2010	2015	2020	2025	2030
IMPORTS	106.10	129.37	200.39	331.51	605.55	1173.90	2004.82	2905.12
EXPORTS	78.85	89.55	145.68	254.48	496.30	1014.58	1789.20	2610.48
R-CON[a]	416.85	517.15	678.13	885.50	1189.19	1470.40	1920.84	2381.20
U-CON[b]	800.25	892.78	1039.90	1371.44	1711.00	2155.54	2860.70	3753.77
INVEST	492.04	681.98	940.09	1223.58	1567.76	2053.17	2503.02	3018.31
GDP	1921.98	2355.28	2990.09	3895.90	4985.85	6319.36	8091.94	10164.56
GOV-CON[c]	245.72	313.60	400.25	510.83	651.96	832.08	1061.97	1355.38

[a] Rural Consumption
[b] Urban Consumption
[c] Government Consumption

Table 7.2: Simulated Macro Economic Variables Annual Growth Rate

Variables	1995	2000	2005	2010	2015	2020	2025	2030	1990-2030
IMPORTS	-0.88	4.05	9.15	10.59	12.81	14.16	11.30	7.70	8.51
EXPORTS	-14.78	2.58	10.22	11.80	14.29	15.37	12.02	7.85	6.98
R-CON[a]	-6.26	4.41	5.57	5.48	6.08	4.34	5.49	4.39	3.61
U-CON[b]	11.48	2.21	3.10	5.69	4.52	4.73	5.82	5.58	5.36
INVEST	1.01	6.75	6.63	5.41	5.08	5.54	4.043	3.82	4.77
GDP	1.60	4.15	4.89	5.44	5.06	4.85	5.07	4.67	4.46
GOV-CON[c]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

[a] Rural consumption
[b] Urban consumption
[c] Government consumption

3. The base year data are not fully consistent.

The first explanation is possible but unlikely. It is because the economic model has been used before in analyzing the Egyptian and Indian economy. The previous runs did not possess such unexpected initial jumps. The chance of having jumps only in the Chinese model but not the previous models is slim.

The second explanation is possible but again unlikely. First of all, it is unlikely for an economy to have such big changes in a five years period unless there are abrupt changes in the political system or the country faces serious natural disasters in the period. By the time of writing this thesis, more than half of the period has passed, and none of the above situations has happened so far[1], and it is unlikely to have an abrupt change in the political system in the near future. Secondly, based on the 1991 to 1993 observation, we do not see such jumps occurring. If the Chinese economy does have the jumps in the initial period, the magnitude of the changes of such economic variables in the 1994 and 1995 years will be huge, and it is extremely unlike to occur. As a result we conclude that the first and second explanation do not properly explain the puzzled jumps.

It is possible for the base year data not to be fully consistent and is likely to be the case in the current situation. Most of the technology coefficients for input - the

[1] The flooding disasters in the southern part of China in 1994 did not have too great an impact to the economy as a whole.

coefficients related the input to the output for each technology used in each sector, and technology coefficients for investment - the coefficients related the amount of investment to the number of capital goods delivered for each technology used in each sector, are brought in by Professor Zhang from China. It is not uncommon that the data prepared by the Chinese authority sometimes contain ambiguity. Therefore, the data set used in the model may not be completely consistent. In addition, some of the data required by the model are not available. At a result, Professor Eckaus and Professor Zhang were required to use their expert judgment to estimate some of those data. Therefore, the third explanation may be the most proper explanation to the initial jump. After the initial period, the model settles at an equilibrium position and the simulated 1995 data set becomes a set of consistent estimates for the next simulation period. Hence, the changes in the economic variables thereafter become reasonable.

From the table, we see that the Chinese GDP is expected to grow at an average 4.46 percent per year rate for the 1990 to 2030 period. It is by no means a high growth rate, but still far lower than those for the past fifteen years. Because a prolong high economic growth period is impossible to sustain, in recent years, economists have been questioning how long the Chinese economy can maintain such high growth rates. The simulation results suggest with a "not long" answer. The simulation suggests that the maximum average growth rate is 5.5 percent per year in a five year period. The double digit growth period is not going to happen again in the future once the Chinese market gets into a more mature phase in her development.

The model also predicts that there will be a huge expansion in the trade sectors of the Chinese economy. If we ignore the initial period data, the import sector will grow at a rate of 9.92 percent per year, while the export sector will grow at an even higher rate - 10.5 percent per year. The rapid expansion of the trade sectors is expected if the Chinese authority continues to carry the open door policy. The huge resource and population base in China provide a huge market for trading. Because of the low living standard to start with and the rapid economic growth, the demand for foreign goods and the ability to supply goods to foreign countries are going to drastically

Table 7.3: Population Trends

	1990	1995	2000	2005	2010	2015	2020	2025	2030
TOTAL	1143.33	1230.48	1324.27	1425.21	1533.84	1650.76	1776.58	1912.00	2057.74
RURAL	841.33	629.44	645.48	691.95	694.34	747.17	788.22	824.70	854.46
URBAN	302.00	601.04	678.79	733.26	839.50	903.58	988.37	1087.30	1203.27

Table 7.4: Population Growth Rate

	1995	2000	2005	2010	2015	2020	2025	2030	1990-2030
TOTAL	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
RURAL	-5.64	0.51	1.40	0.07	1.48	1.08	0.91	0.71	0.04
URBAN	14.76	2.46	1.56	2.74	1.48	1.81	1.93	2.05	3.52

increase in the future. The Chinese economy, as a result, is going to benefit from the huge trade sectors.

The model predicts that the trade will expand up to more than 50% of GDP in 2030 if the open door policy remains in place. Since the Chinese economy is huge, and if trading accounts for half of its GDP, her trade sectors will become the largest in the world by the year 2030. As a result, whatever the trading policy implemented by the Chinese authority will have a great impact on the world economy. The Chinese government's role in the international trade platform will become a lot more important, and the Chinese authority is likely to hold a leading role in the international trade issues.

Table 7.3 shows the predicted total population figures as well and the predicted urban and rural population figures. Table 7.4 shows the corresponding population

Table 7.5: Labor Force Trends

	1990	1995	2000	2005	2010	2015	2020	2025	2030
TOTAL	571.32	654.80	710.33	766.89	835.63	897.05	950.10	1007.55	1082.32
RURAL	431.22	358.78	367.92	394.41	395.77	425.89	449.28	470.08	487.04
URBAN	154.29	342.59	386.91	417.96	478.52	515.04	563.37	619.76	685.87
UN-EMP	14.19	46.58	44.51	45.48	38.66	43.88	62.56	82.29	90.59

