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Balancing Economic Growth and Global Warming in the Development of Jiangxi Province, China

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Abstract

Since the Industrial Revolution, the concentration of greenhouse gases (GHG), primarily carbon dioxide (CO2), has increasingly put pressure on the atmosphere's ability to absorb them. China is the fastest growing major economy in the world and is following a process of rapid industrialization. This process, however, makes a large contribution to global warming through major CO2 emissions. Widespread provision of electricity through coal-fired power plants is just one contributor, but industrial structure, transportation systems and large superblock construction of residential towers also play major roles. The large cities and industrialized provinces of China emit the most CO2, and this requires serious attention. However, stemming this trend elsewhere in China provides a greater opportunity for success. Consequently, the question this paper addresses is what policies can be adopted to reduce CO2 emissions in provincial China, where development is in its early stages, while maintaining economic growth. Jiangxi is one of the provinces of China that has historically been a major agricultural area. In recent years, however, because of the economic development policies of the Chinese central government, mineral deposits, a favorable location and convenient transportation, it is attracting more investment and development (Statistical Bureau of Jiangxi, 2010). Jiangxi, then, provides an excellent case study because the province, although developing quickly, might still produce less CO2 if proper growth policies and actions are implemented. According to the results of this research, CO2 emissions would indeed decline in Jiangxi if the province would adopt new technology for electricity generation and increase the GDP role of the service sector.

Keywords: Provincial Chinese development; economic growth and global warming; CO2 emissions in China; Chinese industrialization; Chinese power production

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Introduction

Since the Industrial Revolution, the concentration of greenhouse gases (GHG), primarily carbon dioxide (CO2), has increasingly put pressure on the atmosphere's ability to absorb them. China is the fastest growing major economy in the world and is following a process of rapid industrialization. This process, however, makes a large contribution to global warming through major CO2 emissions. Widespread provision of electricity through coal-fired power plants is just one contributor, but industrial structure, transportation systems and large superblock construction of residential towers also play major roles.

The large cities and industrialized provinces of China emit the most CO2, and this requires serious attention. However, stemming this trend elsewhere in China provides a greater opportunity for success. Consequently, the question this paper addresses is what policies can be adopted to reduce CO2 emissions in provincial China, where development is in its early stages, while maintaining economic growth. Jiangxi is one of the provinces of China that has historically been a major agricultural area. In recent years, however, because of the economic development policies of the Chinese central government, mineral deposits, a favorable location and convenient transportation, it is attracting more investment and development (Statistical Bureau of Jiangxi, 2010). In 2010, the GDP of the province's second ranking economic sector (industrial production) increased 16.6%, while the province`s GDP increased by 14% to rank No.19 in all of China (National Bureau of Statistics of China, 2010). Jiangxi, then, is an excellent place to study reducing CO2 emissions while maintaining economic growth because the province, although developing quickly, might still produce less CO2 if proper growth policies and actions are implemented.

The approach taken here, then, is to focus on this single province, which has been selected because it has the desired features of a province that has increased CO2 emissions due to the transition from an agricultural economy to an industrial one, and that the annual GDP growth rate of the province is higher than the national average. Under these criteria, the selected province should be less developed than those with major industrial cities, but more so than the provinces which have not upgraded their production. Consequently, the final result should be a province that has started to develop industrially but has not reached complete transformation. Determining how to reduce CO2 emissions in the selected province would, therefore, help China to achieve its national goal of CO2 emissions reduction.

Jiangxi was selected because its annual GDP growth rate was higher than China's average in the past five years. In addition, industrialized investment and energy consumption increased each of those five years, which means the production of the province is undergoing transition.

First, the context of the study is provided through a background presentation followed by sections on climate change policy in China, its recent national develop plans, technical support for energy utilization to reduce CO2 emissions. The study then proceeds to the case study of Jiangxi Province with an analysis of existing conditions. This is followed by sections addressing the research question through 2 measures: (1) transforming the economy by increasing the rate of growth in the services sector, and (2) adopting several new energy forms and supplying new technological support to reduce coal consumption. A series of simulations modifying provincial development policy based on these measures is then run, conclusions drawn and recommendations made.

Background

Global warming, that is, the rising average temperature of the Earth's atmosphere and oceans, is increasingly important; and although greenhouse gases (GHG), a major factor causing this phenomenon, are produced from the natural environment, research has demonstrated that most of these gases are produced from human activities (IEA, 2011). Since the Industrial Revolution, the concentration of greenhouse gases, primarily carbon dioxide (CO2), has increasingly put pressure on the atmosphere's ability to absorb them. The atmosphere controls the temperature of the earth, but it is influenced by the high concentrations of various gases. It retains thermal radiation, and this is why increasing amounts of CO2 cause the atmosphere to be warmer than before (Gore 2009). When the atmospheric temperature is increasing, one of the hazards is that the sea level will rise as well. This situation will influence many of the world's coastal cities such as New York, New Orleans, Lagos, Rotterdam and Singapore.

The World Resource Institute summarized emissions by economic sector in 2005. Electricity and heat were the largest emitters with a quarter of all emissions; industry was ranked 2nd with14.7% of the total. Transportation generated 14.3% of the amount, ranking number 3, while agriculture and land use change followed.

These emissions were 77% carbon dioxide (CO2), 15% Methane (CH4), 7% Nitrous Oxide (N2O) and 1% others. Over 64% of emissions came from energy use. Thus, most of the emissions were produced from coal and other fossil fuel (World Resources Institute, 2008).

According to The World Bank, the largest countries (i.e., the US, China and India) produce more GHG emissions than others. As a developed and industrialized country, the US's economic growth is more stable and is focused on the service sector. In other words, this country is increasingly emerging from high pollution, high labor-intensive and low value-added industry. On the other hand, the large developing countries need to attract more investment to increase their competitive advantage, and to reduce their capital costs to keep growth rates of GDP high. Therefore, developing countries have faster emission growth than the developed countries. This is especially so in China, India, Brazil and Russia.

China, as the fastest growing of the four has had five year economic plans since the 1980s. By 2002, with the10th five year economic plan, the CO2 emissions of China increased faster than in other countries, and this number also reflects its GDP growth. By 2010, China produced around 23% of the GHG of the world (IEA, 2010). According to the IEA, it is now the world's largest carbon producer and had the largest emissions growth last year, up 300 million tons, or 3.8% from 2011 (Ritter, 2013). In the 12th five - year economic plan (2011 - 2015), the goal is GDP growth of 7%, and to keep up development in the middle-western area of the country. This means more high pollution industry will be initiated there. This area is large, with seven provinces neighboring the already developed coastal ones. Lower urbanization and development is significant in these provinces, and the Chinese government believes industrialization is the best path to boost local economic growth and development.

As a result, more investment will flow into these provinces to take advantage of cheap labor, land and natural resources. This step will provide more job opportunities and higher income for the residents and would exacerbate rural-urban migration. However, most of the investments are intended for labor-intensive, but highly polluting industries; and how to deal with this issue while maintaining economic growth is a serious question for these provinces.

Jiangxi is one of these provinces. Historically, it has been a major agricultural area, but because of the economic development policies of the Chinese central government, mineral deposits, a favorable location and convenient transportation, Jiangxi has been attracting more investment and development recently (Statistical Bureau of Jiangxi, 2010). In 2010, the GDP of the province's second ranking economic sector (industrial production) increased 16.6%, while the province`s GDP increased by 14% to rank 19th in all of China (National Bureau of Statistics of China, 2010). This is an excellent place to study reducing CO2 emissions while maintaining economic growth because the province, although developing quickly, still has time to produce less CO2 if proper growth policies and actions are implemented.