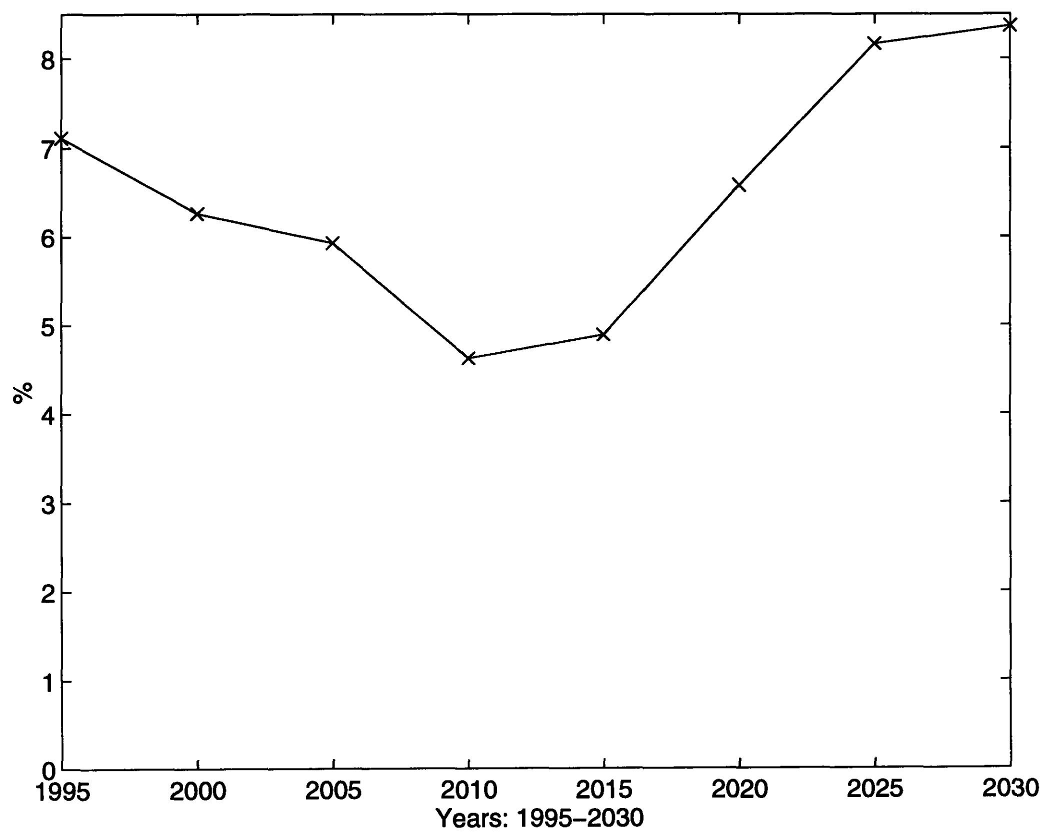
Table 7.6: Labor Force Growth Rate

	1995	2000	2005	2010	2015	2020	2025	2030	1990-2030
TOTAL	2.77	1.64	1.54	1.73	1.43	1.16	1.18	1.44	1.61
RURAL	-3.61	0.51	1.40	0.07	1.48	1.08	0.91	0.71	0.31
URBAN	17.30	2.46	1.56	2.74	1.48	1.81	1.93	2.05	3.80
UN-EMP	26.84	-0.91	0.43	-3.20	2.57	7.35	5.64	1.94	4.75

growth rates for the periods. Table 7.5 contains the labor force figures for both urban and rural areas in addition to the total employed labor. The unemployed population has also been shown in the table. Table 7.6 contains the corresponding labor forces and unemployment growth rates.

The total population is exogenously set to have a 1.48 percent growth. The initial period annual growth rates for both urban and rural populations and labor forces have the same initial unusual big jumps as other macro economic variables have. Some general conclusions, however, can be drawn from the jumps, depending on the sign of the jumps. From the simulated results, there are huge increases in the urban population and urban labor force, at the expense of rural population and rural labor force respectively. In addition, the unemployment rate jumps up instead of jumping down. Therefore, the Chinese economy is likely to have a unstable urban to rural ratio in populations and labor forces in the base year 1990. Therefore the results imply that the urban to rural ratios should be a lot higher in the base year. This is coincided with the current "floating" population problem in which a huge number of rural people are moving to the urban cities to search for better jobs and better livings. Furthermore, it is generally believed that the unemployment figure is underestimated by the Chinese government. Even if the true unemployment rate of the economy is started at such a low level, there are a lot of half-employed labor working in the inefficient SOEs. The implied unemployment rates estimated by the model for the period 1995 to 2030 are much higher than the initial period, and are shown in figure 7-1. The unemployment rate reaches as high as 8.4 percent in the period 2025 to 2030 when the economy slow down to have a 4.67 percent growth in GDP. The unemployment rate, on the other hand, can be as low as 4.6 percent in the 2005

Figure 7-1: Implied Unemployment Rate for the period 1995 to 2030



to 2010 period when the economy is doing relatively well with GDP growing at 5.44 percent per year. The lowest implied unemployment rate, however, is still far above the 2.3 percent unemployment rate in 1992 claimed by the Chinese officials.

The model chooses to have a total labor force always at 57 percent of the total population, which is the maximum percentage allowed by the setting of the model. The employed labor force, however, only constitutes 92 to 96 percent of the total work force in various simulation periods. The model chooses to have maximum work force and have an unemployment population instead of having just enough work force is because there is no cost of unemployment in the setting. The existence of the unemployment also implies that there is no possible productive use of those unemployed labor, and other factors are more scarce than the labor factor. This is because if the excess labor can be used to produce something, the model would choose to have fully employed. And since there are not enough capitals, lands or resources to supplement the labor, part of the labor force becomes unemployed. Since we know that labor in the current agricultural sector requires little complementary, the results imply that as the population grows, the increase in the labor force cannot be fully employed even with the current relatively labor intensive technologies.

figure 7-2 shows the trends of population growths in urban and rural area as percentages of the total population, while figure 7-3 shows the corresponding growths for the labor forces. Both graphs show similar trends of the population and labor movement. The urban population and labor force start at low percentages and jump up rapidly in the first period. After that, both proportions of urban population and labor force increase gradually throughout the whole simulation period. They begin to have a larger share of the total than their rural counterparts after the second simulation period, and the gaps are widening as time goes on. The phenomenon is reasonable since China is going through a series of modernizations. Industrialization and urbanization are main components in the development. As a result, the agricultural sector in the countrysides becomes less important, while the industrial sector in the urban areas gains momentum. The advancement of the country can only be facilitated by a shift of people and labor from rural areas to urban areas.

Figure 7-2: Percentage of Urban and Rural Population to the Total Population

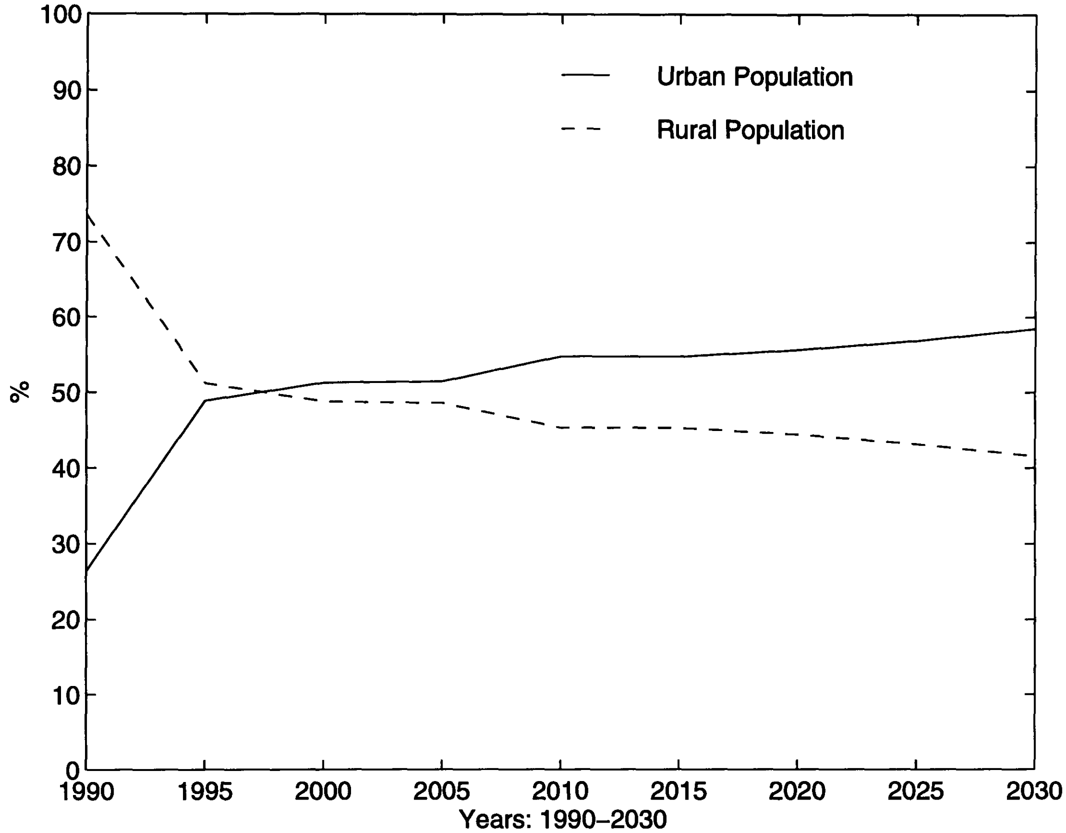


Figure 7-3: Percentage of Urban and Rural Labor Force to the Total Labor Force

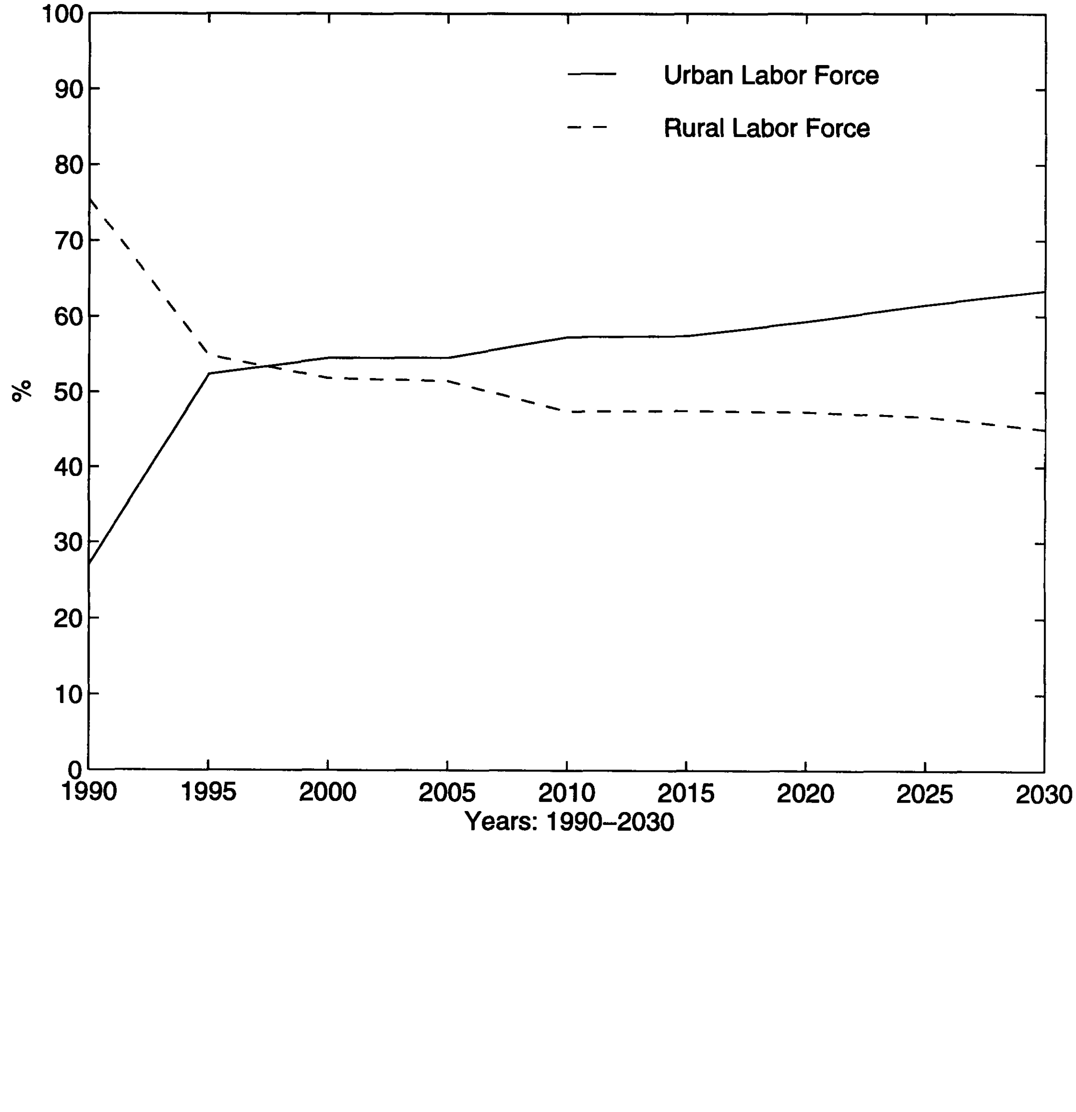
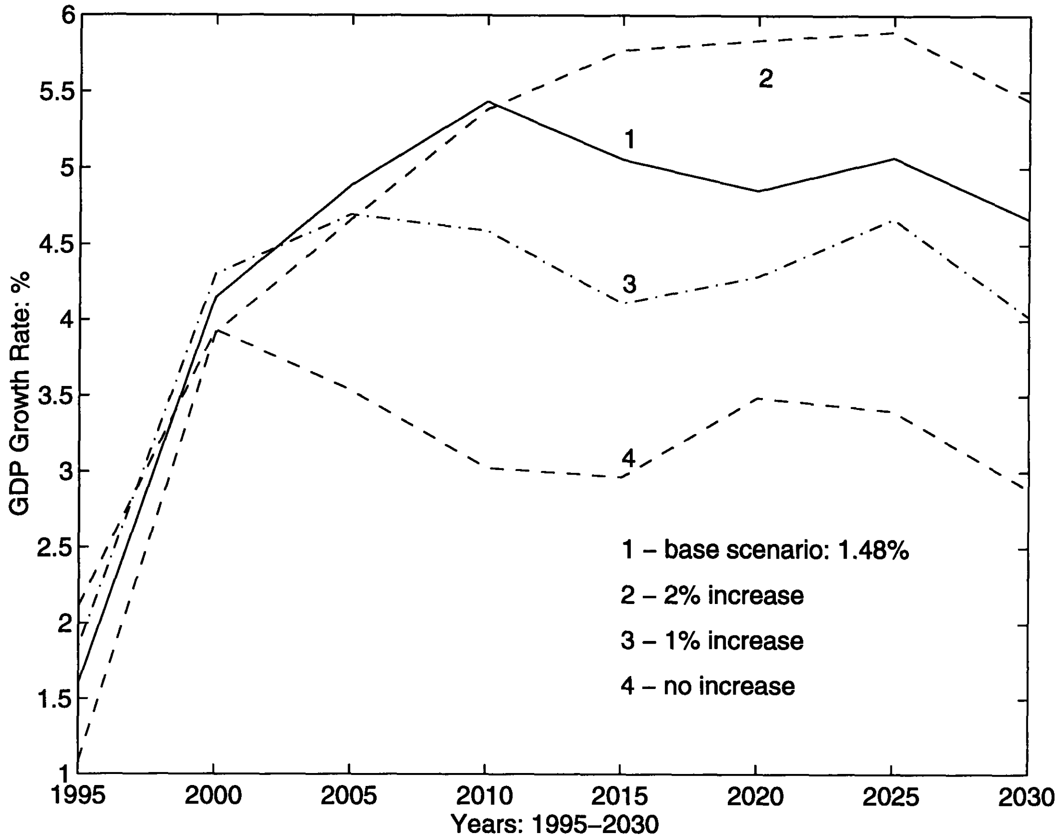