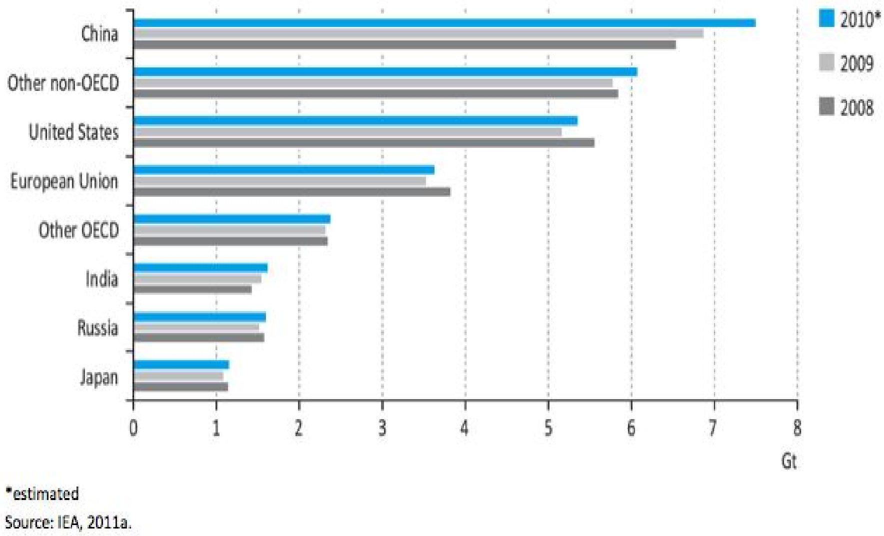
Climate Change Policy in China

In the 12^{th} Five-Year Plan (2011 - 2015), the Chinese government is placing greater emphasis on scientific development and the consideration of the environment and of sustainability for environmental protection. This plan relates industrial policy and energy policy to increased investment in a low-carbon economy to reach it goals. Coal has been a cornerstone of China`s economic growth, with over 80% of the global increase in coal demand coming from China in the past decade. Based on preliminary estimates for 2010, China accounted for nearly half of global coal use (Best & Levina, 2011).

In the past decade, China has pursued industrial and urban development within the powerful growth of its economy. This has led to an unprecedented demand for energy in concentrated population and industrial areas. Consequently, China's primary energy demand increased from 1108 million tons of oil equivalent in 2000 to over 2271 million tons in 2009 (Ibid.). In 2010, coal supplied nearly 67% of China's total primary energy supply. It was utilized by power generation, chemicals and transportation fuels; for power generation, over 78% of China's electricity was produced by coal in 2009. In addition, coal will also be a major energy source in China in the next two or three decades. The demand may remain stable until 2020, when industrial and power sectors will have new energy sources to replace it. However, how to improve the efficiency of power generation is a major issue in China (Ibid.).

The high demand for energy and the related high CO_2 emissions are a concern of all countries, but China's per-capita energy use is still just one-third of the OECD average. However, if energy demand is projected to follow the existing economic strategy and development policy for the next planning period, China's CO_2 emissions may increase from 7.7 gigatons per year (Gt./yr.) to over 10 Gt./yr. by 2035, an increase of over 35% (Ibid.).

Figure 1: Worldwide CO2 Emissions from 2008 to 2010



To mitigate the environmental impact of energy use accompanying development, the Auspices of National Development and Reform Commission published China's National Climate Change Program in 2007. The program states that China will vigorously engage in effective and pragmatic cooperation with the international community as well as individual countries to implement this CNCCP (Auspices of National Development and Reform Commission, 2007). According to the report, China's nationwide annual mean air temperature would increase by 1.3 - 2.1°C in 2020 and 2.3 - 3.3°C in 2050 as compared with that in 2000 if no action is taken.

Despite the steady economic development of the county, the emission intensity, defined as CO_2 emissions per unit of GDP, has been declining generally in China.

According to the International Energy Agency (IEA), China's emission intensity fell to 2.76 kg.CO2/US$ (in constant 2000 US$) in 2004, as compared to 5.47 kg.CO2/US$ in 1990, a 49.5% decrease. For the same period, the average emission intensity of the world dropped only 12.6% and that of the OECD countries 16.1% (Ibid.).

However, as noted above, China's primary energy mix is dominated by coal at 68.9%, while the world average is only 27.8%. Compared with oil and natural gas, coal's carbon content per unit of calorific value is 36% and 61%, respectively; and China's energy efficiency is about 10% lower than that of the developed countries, with a per unit energy consumption of energy-intensive products about 40% higher than the advanced international level. This leads to the program's 6 principles. They are: (1) to address climate change within the framework of sustainable development; (2) to follow the principle of "common but differentiated responsibilities" of the UNFCCC; (3) to place equal emphasis on both mitigation and adaptation; (4) to integrate climate change policy with other interrelated policies; (5) to rely on the advancement and innovation of science and technology, and (6) to participate in international cooperation actively and extensively (Ibid.).

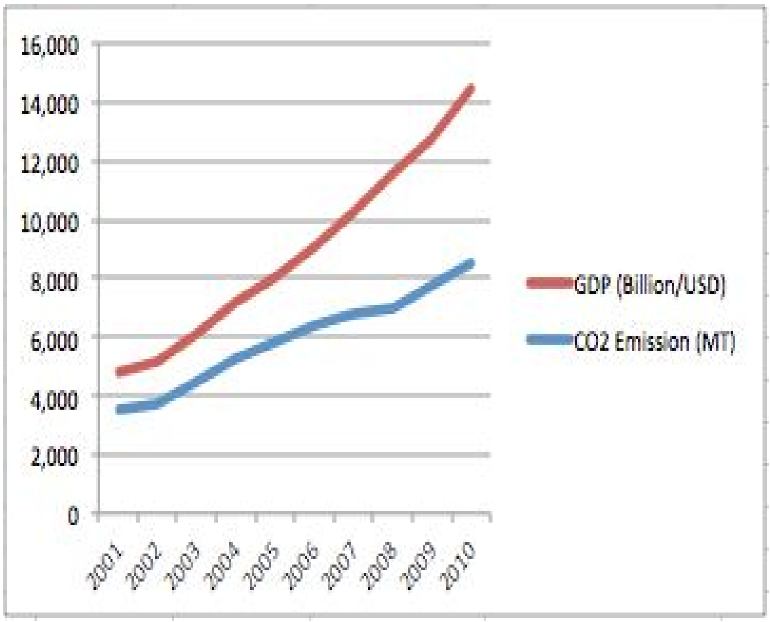
National Development in China

The five - year plans are a series of social and economic development steps that help the government navigate the future, and three plans, the first to include environmental matters explicitly, will be reviewed here. These includes: the 10^{th} (2001 – 2005), 11^{th} (2006 - 2010) and 12^{th} (2011 - 2015).

In the 10^{th} five - year plan, China focused on a number of special projects, which included: urbanization, population, employment, social security, technology, education, high-tech industry, ecological construction, environmental conservation, water conservancy, transportation system and energy. With regard to environmental conservation, inefficient and highly polluting equipment was replaced by modern facilities in the chemical, spinning and automobile industries. This policy was part of a major strategy to upgrade industrial production. In addition, the government provided benefits for high-tech industry to attract more investors to set up high-tech factories.

Even though CO2 emissions increased by 34.5%, 4 times the GDP growth of 8.6%, the plan did not include significant mitigation. However, this was the first time a Chinese five - year plan considered the environment (Ibid.).

Figure 2: GDP and CO2 Emissions Amount in China



Source: Statistical Bureau of Jiangxi, 2010

In the 11th five - year plan, more polices were developed with regard to the environment. First, energy used per unit of GDP over the period 2006 - 2010 was to be reduced by 19% compared with the 2001 - 2005 period. This meant that around 1460 million tons of CO2 emissions would be saved. Moreover, 3 million tons of coal would be replaced by renewable energy. China has a high potential to develop renewable energy, including water, wind, sun and biomass energy. Expanding the public transportation system was another strategy to reduce CO2 emissions. By the end of the plan, CO2 emissions increased by 24.9%, compared with a GDP increase of 11.2%. Thus, the emissions increased at twice the rate of GDP, which was a significant improvement over the previous plan (Zhi, 2011).

In the current 12th five - year plan, initiated in 2011, carbon reduction instead of GDP growth is the major goal in China. This decision will increase the speed of industrial upgrading. The "World Factory" will be transformed to a "World Market" in this period. In order to implement this policy, Congress prepared the seven concepts of green industry, including energy saving, new energy, new materials, electric vehicles, new medicine, biotechnology and the information industry. New energy includes hydropower, nuclear power, wind power, solar power, biogas, geothermal and high-efficiency coal use. China expects that CO2 emissions will be reduced by 40% to 50% by 2020, and that over 15% of fuel energy will be replaced by new energy. China had 7,771 million tons of CO2 emissions in 2009, which means the number will go down to around 5,3000 million tons in 2020 (Skypower Ltd., 2011).