Figure 7-4: Effects of Different Rates of Population Increase on GDP

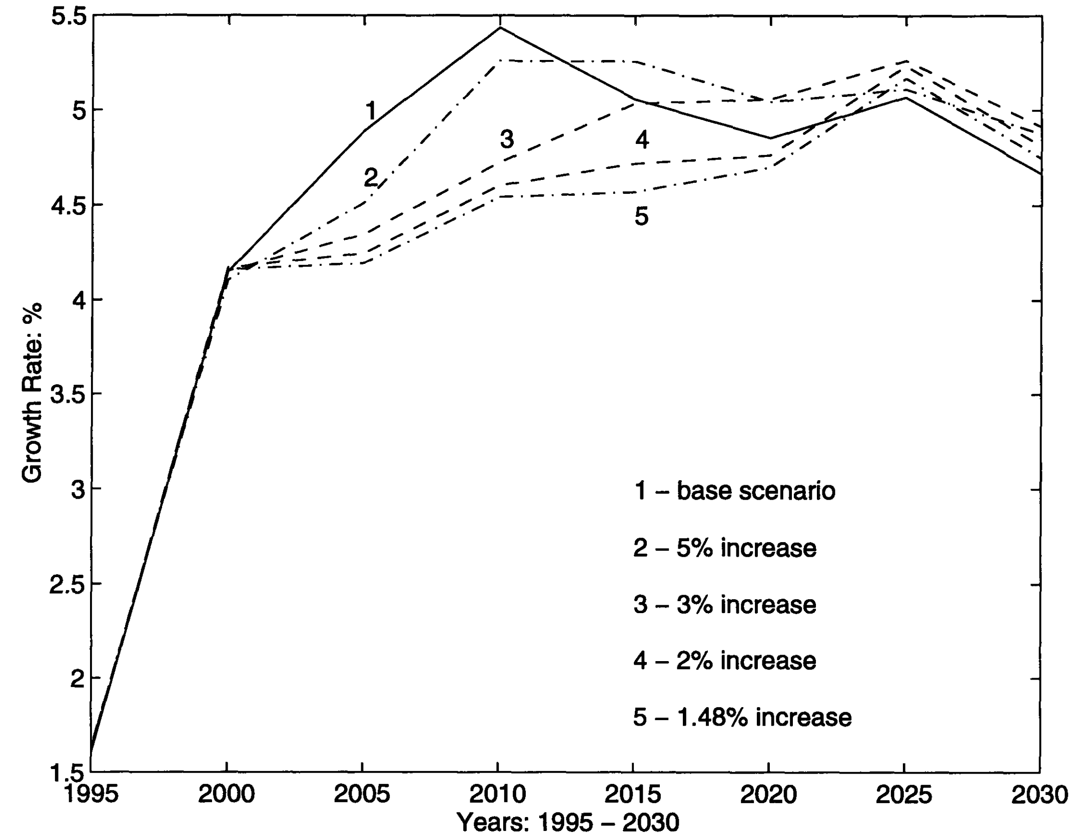


Government Policies on Total Population

The relationship between different policies on total population growth and the GDP values for the period 1995 to 2030 are shown in figure 7-4. A general conclusion can be drawn from the simulated results. The faster the growth of the total population, the faster the economic growth. Although China havs a large population currently, the economy will still be benefited if the government allows the population to grow at a high rate. If the Chinese authority decides to hold the population constant, the average growth rate of the economy for the next 40 years can only achieve 3.17 percent, which is far below the 4.46 percent in the basic scenario. Therefore, the Chinese government has to choose between rapid economic growth and the huge population size problems. One thing needs to keep in mind is that the model does not explicitly take the social problems created by over-populated into its objective function directly. The adverse effects only affect the objective function indirectly. Therefore, those adverse effects of over-populated problems are only treated as secondary effects, which may create a bias towards having more populated. In addition, the model does not have substitution of capital for labor. So the output of the society cannot grow if the labor force size is not increasing. This may also exaggerate the importance of increasing labor force size.

The major reason to have a better economy when the population increases is that there has more labor available for production and hence the total output of the society increases if the increased labor goes into the production units. This explanation seems to contradict to the previous discussion, section 7, that the economy simply does not have enough resources to supplement the labor and the excess labor are not productive at all. If we, however, take a closer look at the 2 percent increase in population scenario and the basic scenario, we find that the results are totally consistent. We notice that although the higher population growth will result a more vigorous economy in the long run, in short run, however, the faster growing population causes more problems to the economy. The economy can only achieve a lower growth rate for the first couple periods. From figure 7-4, the GDP growth in the 2 percent increase in population scenario is constantly less than that in the basic scenario until 2015, if we ignore the initial unstable period. After 2015, the 2 percent case takes the lead. And this is consistent with the observed implied unemployment rate in the basic scenario, figure 7-1. The implied unemployment rate from the basic scenario is relatively high to start with and then graduately drops to its lowest level in 2010. This implies that the economy is adjusting its labor market in this early period. and the economy will find it more difficult to incorporate the excess labor force into the economy if there are more labor available, as in the 2 percent case. Once the the simulation reaches 2010 and the economy has developed a better method to allocate excess labor, the positive effect of larger labor force then kicks in. Therefore, we conclude that larger population size will only benefit the economy in the long run, but causes more troubles in short run.

Figure 7-5: Effects of Different Restrictions on Urban Population Growth



Government Policies on Urban and Rural Population Movement

Figure 7-5 shows the GDP growth rates of different scenarios. The scenarios are

- the basic scenario: no restriction on population movement;
- allowing a maximum of 5 percent increase in urban population;
- allowing a maximum of 3 percent increase in urban population;
- allowing a maximum of 2 percent increase in urban population; and
- allowing a maximum of 1.48 percent increase in urban population.

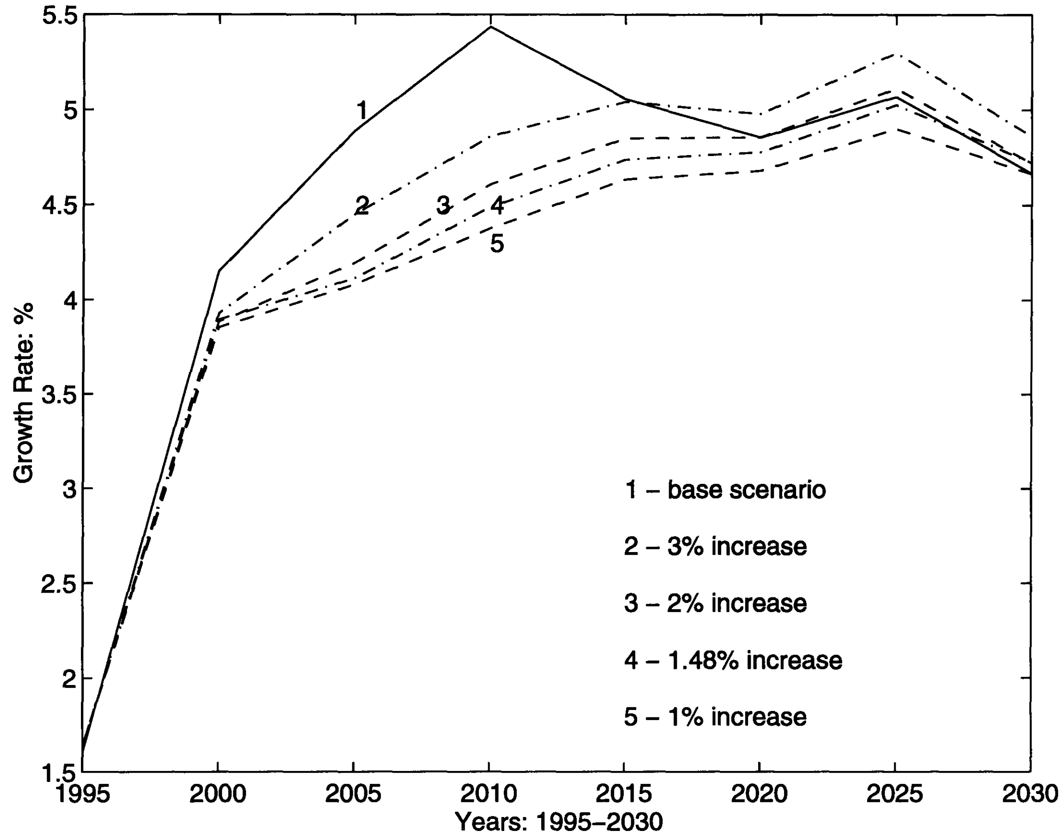
The simulated results suggest that, in general the more the freedom in population movement, the higher the GDP growth rate for the next fifteen years. The trend is kind of reversed after 2010, with an optimal policy of 3 or 5 percent allowance in urban population growth.

In the basic scenario, there is no explicit restriction in the growth of the urban population. We see from the graph that the economy rapidly achieves a vigorous growth in the short run, but slows down after the growth reaches its height in 2010. The economy fluctuates a lot in comparison to the other scenarios and performs worse than others in the long run. The absolute GDP value, however, is higher in the no restriction case.

The linear-programming model is set to choose the highest absolute values for the objective function but pays no regard to the trends of the economic variables as long as the patterns are consistent with all the constraints. In addition, it does not explicitly take the adverse effects of overcrowding problems into account. So a high value of the objective function does not necessarily imply an excellent economic condition for the country. Country planners, on the other hand, need to consider the pattern of the economic growth and prevent fluctuations to occur. They are also required to take externalities into account when planning out for the economy. As a result, although the model gives the basic scenario the highest objective value, without further considering of other aspects of the simulation results, we cannot conclude that the basic scenario is the best case for a country. In addition, the model may overestimate the GDP growth rate since there is no direct account for the overcrowding problems, specifically in the urban areas in the current case. As a result, the no restriction policy may not be the optimal policy to adopt. The 3 percent increase in urban population policy does not generate a rapid growth in short run but it has less fluctuation and is more optimal in the long run. The 5 percent increase in urban population policy produces a faster growth in short run, but with more fluctuations and worse performance than the 3 percent case in the long run.

In conclusion, it may be wiser for the Chinese government to constrain the population movement in the earlier periods so as to achieve a higher economic growth in the long run. If the Chinese authority is myopic and applies no control in the population movement, the Chinese economy can achieve a vigorous growth in the coming

Figure 7-6: Effects of Different Rules on Urban Labor Movement on GDP



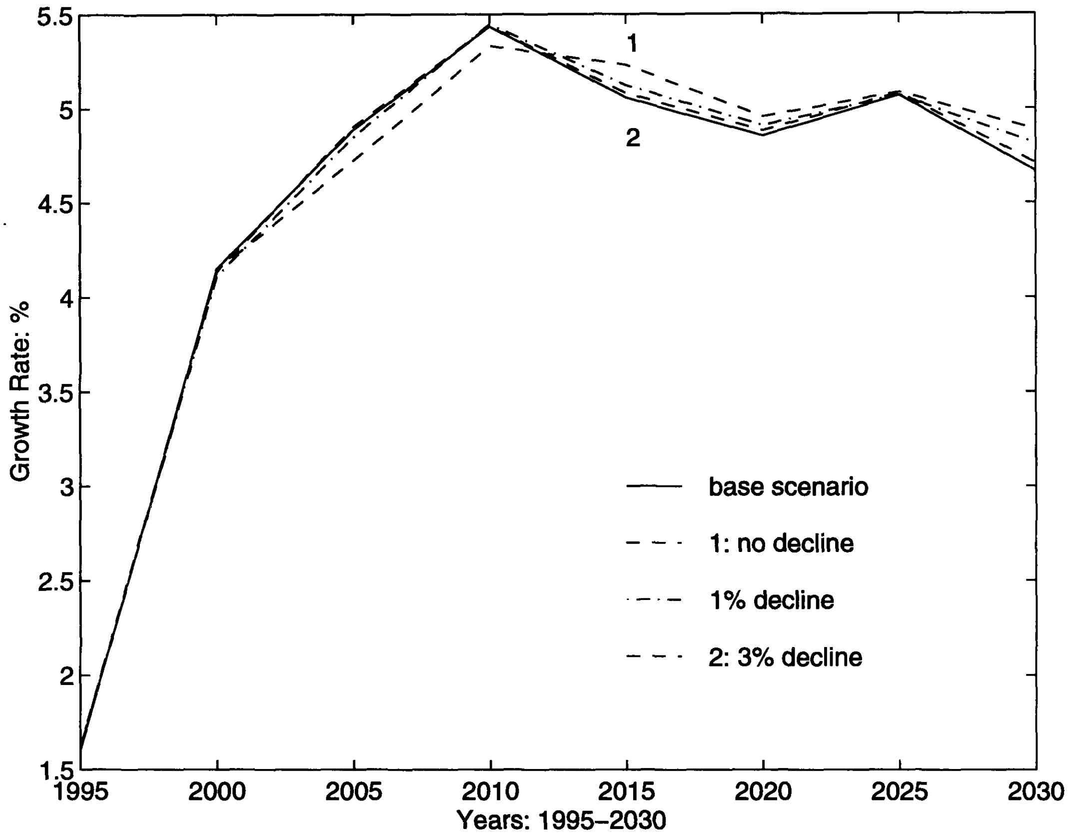
10 to 15 years, but at the same time, generates economic and social problems that are created by the sudden huge increase in urban population.