In the 10th five - year plan, the GDP rate of increase compared to the CO2 emission growth rate was 1:4; in 11th five - year plan, the rate was down to 1:2. These numbers show that in recent years, China's GHG emissions have been improving relative to economic growth. Upgrading industrial production and focusing on green production are the goals for the current period, and lower emission growth can be expected.

Existing Technical Support for Energy Utilization that Reduces CO2 Emissions

China is the largest coal consumer in the world, and most of the coal is used to produce cheap electricity in order to have more competitive industries. However, when China agreed to and signed the world climate treaty (2009), it obligated itself to reduce carbon dioxide emissions and pursue renewable energy (Eastman, 2003). Technical and renewable energy options, which are a key strategy in the current five year plan, are discussed below.

Power plants consume large amounts of coal, and most GHG emissions are also produced from these plants. That is one of the reasons why clean coal technologies have become increasingly more important to many countries of the world. A crucial question, then, is how the equipment to reduce emissions can be upgraded to mitigate CO2 emissions. The Clean Coal Technology Demonstration Program was initiated in 1985 with the objective of demonstrating a new generation of advanced coal utilization technologies.

The Power Plant Improvement Initiative (PPII) and the Clean Coal Power Initiative (CCPI) are two other projects that followed the CCTDM. Over the past 25 years, these projects have successfully demonstrated technologies can increase efficiency and reduce emissions (Miller, 2011).

Bringing on line new power plants to reduce emissions is one thing China can do; and Europe and the US have begun to cooperate with China on a near-zero emissions coal project. The first clean coal-fired power plant is being built in Tianjin, supported by Integrated Gasification Combined Cycle (IGCC) technology (Wang, 2009). The first carbon capture and storage (CCS) power plant became operational at the end of 2010 (Vazaios, 2010). Although a clean coal power plant is a very significant project, people can utilize other renewable energy forms such as wind, solar power, etc. instead, and they are included in China's renewable energy strategy of the 12th five - year plan.

Renewable energy not only provides to the public the benefits of energy efficiency, but also provides new economic development opportunities (Nogee, 2000). Wind power, solar, hydro, nuclear, biogas and geothermal are all to be utilized in the 12th five - year plan. Recently, China's wind sector has received increasing attention. In 2007, over 15 % of all global wind investment occurred in China (Xie & Economides, 2009), and by 2010, China was producing over 20 million kilowatts, thereby surpassing Spain as the number 3 wind power user in the world.

Recently, solar power has not only been utilized in developing nations to provide cheaper electricity, but has also been implemented in industrial countries. In Japan, companies were encouraged to install solar roofing material, and over 70,000 houses have solar installations. Germany is the world leader of solar power. Over 9,785 megawatts were produced in 2010. China produced 305 megawatts in the same year. Even though China is the largest solar panel manufacturer, it hasn't installed enough yet at home (Zachary, 2010). This situation will be improved in the 12th five - year plan.

Whereas nuclear energy can be dangerous, it provides zero emissions and sustainable energy to address the carbon dioxide problem (Bily, 2006). Nuclear energy is a controversial option, but benefits, especially for GHG emissions, cannot be ignored. China started to develop nuclear power plants in the 1970s, and they began to operate in 1991.

Currently, there are six power plants in operation, producing 2.15% of total electricity, but eleven more will be completed before 2015 (Wang, 2010).

China still has a lot of rural villages inland, which is the best location to develop biogas energy. By 1985, China started to develop biogas resources in rural areas to be utilized in cooking, heating and lighting. In the 11th five - year plan, China invested 4 billion dollars to promote this energy. In the next five years, the goal is to produce 44 billion cubic meters of biogas and apply it to transportation, industry and cities (Du, 2010).

According to another report, the amount of energy used will increase to 45 million standard tons of coal (Li, 2006). In order to accomplish the goal of a 15% reduction in fossil fuel energy use, hydropower should provide 350 million kilowatts; wind power should provide 150 million kilowatts; solar power should produce 20 million kilowatts; biogas power should produce 30 million kilowatts, and nuclear power should produce 80 million kilowatts in 2020 (Hsu, 2011).

Case Study

Having set the context, it is now important to explain why Jiangxi Province has been selected as the case study for analyzing how CO2 emissions can be reduced in developing provincial China while maintaining economic growth. As is well known, most of the urban population growth, economic activity and development have happened on China's eastern rim. With more and more population and investment have come more CO2 emissions in this area. China's government is now trying to balance the growth of the nation by developing the interior parts of the country to the west. China has three levels of major city (Lee, 2009), and these levels are important in understanding economic development in the country.

First level cities, such as Beijing and Shanghai, are located predominantly near the coast. Most of them have already passed through the initial industrial period. They are changing their economic structure from industrial to service, which means these cities' economies will keep growing without industrial production, and their CO2 emissions probably will go down. Beijing is a typical case. After the 2008 Olympic Games, Beijing had high population and economic growth for the year. However, the CO2 emissions didn't go up as would be expected (Zhao, 2011).

The situation demonstrates that in the late industrial period, CO_2 emissions are more controllable than before, and it also suggests that other cities will soon undergo the same changes.

The second level cities are located in the mid - east or are adjacent to the coastal provinces. The characteristics of these cities are a growing population, cheap labor, increasing investment and a rich natural resource base to support industrial production. In economic structure, agriculture production still plays a critical role in the province. However, industrial development is growing because of favorable conditions for investment. An industrial city requires a lot of workers who come from rural areas, and this provides an opportunity to develop the city's infrastructure to make it more competitive. In addition, more resources are consumed, and CO_2 emissions increase. Of note is that most of the CO_2 emissions of China are produced in the provinces where these second level cities are located (Auspices of National Development and Reform Commission, 2007). Although the central government of China has published the National Climate Change Program, the new five - year economic develop strategy should be more coordinated with the Climate Change Program. Unfortunately, that is not the case.

The third level cities are located in the middle and eastern parts of China. Agriculture and livestock are the major production sectors of the area. The significant cities are origins of less GDP and lower energy consumption. That's why the CO_2 emission growth rate and total amount are lower compared with other more industrialized cities (Ibid.).

The approach taken here, then, is to focus on a single province between the second and third levels. The desired features of the province are that it has increased CO_2 emissions due to the transition from an agricultural economy to an industrial one, and that the annual GDP growth rate of the province is higher than the national average. Under these criteria, the selected province should be less developed than those with major industrial cities, but more so than the provinces which have not upgraded their production. Consequently, the final result should be a province that has started to develop industrially but has not reached complete transformation. Determining how to reduce CO_2 emissions in the selected province would, therefore, help China to achieve its national goal of CO_2 emissions reduction. Jiangxi was selected because its annual GDP growth rate was higher than China's average in the past five years.

In addition, industrialized investment and energy consumption increased each of those five years, which means the production of the province is undergoing transition.

Jiangxi Province borders Zhejiang and Fujian Provinces to the east, Guangdong to the south, Hunan to the west, and Hubei and Anhui to the north. Jiangxi's northern border is the Yangtze River, and it connects to Wuhan upstream and to Nanjing and Shanghai downstream. Both the Beijing - Kowloon and Zhejiang - Jiangxi railways run through the whole province, which provides it with convenient transportation (Statistical Data, 2011). The provincial population was 41.68 million in 2000 and 44.62 million in 2010, of whom, 11.48 million were urban in 2000, i.e., 27% of the total population, and 19.66 million by 2010, or 44% of the total. The province's population growth rate was 7% annually from 2000 to 2010. Nanchang, the provincial capital, had over 5 million people in 2010.

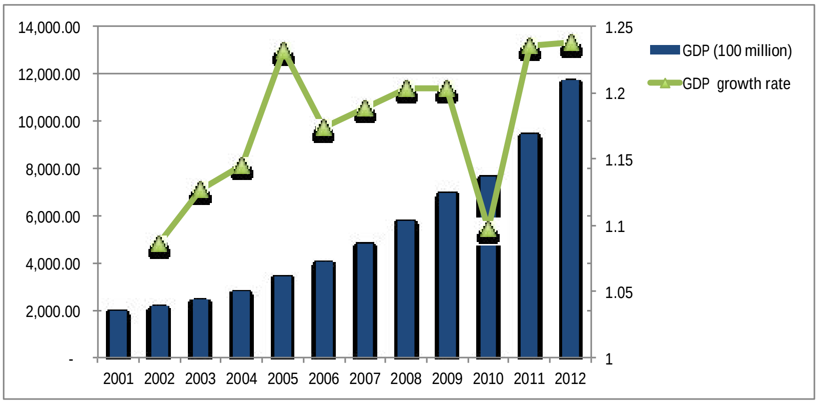
Figure 3: Jiangxi Province Overview

The 10th five year plan period (2001 - 2005) was an extraordinary one for Jiangxi Province. The GDP of Jiangxi increased from 200 billion Yuan to 407 billion RMB, equal to an annual growth rate of 11.6%; the three major sectoral shares were 18.9% of for primary industry (agriculture), 47.4% for secondary industry (industry and construction), and 33.7% for tertiary industry (transport, retail and finance). The industrial sector became a major factor in the province's economic growth, and urbanization was up to 37% by 2005 (China Investment Yearbook Editorial Board, 2007).

In the period of the 11th five - year plan (2006-2010), Jiangxi had stronger development and economic growth, which built on the results of the previous period. The new strategies were rural modernization, upgrading industrial production, increasing urbanization, becoming economically internationalized and strengthening the infrastructure. By 2010, the GDP of Jiangxi had increased from 482 billion RMB in 2006 to 945 billion RMB, equal to an annual growth rate of 13.2%; the three major sectoral production shares were 12.8% for primary industry, 55% for secondary Industry and 32.2% for tertiary industry. Urbanization was 44.8% by 2010 (Jiangxi Development and Reform Commission, 2011).

In the 12th five - year plan, the major economic goals of the province include (1) increasing GDP up to 1800 billion RMB, with an average annual growth rate of no less than 11%; (2) secondary and tertiary Industry are to become 90% of total GDP, and (3) urbanization is to be 52.8% (Ibid.).

Figure 4: GDP and Growth Rate Trend of Jiangxi Province, 2001 – 2011



Source: Statistical Bureau of Jiangxi, 2011

Industrial development is a major factor in supporting Jiangxi's economic growth. However, CO_2 emissions have increased along with economic growth in the past 10 years. Even though China's published its Climate Change Program in 2007, CO_2 emissions are still rising with the economic growth of Jiangxi Province. According to the report of Jiangxi Social Sciences, CO_2 emissions increased in a stable fashion by 1.9% per year between 1995 and 2000. However, the CO_2 growth rate increased by16.3% annually between 2002 and 2009. This report illustrated that the CO_2 emissions had developed a stronger relationship with economic growth, especially with industrial production (Fu & Lu, 2011). Therefore, Jiangxi Province is an appropriate case to understand how to achieve a balance between CO_2 emissions and economic growth, and policy alternatives to accomplish this goal are explored below.

Analysis of Existing Conditions

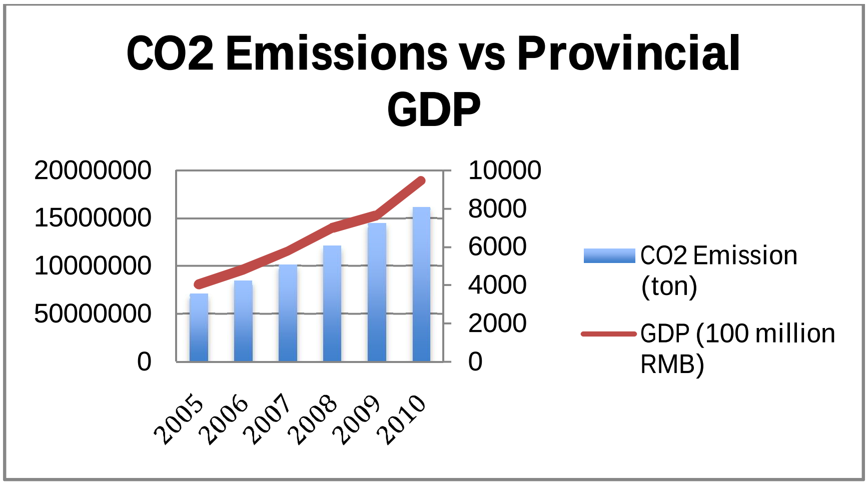
In order to determine suitable policies for the provincial government to follow to reduce CO_2 emissions, a review and analysis of the existing structure of growth and development in the provincial economy is first required. The factors to be considered include the existing CO_2 emissions produced, GDP growth effects in terms of the quantity of emissions produced, the structure of the economy and the structure of energy use in the province. These are discussed below.

Emissions Produced in the Province

The statistics used to present an overview of CO_2 emissions in Jiangxi Province are those from 2005 to 2010, which are the most recent numbers available. During this period, the CO_2 emission growth rate of Jiangxi was 16.3% annually. At the same time, the GDP growth rate of the province was 16.8% annually (Statistical Bureau of Jiangxi, 2011). However, as Figure 5 shows, the provincial GDP growth rate is very high and does not seem sustainable (Sun, 2011). Moreover, as the figure also illustrates, CO_2 emissions have also grown quickly; and they are expected to keep rising without policy changes, which is unacceptable for China's Climate Change Program. Reducing CO_2 emissions by 25% is a goal of the program (Auspices of National Development and Reform Commission, 2007), but that would not occur in Jiangxi if current trends continue.

Therefore, developing an understanding of the economic growth effects on the production of emissions is the first step of the analysis and is presented in the following section.

Figure 5: CO2 Emissions Produced vs. Provincial GDP Growth



Source: Statistical Bureau of Jiangxi, 2011

Economic Growth Effects on Emissions Production

While CO2 emission growth in parallel with rising GDP has generally been the rule in Jiangxi Province, because of technical improvements, industrial upgrading, better energy efficiency, etc., it is difficult to estimate emission numbers for the future.

Structure of Economy

The industrial sector (secondary sector) is a high-density coal consumption sector compared to agriculture (primary sector) and services (tertiary sector) (IPCC, 2008). It also means the CO2 emissions are collateral with industrial GDP growth. This is the situation that is happening in Jiangxi Province. Industrial development has been exploding since 2000, and the rate of growth has been higher than those of agriculture and services (See Table 1).

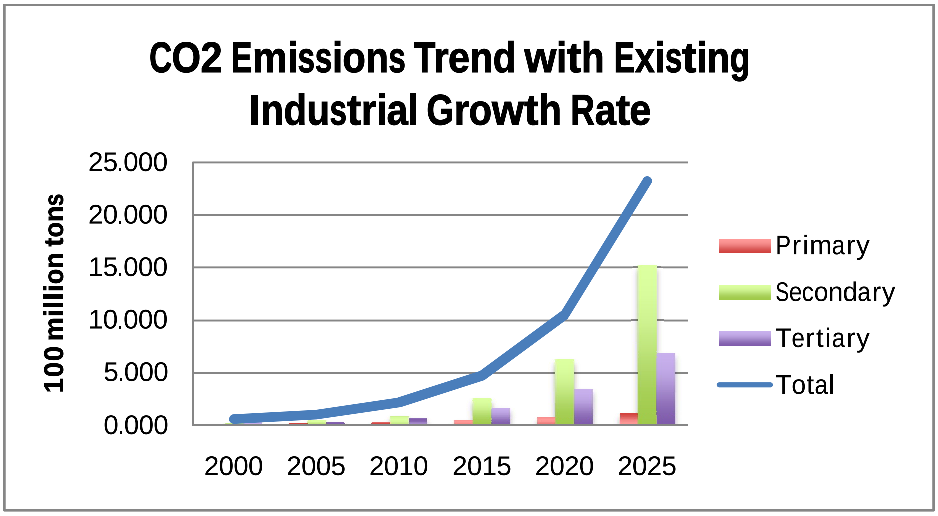
The primary sector's growth rate has been at the bottom during the past five years (10.76%), while the tertiary sector has been higher at 17.25%, and the secondary or industrial sector has been the core of Jiangxi's economic development with a growth rate of 21.91%, twice that of the primary sector. Thus, if the province continued with the existing growth rates, the curves of GDP and CO2 emissions would increase significantly as Figure 8 shows.