Government Policies on Urban Labor Movement

The different effects of different restrictions about the urban labor movement on the GDP growth rates are shown in figure 7-6. The basic scenario provides no restriction on urban labor movement, where the other scenarios have posed a maximum of 3, 2, 1.48 and 1 percent increase in the urban labor force. The observation is similar to that in the previous section: the greater the allowance in the growth of urban labor force, the greater the economic growth. The economy, however, will perform worse in the long run if no restriction is imposed on the urban labor force size.

The conclusions drawn from the simulations are also more or less the same as that are drawn in previous section. The Chinese government will be better off if

Figure 7-7: Effects of Different Rules on Rural Labor Movement on GDP



it can have a longer vision on its economy and applies labor movement controls in the urban areas. The huge number of labor inflow into the urban areas in the basic scenario seems to cause a long term problem to the economy, even though it creates an immediately vigorous expansion. A step by step, controlled relaxation of urban labor force size provides a less fluctuated and a more long-lasting growing economy.

Government Policies on Rural Labor Movement

The effects of various rural labor movement policies on the GDP are shown in figure 7-7. The scenarios are no restriction in rural labor movement - basic scenario, no decline in rural labor force, a maximum of 1 percent decline, and a maximum of 3 percent decline in rural labor force. To a first order approximation, the differences among the various scenarios are negligible, contrary to the comparsions made in previous sections. As a result, the restrictions on the rural labor force seem to provide less distortions to the economy than the restrictions on urban labor movement.

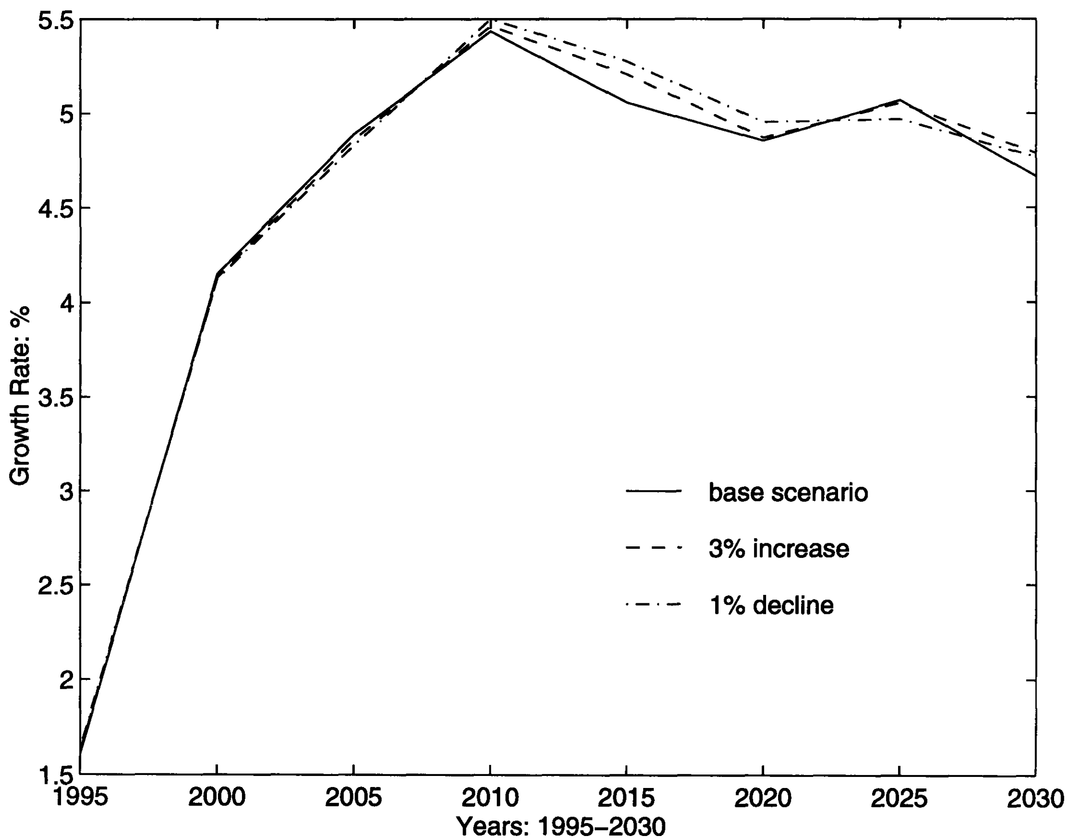
The less distortion observation may be explained as follow. Since we know that the urban areas are developing rapidly, there exists excess labor demand in the urban cities, and hence causes a huge increase in the size of urban labor force at the expense of rural labor force if no restriction on labor movement is imposed. In the current cases, we, however, restrict the declination of rural labor force, and as a consequence, restrict the number of rural labor to work in the urban areas so as to fill the excess labor demand in the cities. As a result, instead of hiring people from the rural areas, the urban industries recruit people who are not originally in the labor force, for example women, to join to the urban industries. Therefore, the total urban labor force expands without significantly shrinking the size of the rural labor force. And the result is to provide a less distorted impact on the rural industries, while keeping the urban industries growing at reasonable fast paces.

The explanation is further supported by the observation that the population movement in the current case is more or less the same as that in the constraining urban labor movement case. As a result, we can conclude that the restriction policies on rural labor are more effective and produce less distortion to the economy than the restrcition policies on urban labor.

Government Policies on Unemployment

The effects of various government policies on unemployment to GDP growth rate are shown in Figure 7-8. The scenarios are no restriction, a maximum of 3 percent increase, and a minimum of 1 percent decline in the unemployment population. Similar to the policies in rural labor movement, there is no major distortion to the economy in applying restrictions on the unemployment rate. The primary reason for such an observation is that although many people are working, a lot of them are not working in the most efficient way or supplemented with enough capitals. Therefore, taking some of them out from the employment does not have a great impact on the economy. Although the differences among various scenarios are not significant, it seems that the more vigorous the restrictions on unemployment rate are, the better the economy will

Figure 7-8: Effects of Different Unemployment Policies on GDP



perform. The results seem to be counter-intuitive in the first sight. If we, however, recall from Chapter 6 that how the reduction in unemployment rate is enforced, we know that the Chinese government will keep running the inefficient SOEs to lower the unemployment rate. Therefore, the results from the simulation suggest that even though the SOEs are inefficient, their existence will still add positive value to the society. As a result, the Chinese government can force the excess labor to stay in their own units without severely affecting the economy.

Chapter 8

Conclusion and Future Works

8.1 Conclusion

The model predicts that the Chinese economy will still be growing at a high rate, 4.5 percent per year on average, but can no longer grow at a rate comparable to the nearly double digits growth as in previous fifteen years. Its trade sector becomes huge and extremely important. It will constitute more half of the GDP by the year 2030. As a result, we can expect that China is going to become one of the most influential political and economical superpowers in the near future.

The simulation results have shown that the urban population size will increase at a much faster rate than the rural population size. The rural population size grows at 0.04 percent a year if no control has imposed on the population movement, while the natural growth for the country as a whole is 1.48 percent a year. As a result, there will be a massive migration from rural areas to urban areas which means the current "floating" population problem is likely to continue in the future. The problems associated with the massive migration are not predicted from the simulation but can be expected to be some social problems, such as over-crowding, job pressure and increasing crime rate in the urban areas as well as labor shortage in the rural areas. The reason for such massive migration is the result of the modernizations happening in China. The urbanization and industrialization in the development process create simply such a shift of people and labor.

The implied unemployment rate from the simulation is far higher than that of the officially claimed. The implied unemployment rates for the simulated period range from 4.6 to 8.4 percent depending on the contemporary economic conditions. From the experiences in the developed countries, we see that these higher implied rates are more reasonable for an efficient economy to sustain. The existence of such unemployment also implies that as the population grows, the increase in the labor force cannot be fully employed even with the current relatively labor intensive technologies.

Even though huge population size causes problems, the model still suggests that a larger population size will be more beneficial to the Chinese economy in the long run. We, however, need to keep in mind that the model does not take the adverse effects of huge population size directly into its objective function, therefore, there may exist a bias for the model to choose a larger population size. If the Chinese authority decides to impose population and labor movement constraints, a restriction on the rural labor movement will provide less distortions to the society. The reason is when the movement of rural labor is constrained, it will create a labor shortage in the urban areas because of the high demand. As a result, the urban industries start to recruit people who are not originally in the labor force and hence the total labor force size increases, and there will have less adverse impacts on both the urban and rural industries.

One interesting implication from the simulated results is that the SOEs has its value to the society although they are grossly inefficient. They can serve as a place to accommodate excess labor as well as add values to the society output. The model predicts when the Chinese authority is trying to suppress the unemployment rate by allocating the excess labor to work in the inefficient SOEs, the economy will perform better than having the excess labor unemployed. We, however, can expect that the beneficial effect of forcing labor to work in SOEs diminishes as the market reform gets into a more mature and complete phase.

8.2 Future Works

The major obstacle to the analytical work in this thesis is the incompleteness of the available data set. Due to the limited time available, a completely consistent set of data is unable to obtain. In order to have a more precise prediction of the future Chinese economic conditions, a more accurate set of data, however, is necessary. Therefore, we leave the searching for a more complete data set to the future researchers who will continue this project.

With the current program available, it will be relatively easy to continue the research on air pollution issue in China. The current program already has the energy module, section 5.1, incorporated. The results from the energy model, however, are not used in the current analysis. Future analysis on the energy policies in China can make use of this existing program.

Besides the above two suggestions for future works, there are some minor modifications can be made to the model. The first and the most obvious modification is to change the total population variable from exogenous to endogenous. Special consideration, however, is needed when constraining how fast the total population size can be increased or decreased.

Secondly, the model does not allow substitution of capital for labor. This substitution ability can be added to the model in the future. The substitution function between capital and labor, however, should be carefully chosen. For example, if we choose a linear substitution function, since we are using linear-programming technique, the solution will likely to stay at an extreme point, in other words, the model is likely to use capitals only or labor only.

As mentioned in section 5.2, the urban and rural discounted consumption utility function are the same. We, however, know that when the same basket of goods is consumed, the urban people will have different utility levels than the rural people. So the next step in modifying the model is to have different discounted utility functions for urban and rural people.

Another important modification that can be made to the objective function is to take the adverse effects of over-crowding directly into the formulation. As a result, the population and labor movement patterns as well as their effects to the society can be more accurately estimated.

The final remark on the modification is to add the age distribution into the model. In general, youngsters are more willing and easier to move from one place to the other than the old. Therefore, the incorporation of age distribution effect into the model should help in the analysis of the population and labor movement.

Appendix A

Equations and Constraints

Objective Function

$$W = \sum_t (\frac{1}{1+\rho})^t (N_t^U U(C_{i,t}^U) + N_t^R U(C_{i,t}^R)) \tag{A.1}$$

$$U(C_{x,t}) = \sum_i \beta_i ln(\frac{C_{i,t}^x}{N_t^x} - \gamma_i) \qquad where \quad x = U, R \tag{A.2}$$

Accounting Identities

$$X_{i,t} + M_{i,t} = Z_{i,t} + C_{i,t}^U + C_{i,t}^R + \overline{G}_{i,t} + I_{i,t} + E_{i,t} \tag{A.3}$$

$$X_{i,t} = \sum_k X_{i,k,t} \tag{A.4}$$

$$Z_{i,t} = \sum_j \sum_k a_{i,j,k} X_{j,k,t} \tag{A.5}$$

$$F_t = \sum_i M_{i,t} - \sum_i E_{i,t} \tag{A.6}$$

$$B_t = F_t + \bar{i}_t D_t + \overline{FP}_t - \overline{W}_t - \overline{T}_t \tag{A.7}$$

Population and Labor Identities

$$\overline{N}_t = N_t^U + N_t^R \tag{A.8}$$

$$UL_t + RL_t = \sum_{j,k} LAB_{j,k,t} + UNEM_t \tag{A.9}$$

Labor Bounds and Substitution Constraints

$$UL_t \leq \iota^u N_t^U \tag{A.10}$$

$$RL_t \leq \iota^r N_t^R \tag{A.11}$$

$$UL_t \leq g_t^{UL} UL_{t-1} \tag{A.12}$$

$$RL_t \geq g_t^{RL} RL_{t-1} \tag{A.13}$$

$$\sum_j ULIN_{j,t} \leq UL_t - UL_{t-1} \tag{A.14}$$

$$\sum_j RLIN_{j,t} \leq RL_t - RL_{t-1} \tag{A.15}$$

$$ULIN_{j,t} \leq \phi_{j,t}^U (UL_t - UL_{t-1}) \tag{A.16}$$

$$RLIN_{j,t} \leq \phi_{j,t}^R (RL_t - RL_{t-1}) \tag{A.17}$$

$$\sum_{\forall i \in Group} SUB_{i,t} \leq \sum_{\forall i \in Group,k} \tau LAB_{i,k,t-1} \tag{A.18}$$

$$\sum_l LAB_{j,k,t} \leq \sum_l (1-\tau) LAB_{j,k,t-l} + SUB_{j,t} + ULIN_{j,t} + RLIN_{j,t} + \phi_j^{UN} UNEM_t \tag{A.19}$$