Table 1: Jiangxi Province's Sectoral Growth Rates, 2005 – 2010

Year	Primary	secondary	tried
2005	727.37	1917.47	1411.92
2006	786.37	2419.74	1614.65
2007	905.77	2975.53	1918.95
2008	1060.38	3554.81	2355.86
2009	1098.66	3919.45	2637.07
2010	1206.98	5122.88	3121.4
2010 Industry Rate	1	4.2443	2.586
Average Growth Rate (2005-2010)	10.76%	21.91%	17.25%

Source: Statistical Bureau of Jiangxi, 2011

Figure 6: CO2 Emissions Trend with Existing Industrial Growth Rate



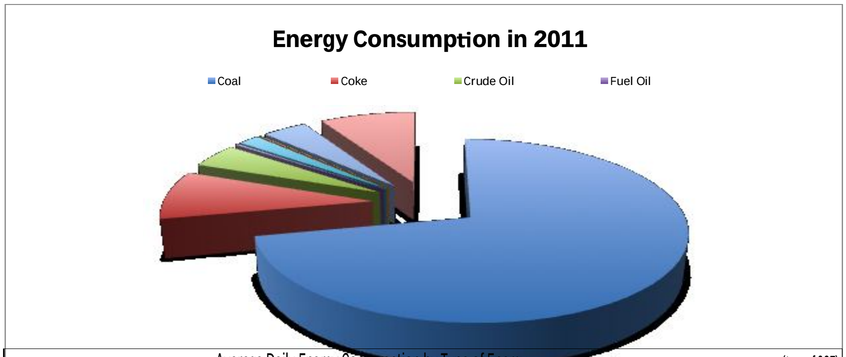
Source: Calculated by the authors

In order to know how much CO_2 would be emitted by each economic sector, it is necessary to calculate the per capita coal consumption that is required per unit of GDP, which is 0.000002045 for the primary sector, 0.000120806 for the secondary sector, and 0.000000661 for the tertiary sector. Comparing all of the sectors, the ratio is 1 (primary): 59.073 (secondary): 0.3232 (tertiary). From the results, one can understand that adjusting the secondary and tertiary industry rates of coal use per unit of GDP is a potential strategy of the province to mitigate the growth rate of emissions.

Structure of Energy Use

Energy use, more specifically, the combustion of fossil fuels, is tightly tied to CO_2 emissions (The World Bank, 2009), and this is the existing situation in Jiangxi Province. That is, fossil fuels are the major fuel sources, and most of this energy is utilized by power plants, transportation and for domestic heating. From the data, it can be seen that the trend is accelerating. In 2011, over 82% of energy use in the province was from coal and coke (Figure 7). In Figure 8, it can be observed that the consumption of raw coal has increased with GDP growth; however, the amounts of gas, oil and hydropower remain almost the same.

Figure 7: Energy Consumption in 2011

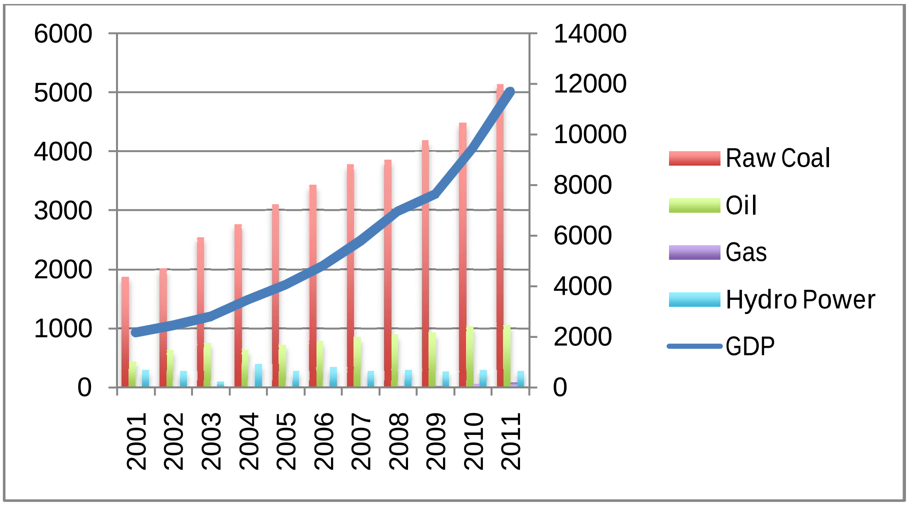


Average Daily Energy Consumption by Type of Energy (ton of SCE)

Year	Total	Coal	Coke	Crude Oil	Fuel Oil	Gasoline	Kerosene	Diesel Oil	Electricity
1990	47,460	62,079	4,308	4,249	642	1,159	145	1,245	3,497
1995	65,525	83,270	5,147	6,317	732	1,152	87	1,584	4,965
2000	68,630	67,634	5,642	9,073	937	1,602	62	2,871	6,407
2005	117,425	119,132	12,407	10,083	852	2,233	196	7,454	10,739
2009	159,248	146,743	19,463	12,375	604	2,115	210	8,032	16,691
2010	171,192	171,130	21,167	12,875	648	4,235	233	10,103	19,192
2011	189,813	191,463	23,899	11,857	734	5,007	248	10,755	22,879

Source: Statistical Bureau of Jiangxi, 2011

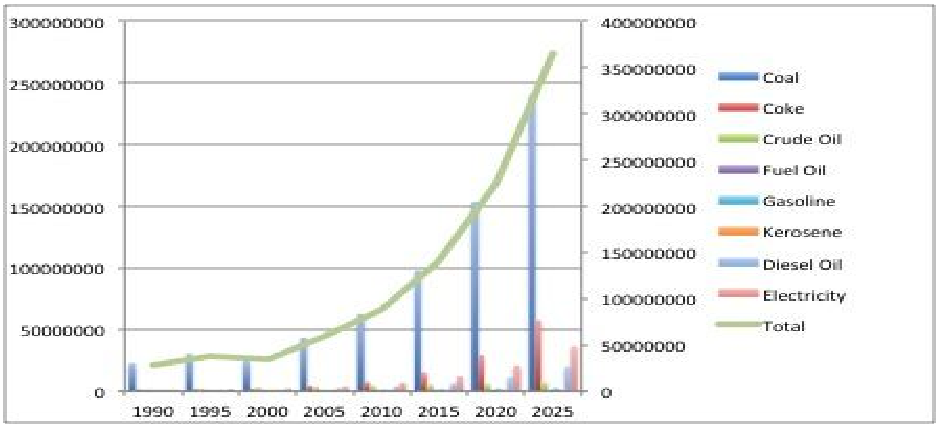
Figure 8: Energy Consumption from 2001 – 2011 in Jiangxi Province



Source: Statistical Bureau of Jiangxi, 2011

In Exhibit 8, it is clear that raw coal consumption is projected to grow at a similar rate to national GDP, while oil and hydro energy are not exploited, and gas is used only after 2005. This is despite the fact that all evidence indicates that coal is not only a cornerstone of the economy, but also is a major cause of CO2 emissions.

Figure 9: Energy Consumption in Jiangxi Province, 1990 – 2025, at Current Growth Rates



Source: Calculated by the authors

Consequently, if the province doesn't adopt any policies to deal with coal demand, which will rise to around 240 million tons in 2025 at the existing growth rate, coal use will be almost four times that of 2010 in that year (Figure 9 above).

In order to slow CO2 emission growth, reducing coal consumption and implementing industrial transformation are potential strategies. How this goal might be achieved using these strategies, and what the results might be in Jiangxi Province, is discussed in the next section.

Modified Development Policies to Reduce Emissions

From the economic growth effect analysis, two measures were found to reduce CO2 emissions. The first is to maintain the GDP growth rate, but transform the economy by increasing the rate of growth of the service industry, while the second is to adopt several new energy forms and supply new technical support to reduce coal consumption. The following paragraphs modify provincial development policy to reduce emissions in these two ways.

Policy 1: Increase the GDP of the Service Industry

Initially, agriculture is a developing economy's most important sector. But as income per capita rises, agriculture loses its primacy, giving way first to a rise in the industrial sector, then to a rise in the service sectors. These two consecutive shifts are called industrialization and post industrialization. All growing economies are likely to go through stages. (The World Bank, 2007)

This statement can be used to consider if the province is progressing to the stage of post industrialization. When incomes rise, the service requirements for health, education, entertainment, etc. increase as well. The provision of these items will generate lower CO2 emissions per unit of output than the production of industrial materials.

In Jiangxi Province, the rate of coal consumption per unit of GDP by economic sector is 1 (primary sector: agriculture) to 59.072 (secondary sector: industry) to 0.3232 (tertiary sector: services), which were calculated previously.

This means that if the province transforms one percent of GDP from industry to services in 2011, the province would save around 1,312,969 tons of coal consumption, which would account for 1.904% of the year's CO2 emissions. In this way, the province could maintain its economic growth and reduce CO2 emissions significantly, while simultaneously increasing provincial employment in services.

Table 2: Reduced Coal Consumption and CO2 Emissions by Different Transformation Rates

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO_2 Emissions
2011	324,514.21	68,011,796.23	241,395.01	68,577,705.45	185,159,804.72
-1%	324,514.21	66,698,827.19	248,579.38	67,271,920.79	181,634,186.12
-2%	324,514.21	65,385,858.15	255,763.76	65,966,136.12	178,108,567.53
-3%	324,514.21	64,072,889.11	262,948.14	64,660,351.46	174,582,948.94
-4%	324,514.21	62,759,920.07	270,132.51	63,354,566.79	171,057,330.35
-5%	324,514.21	61,446,951.03	277,316.89	62,048,782.13	167,531,711.75
Source: Calculated by the authors					

Table 2 shows the results of a 15% GDP growth rate in 2011, and transforms 1% - 5% of GDP from the secondary sector to the tertiary sector. The results show the strategy is workable and around 1.9% of total CO2 emissions would be saved at the same economic growth rate. Therefore, increasing the speed of industrial transformation is an option with high potential.

Policy 2: Reduce the Coal Consumption of Coal-Fired Power Plants

Around 30% of provincial coal use is for electricity generation, so the question arises as to how best to power the plants in the future to produce more electricity to satisfy growing demand. This is an issue in any fast growing developing country. Coal-fired power plants were the option chosen by the Chinese government because they are relatively simple technologically, have low maintenance costs and because the country has a rich supply of this raw material. On the other hand, these plants produce substantial chemical waste and pollution, of which CO2 is a major emission.

Table 3 reveals that over 42% of the coal consumption of Jiangxi Province in 2010 was to provide electricity and heat. At present, 16 coal-fired power plants are running in the province, and if the plants consume an equal amount of coal, that is, 2.63% of coal consumption, almost 1,609,473 tons of coal was used in 2010. According to International Energy Agency (IEA) data, the coal used would produce around 2.76 tons of CO_2 emissions per ton of coal consumed by power plants (IEA, 2011). Therefore, calculations demonstrate that each power plant emitted around 2,832,672 tons of CO_2 in 2010.

Table 3: Energy for Electricity Generation

	Raw Coal	Cleaned Coal	Other Washed Coal	Total (tons)
Total Consumption	51456824	9337790	339509	61134123
For Electricity & Heat	25751572	-	-	25751572
For Gas	-	71143	-	71143
For Water	260	-	-	260
Rate for Electricity	0.500450086	-	-	0.421230742

Source: Statistical Bureau of Jiangxi, 2011

In addition, electricity shortages are a major problem in the summer and winter in Jiangxi Province. The shortage was 76.04 million kWh in 2011, and is projected to be 155.649 million kWh in 2015. In order to provide more electricity and reduce CO_2 emissions, the provincial government should focus on building more power plants and adopting cleaner and more efficient power generation through improved technology. Three potential options are discussed below:

Table 4: Fossil Fuel Emission Levels

Fossil Fuel Emission Levels
- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

The first technical option is natural gas powered electricity generation. Coal (and nuclear) power plants have been utilized since 1970 because coal is the most economical energy resource. However, due to economic forces, environmental considerations and technological change, natural gas has become a very popular fuel for the generation of electricity. Natural gas is the cleanest of all the fossil fuels, which include oil and coal, as well as natural gas. From Table 4, one can see that coal-produced carbon dioxide is twice that of natural gas. Consequently, if Jiangxi built natural gas-fired electric power plants to replace the coal-fired power plants, CO2 emissions would fall by 50%. Near-Zero Emission Power Plants, or plants using what is also called Carbon Dioxide Capture and Storage Technology, comprise a second technical option. The process of electricity generation is similar to a conventional plant; however, the emissions are not exhausted via a chimney, but are instead stored underground. The technology is not very popular around the world because tests are still being conducted, and the capital costs remain very high. However, it should be considered as firmer data become available.

Renewable energy is the third technical option the province can adopt, especially in the form of wind and solar powered plants. Both forms of energy are utilized widely in the world; however, they are not suitable to install for all of Jiangxi Province because of environmental limitations. Wind power plants, for instance, should be located in the monsoon belt in order to capture enough power to turn their rotors, and solar power installations should be placed where there would be enough sunshine to provide heat to produce steam for turbines. Since developing a renewable energy industry is one of the major goals of Jiangxi Province, total electricity production from renewable energy is combined with hydropower in the third simulation of the policy simulation section, which follows (See Exhibit 16 below).

Policy Simulations

The simulations in this section estimate how much coal consumption could be saved under different strategies, and estimates the corresponding CO2 emissions. Two major policies are utilized here; the first reduces coal consumption from electricity generation, and the second increases the GDP of the tertiary sector (services). In order to provide reasonable projections, it is assumed that the economic growth rate for China will slow over the next fifteen years, which is already the case in 2013.

However, Jiangxi Province is what is called in Chinese terminology a second line city, which means the secondary economic sector is planned to become a major engine of growth at the same time. Consequently, the overall growth rate in the province is expected be higher than the annual average of China. It is assumed, then, for both sets of simulations, that the provincial GDP growth rate is 15% from 2011 to 2015, 10% from 2016 to 2020, and 8% from 2021 to 2025.

Electricity Generation Simulations

The first simulation for electricity generation, illustrated by Table 5, follows the existing growth in demand for electricity to estimate how much would be consumed in the next fifteen years without any policy changes or additional technical support. This will then be followed by simulations that will consider different ways to reduce the shortage in electricity produced and see what the effects are on CO2 emissions.

Table 5: Simulation of Electricity Generation and CO2 Emissions with a Continuation of the Existing Situation

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent (ton)	CO2 Emission (ton)
2011	804.89	632.21	-	96.62	76.05	21,300,503.55	57,511,359.59
2012	924.81	727.04	-	106.29	91.48	24,495,579.08	66,138,063.52
2013	1,062.61	836.10	-	116.92	109.60	28,169,915.94	76,058,773.05
2014	1,220.94	961.52	-	128.61	130.82	32,395,403.34	87,467,589.01
2015	1,402.86	1,105.74	-	141.47	155.65	37,254,713.84	100,587,727.36
2016	1,543.15	1,216.32	-	155.61	171.21	40,980,185.22	110,646,500.10
2017	1,697.46	1,337.95	-	171.18	188.34	45,078,203.74	121,711,150.11
2018	1,867.21	1,471.74	-	188.29	207.17	49,586,024.12	133,882,265.12
2019	2,053.93	1,618.92	-	207.12	227.89	54,544,626.53	147,270,491.63
2020	2,259.32	1,780.81	-	227.83	250.68	59,999,089.18	161,997,540.79
2021	2,440.07	1,923.28	-	250.62	266.17	64,799,016.32	174,957,344.05
2022	2,635.27	2,077.14	-	275.68	282.45	69,982,937.62	188,953,931.58
2023	2,846.09	2,243.31	-	303.25	299.54	75,581,572.63	204,070,246.10
2024	3,073.78	2,422.77	-	333.57	317.43	81,628,098.44	220,395,865.79
2025	3,319.68	2,616.60	-	366.93	336.16	88,158,346.32	238,027,535.06

Source: Calculated by the authors

In Table 6, one can see that if the electricity shortage is reduced by building coal-fired power plants, the CO2 emissions will increase to 270,759,870 tons in 2025 for electricity production.