Production Constraints

$$X_{j,k,t} \leq \eta_{j,k,t}^{labor} LAB_{j,k,t} \tag{A.20}$$

$$\sum_k LAND_{k,t} \leq \overline{LAND}_t \tag{A.21}$$

$$X_{agric,k,t} \leq \eta_{l,t}^{land} LAND_{k,t} \tag{A.22}$$

$$X_{i,k,t} \leq \eta_{j,k,t}^{capital} K_{\imath,k,t} \tag{A.23}$$

$$\sum_k X_{i,k,t} \leq \varrho_i^r q_i R_{i,t} \tag{A.24}$$

Investment Constraints

$$I_{i,t} \geq \sum_{j,k} b_{i,j,k} ICOR_{j,k} \Delta K_{j,k,t+1} \tag{A.25}$$

$$\sum_{k} K_{i,k,2055} \geq (1 + g_i^{term}) \sum_{k} K_{i,k,2050} \tag{A.26}$$

$$\sum_{i,t} I_{i,t} \leq \overline{I}^{1990} \tag{A.27}$$

Fuel Substitution Constraints

$$DFUEL^{U}_{idf,t} \geq \mu_{min,idf} C^{U}_{dom_fuel,t} \tag{A.28}$$

$$DFUEL^{U}_{idf,t} \leq \mu_{max,idf} C^{U}_{dom_fuel,t} \tag{A.29}$$

$$DFUEL^{R}_{idf,t} \geq \mu_{min,idf} C^{R}_{dom_fuel,t} \tag{A.30}$$

$$DFUEL^{R}_{idf,t} \leq \mu_{max,idf} C^{R}_{dom_fuel,t} \tag{A.31}$$

$$CFUEL_{icf,t} \geq \sum_{i,k} \nu_{min,icf,k} a_{com_fuel,i,k,t} X_{i,k,t} \tag{A.32}$$

$$CFUEL_{icf,t} \leq \sum_{i,k} \nu_{max,icf,k} a_{com_fuel,i,k,t} X_{i,k,t} \tag{A.33}$$

Trade Constraints

$$M_{i,t} \geq (1 - m_{i,t}^{fall}) M_{i,t-1} \tag{A.34}$$

$$M_{i,t} \leq (1 + m_{i,t}^{rise}) M_{i,t-1} \tag{A.35}$$

$$M_{i,t} \leq 0.1 (\frac{1}{\overline{P}^{m}_{i,t}}) \sum_{k} X_{i,k,t} \tag{A.36}$$

$$E_{i,t} \leq (1 + e_{i,t}^{rise}) E_{i,t-1} \tag{A.37}$$

$$E_{i,t} \geq (1 - e_{i,t}^{fall}) E_{i,t-1} \tag{A.38}$$

Dynamic Linkages

$$K_{i,k,t} = K_{i,k,t}(1 - d_{i,k}^{old}) + d_{i,k}^{new} \Delta K_{i,k,t} \tag{A.39}$$

$$R_{i,t} = (1 + g_i^{res})^5 R_{i,t-1} - (\frac{5}{2})(\frac{1}{q_i}) \sum_k (X_{i,k,t} + X_{i,k,t-1}) \tag{A.40}$$

$$D_t = D_{t-1} + \frac{5}{2}(B_t + B_{t-1}) \tag{A.41}$$

Emission Equations

$$EFX_{emi,i,t} = \sum_{j,k} \varepsilon_{emi,i}^{pf} a_{i,j,k,t} X_{j,k,t} \tag{A.42}$$

$$EFC_{emi,i,t} = \varepsilon_{emi,i}^{cf}(C_{i,t}^U + C_{i,t}^R) \tag{A.43}$$

$$EX_{emi,j,t} = \sum_k \varepsilon_{emi,j}^p X_{j,k,t} \tag{A.44}$$

$$EK_{emi,j,th} = \sum_k \varepsilon_{emi,j}^s X_{j,k,t} \tag{A.45}$$

$$EM_{emi,t} = \sum_i EFX_{emi,i,t} + \sum_i EFC_{emi,i,t} + \sum_j EX_{emi,j,t} + \sum_j EK_{emi,j,t} \tag{A.46}$$

$$SEM_{emi,t} = \varrho_{emi,t}^s SEM_{emi,t-1} + \varrho_{emi,t}^c (\frac{EM_{emi,t} + EM_{emi,t-1}}{2}) \tag{A.47}$$

Bibliography

[1] Gary Jefferson Alan Gelb and Inderjit Singh. Can communist economies transform incrementally? the experience of china. 1993.

[2] Judith Banister. *China's Changing Population.* Stanford University Press, Stanford, California, 1987.

[3] The World Bank. *China Reform and the Role of the Plan in the 1990s.* 1992.

[4] State Statistical Bureau. *China Statistical Yearbook.* Beijing, China, 1993.

[5] Eliana Cardoso and Shahid Yusuf. Red capitalism: Growth and inflation in china. 1994.

[6] Supriya Lahiri Charles R. Blitzer, Richard S. Eckaus and Alexander Meeraus. A general equilibrium analysis of the effects of carbon emission restrictions on economic growth in a developing country. 1990.

[7] Samuelson P. Dorfman, R. and R. Solow. *Linear Programming and Economic Analysis.* McGraw-Hill Book Company, New York, 1958.

[8] Richard S. Eckaus. The metamorphosis of giants: China and india in transition. 1994.

[9] S. Gass. *Linear Programming - Methods and Applications.* McGraw-Hill Book Company, New York, 1985.

[10] W Holstein. *Asia's Changing Face.* Business Week, November 28, 1994, 1994.

[11] A. Hussain and N. Stern. Effective demend, enterprise reforms and public finance in china. 1991.

[12] Wang Jiye and Terence H. Hull. *Population and Development Planning in China.* Allen and Unwin, Singapore, 1991.

[13] Gale D. Johnson. Effects of institutions and policies on rural population growth with application to china. 20(7), September 1994.

[14] R. J. R. Kirkby. *Urbanisation in China: Town and Country in a Development Economy 1949-2000 AD.* Croom Helm, London and Sydney, 1985.

[15] Department of International Economic and Scoial Affairs. Case studies in population policy: China. 1989.

[16] H. Yuan Tien. *China's Strategic Demographic Initiative.* Praeger, New York, 1991.

[17] Shahid Yusuf. China's macroeconomic performance and management during transition. 1994.