Table 6: Provision of Coal-Fired Power Plants Only

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent (ton)	CO2 Emission (ton)
2010	700.51	549.75	-	87.84	62.92	20,807,498.54	56,180,246.06
2011	804.89	708.26	-	96.62	-	24,053,993.70	64,945,783.00
2012	924.81	818.53	-	106.29	-	27,798,834.44	75,056,852.98
2013	1,062.61	945.70	-	116.92	-	32,117,736.00	86,717,887.21
2014	1,220.94	1,092.33	-	128.61	-	37,097,841.43	100,164,171.86
2015	1,402.86	1,261.39	-	141.47	-	42,839,438.84	115,666,484.87
2016	1,543.15	1,387.53	-	155.61	-	47,123,382.72	127,233,133.36
2017	1,697.46	1,526.29	-	171.18	-	51,835,721.00	139,956,446.69
2018	1,867.21	1,678.91	-	188.29	-	57,019,293.10	153,952,091.36
2019	2,053.93	1,846.81	-	207.12	-	62,721,222.41	169,347,300.50
2020	2,259.32	2,031.49	-	227.83	-	68,993,344.65	186,282,030.55
2021	2,440.07	2,189.45	-	250.62	-	74,358,058.02	200,766,756.66
2022	2,635.27	2,359.59	-	275.68	-	80,136,473.05	216,368,477.23
2023	2,846.09	2,542.85	-	303.25	-	86,360,138.32	233,172,373.45
2024	3,073.78	2,740.21	-	333.57	-	93,062,971.55	251,270,023.18
2025	3,319.68	2,952.75	-	366.93	-	100,281,433.65	270,759,870.87
Source: Calculated by the authors							

In Table 7, one can see that the CO2 emissions decline in the next fifteen years if the province adopts hydropower for electricity generation. Before 2010, only 10% of electricity was generated from hydropower, but the percentage will increase to 15% from 2015 and 20% from 2020. In this way, CO2 emissions number would decline to 239,481,910 tons.

Table 7: Increased Hydropower (Including Renewable Energy) Only

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent (ton)	CO2 Emission (ton)
2010	700.51	549.75	-	87.84	62.92	20,807,498.54	56,180,246.06
2011	804.89	632.21	-	96.62	76.05	24,053,993.70	64,945,783.00
2012	924.81	727.04	-	106.29	91.48	27,798,834.44	75,056,852.98
2013	1,062.61	836.10	-	116.92	109.60	32,117,736.00	86,717,887.21
2014	1,220.94	961.52	-	128.61	130.82	37,097,841.43	100,164,171.86
2015	1,402.86	1,105.74	-	141.47	155.65	42,839,438.84	115,666,484.87
2016	1,543.15	1,216.32	-	162.69	164.14	46,883,157.27	126,584,524.64
2017	1,697.46	1,337.95	-	187.09	172.42	51,295,213.73	138,497,077.08
2018	1,867.21	1,471.74	-	215.15	180.31	56,107,036.95	151,488,999.77
2019	2,053.93	1,618.92	-	247.43	187.58	61,352,387.77	165,651,446.97
2020	2,259.32	1,780.81	-	284.54	193.97	67,067,470.73	181,082,170.97
2021	2,440.07	1,923.28	-	341.45	175.34	71,273,238.34	192,437,743.53
2022	2,635.27	2,077.14	-	409.74	148.39	75,583,541.36	204,075,561.67
2023	2,846.09	2,243.31	-	491.69	111.10	79,960,357.41	215,892,965.00
2024	3,073.78	2,422.77	-	590.02	60.98	84,353,345.28	227,754,032.27
2025	3,319.68	2,616.60	-	708.03	(4.94)	88,697,004.05	239,481,910.94
Source: Calculated by the authors							

Table 8 assumes the shortage is covered by natural gas fed electricity generation, and that hydropower increases from 2015. In this simulation, CO2 emissions would decline to 174,529,361 tons in 2025.

Table 8: Natural Gas Electricity Generation Beginning in 2015

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent by Coal (ton)	Stand Coal Equivalent by Gas (ton)	CO2 Emission (ton)
2010	700.51	549.75	-	87.84	62.92	20,807,498.54	-	56,180,246.06
2011	804.89	632.21	-	96.62	76.05	24,053,993.70	-	64,945,783.00
2012	924.81	727.04	-	106.29	91.48	27,798,834.44	-	75,056,852.98
2013	1,062.61	836.10	-	116.92	109.60	32,117,736.00	-	86,717,887.21
2014	1,220.94	961.52	-	128.61	130.82	37,097,841.43	-	100,164,171.86
2015	1,402.86	1,105.74	-	141.47	155.65	42,839,438.84	-	115,666,484.87
2016	1,543.15	1,105.74	274.72	162.69	-	37,553,264.61	9,329,892.66	114,735,560.96
2017	1,697.46	1,105.74	404.63	187.09	-	37,553,264.61	13,741,949.12	121,044,801.70
2018	1,867.21	1,105.74	546.31	215.15	-	37,553,264.61	18,553,772.34	127,925,708.90
2019	2,053.93	1,105.74	700.76	247.43	-	37,553,264.61	23,799,123.15	135,426,560.56
2020	2,259.32	1,105.74	869.04	284.54	-	37,553,264.61	29,514,206.12	143,599,129.20
2021	2,440.07	1,105.74	992.87	341.45	-	37,553,264.61	33,719,973.73	149,613,376.89
2022	2,635.27	1,105.74	1,119.79	409.74	-	37,553,264.61	38,030,276.75	155,777,110.20
2023	2,846.09	1,105.74	1,248.66	491.69	-	37,553,264.61	42,407,092.79	162,035,957.15
2024	3,073.78	1,105.74	1,378.01	590.02	-	37,553,264.61	46,800,080.67	168,317,929.82
2025	3,319.68	1,105.74	1,505.91	708.03	-	37,553,264.61	51,143,739.44	174,529,361.85

Source: Calculated by the authors

This simulation illustrated by Table 9 assumes additional natural gas fed electricity generation would be substituted for 2% of anticipated coal produced power annually from 2016. The result is that CO2 emissions would decline to 166,600,352 tons in 2025.

Table 9: Reduced Coal Consumption by 2%

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent by Coal (ton)	tand Coal Equivaler by Gas (ton)	CO2 Emission (ton)
2010	700.51	549.75	-	87.84	62.92	20,807,498.54	-	56,180,246.06
2011	804.89	632.21	-	96.62	76.05	24,053,993.70	-	64,945,783.00
2012	924.81	727.04	-	106.29	91.48	27,798,834.44	-	75,056,852.98
2013	1,062.61	836.10	-	116.92	109.60	32,117,736.00	-	86,717,887.21
2014	1,220.94	961.52	-	128.61	130.82	37,097,841.43	-	100,164,171.86
2015	1,402.86	1,105.74	-	141.47	155.65	42,839,438.84	-	115,666,484.87
2016	1,543.15	1,105.74	274.72	162.69	-	37,553,264.61	9,329,892.66	114,735,560.96
2017	1,697.46	1,083.63	426.74	187.09	-	36,802,199.32	14,493,014.41	120,090,948.78
2018	1,867.21	1,061.96	590.10	215.15	-	36,066,155.33	20,040,881.62	126,037,080.11
2019	2,053.93	1,040.72	765.78	247.43	-	35,344,832.23	26,007,555.54	132,621,851.43
2020	2,259.32	1,019.90	954.88	284.54	-	34,637,935.58	32,429,535.15	139,896,661.33
2021	2,440.07	999.50	1,099.11	341.45	-	33,945,176.87	37,328,061.47	145,031,105.46
2022	2,635.27	979.51	1,246.02	409.74	-	33,266,273.33	42,317,268.03	150,332,631.28
2023	2,846.09	959.92	1,394.48	491.69	-	32,600,947.87	47,359,409.54	155,746,514.88
2024	3,073.78	940.73	1,543.03	590.02	-	31,948,928.91	52,404,416.38	161,200,423.47
2025	3,319.68	921.91	1,689.74	708.03	-	31,309,950.33	57,387,053.72	166,600,352.71

Source: Calculated by the authors

Table 10 assumes that the rate of decrease in coal consumption is 5% instead of 2%. The CO2 emissions would now decline to 156,894,977 tons.

Table 10: Reduced Coal Consumption by 5%

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent by Coal (ton)	Stand Coal Equivalent by Gas (ton)	CO2 Emission (ton)
2010	700.51	549.75	-	87.84	62.92	20,807,498.54	-	56,180,246.06
2011	804.89	632.21	-	96.62	76.05	24,053,993.70	-	64,945,783.00
2012	924.81	727.04	-	106.29	91.48	27,798,834.44	-	75,056,852.98
2013	1,062.61	836.10	-	116.92	109.60	32,117,736.00	-	86,717,887.21
2014	1,220.94	961.52	-	128.61	130.82	37,097,841.43	-	100,164,171.86
2015	1,402.86	1,105.74	-	141.47	155.65	42,839,438.84	-	115,666,484.87
2016	1,543.15	1,105.74	274.72	162.69	-	37,553,264.61	9,329,892.66	114,735,560.96
2017	1,697.46	1,050.46	459.91	187.09	-	35,675,601.38	15,619,612.35	118,660,169.40
2018	1,867.21	997.93	654.12	215.15	-	33,891,821.31	22,215,215.64	123,275,675.91
2019	2,053.93	948.04	858.46	247.43	-	32,197,230.25	29,155,157.52	128,624,396.92
2020	2,259.32	900.64	1,074.14	284.54	-	30,587,368.74	36,480,101.99	134,752,441.44
2021	2,440.07	855.60	1,243.01	341.45	-	29,058,000.30	42,215,238.05	138,824,391.21
2022	2,635.27	812.82	1,412.71	409.74	-	27,605,100.28	47,978,441.08	143,142,941.51
2023	2,846.09	772.18	1,582.22	491.69	-	26,224,845.27	53,735,512.14	147,648,864.58
2024	3,073.78	733.57	1,750.18	590.02	-	24,913,603.01	59,439,742.28	152,265,559.57
2025	3,319.68	696.89	1,914.76	708.03	-	23,667,922.86	65,029,081.19	156,894,977.82

Source: Calculated by the authors

The simulation in Table 11 combines hydropower technical support, natural gas electricity generation, a 5% reduction in coal consumption and zero emissions technology. In other words, if the emissions from coal could be 100% saved by carbon storage technology, the CO2 emissions would only come from natural gas electricity generation. The CO2 emissions would then decline to 92,991,586 tons, which is a 66.7% reduction compared to only building coal-fired power plants.

Table 11: Reduced Coal Consumption by 5% with Zero Emission Technology

Year	Total (100 million kwh)	Thermal/Coal (100 million kwh)	Thermal/Gas (100 million kwh)	Hydro (100 million kwh)	Shortage (100 million kwh)	Stand Coal Equivalent by Coal (ton)	Stand Coal Equivalent by Gas (ton)	CO2 Emission (ton)
2010	700.51	549.75	-	87.84	62.92	20,807,498.54	-	56,180,246.06
2011	804.89	632.21	-	96.62	76.05	24,053,993.70	-	64,945,783.00
2012	924.81	727.04	-	106.29	91.48	27,798,834.44	-	75,056,852.98
2013	1,062.61	836.10	-	116.92	109.60	32,117,736.00	-	86,717,887.21
2014	1,220.94	961.52	-	128.61	130.82	37,097,841.43	-	100,164,171.86
2015	1,402.86	1,105.74	-	141.47	155.65	42,839,438.84	-	115,666,484.87
2016	1,543.15	1,105.74	274.72	162.69	-	37,553,264.61	9,329,892.66	13,341,746.51
2017	1,697.46	1,050.46	459.91	187.09	-	35,675,601.38	15,619,612.35	22,336,045.66
2018	1,867.21	997.93	654.12	215.15	-	33,891,821.31	22,215,215.64	31,767,758.36
2019	2,053.93	948.04	858.46	247.43	-	32,197,230.25	29,155,157.52	41,691,875.25
2020	2,259.32	900.64	1,074.14	284.54	-	30,587,368.74	36,480,101.99	52,166,545.85
2021	2,440.07	855.60	1,243.01	341.45	-	29,058,000.30	42,215,238.05	60,367,790.41
2022	2,635.27	812.82	1,412.71	409.74	-	27,605,100.28	47,978,441.08	68,609,170.74
2023	2,846.09	772.18	1,582.22	491.69	-	26,224,845.27	53,735,512.14	76,841,782.36
2024	3,073.78	733.57	1,750.18	590.02	-	24,913,603.01	59,439,742.28	84,998,831.46
2025	3,319.68	696.89	1,914.76	708.03	-	23,667,922.86	65,029,081.19	92,991,586.11

Source: Calculated by the authors

Industrial Transformation Simulations

Five simulations are created and discussed in this section, including 1% to 5% of provincial GDP transformations from a secondary economic sector based economy (industry) to a tertiary economic sector driven one (services).

Table 12 shows that with unchanged economic sectoral growth rates, CO_2 emissions in 2025 will be quadruple those of 2011 in Jiangxi Province, while Tables 13 through 17 show the emissions savings due to 1%, 2%, 3%, 4% and 5% transformations respectively.

Table 12: CO_2 Emissions Simulation with Existing Sectoral Growth Rates

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO2 Emission
2011	324,514.21	68,011,796.23	241,395.01	68,577,705.45	185,159,804.72
2012	373,191.34	78,213,565.67	277,604.26	78,864,361.27	212,933,775.42
2013	429,170.04	89,945,600.51	319,244.90	90,694,015.46	244,873,841.74
2014	493,545.55	103,437,440.59	367,131.64	104,298,117.78	281,604,918.00
2015	567,577.38	118,953,056.68	422,201.38	119,942,835.44	323,845,655.70
2016	624,335.12	130,848,362.35	464,421.52	131,937,118.99	356,230,221.27
2017	686,768.63	143,933,198.58	510,863.67	145,130,830.89	391,853,243.39
2018	755,445.50	158,326,518.44	561,950.04	159,643,913.98	431,038,567.73
2019	830,990.05	174,159,170.29	618,145.04	175,608,305.37	474,142,424.51
2020	914,089.05	191,575,087.32	679,959.55	193,169,135.91	521,556,666.96
2021	987,216.17	206,901,094.30	734,356.31	208,622,666.78	563,281,200.31
2022	1,066,193.47	223,453,181.84	793,104.81	225,312,480.13	608,343,696.34
2023	1,151,488.94	241,329,436.39	856,553.20	243,337,478.54	657,011,192.05
2024	1,243,608.06	260,635,791.30	925,077.46	262,804,476.82	709,572,087.41
2025	1,343,096.71	281,486,654.61	999,083.65	283,828,834.96	766,337,854.40
Source: Calculated by the authors					

Table 13: CO_2 Emissions Simulation with 1% GDP Transformation

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO2 Emission
2011	324,514.21	66,698,827.19	248,579.38	67,271,920.79	181,634,186.12
2012	373,191.34	76,703,651.27	285,866.29	77,362,708.90	208,879,314.04
2013	429,170.04	88,209,198.96	328,746.24	88,967,115.24	240,211,211.15
2014	493,545.55	101,440,578.80	378,058.17	102,312,182.53	276,242,892.82
2015	567,577.38	116,656,665.63	434,766.90	117,659,009.91	317,679,326.74
2016	624,335.12	128,322,332.19	478,243.59	129,424,910.90	349,447,259.42
2017	686,768.63	141,154,565.41	526,067.95	142,367,401.99	384,391,985.36
2018	755,445.50	155,270,021.95	578,674.74	156,604,142.18	422,831,183.90
2019	830,990.05	170,797,024.14	636,542.22	172,264,556.40	465,114,302.29
2020	914,089.05	187,876,726.56	700,196.44	189,491,012.04	511,625,732.52
2021	987,216.17	202,906,864.68	756,212.15	204,650,293.01	552,555,791.12
2022	1,066,193.47	219,139,413.86	816,709.12	221,022,316.45	596,760,254.41
2023	1,151,488.94	236,670,566.96	882,045.85	238,704,101.76	644,501,074.76
2024	1,243,608.06	255,604,212.32	952,609.52	257,800,429.90	696,061,160.74
2025	1,343,096.71	276,052,549.31	1,028,818.28	278,424,464.30	751,746,053.60
Source: Calculated by the authors					

Table 14: CO_2 Emissions Simulation with 2% GDP Transformation

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO2 Emission
2011	324,514.21	65,385,858.15	255,763.76	65,966,136.12	178,108,567.53
2012	373,191.34	75,193,736.87	294,128.32	75,861,056.54	204,824,852.66
2013	429,170.04	86,472,797.41	338,247.57	87,240,215.02	235,548,580.56
2014	493,545.55	99,443,717.02	388,984.71	100,326,247.28	270,880,867.64
2015	567,577.38	114,360,274.57	447,332.42	115,375,184.37	311,512,997.79
2016	624,335.12	125,796,302.03	492,065.66	126,912,702.80	342,664,297.57
2017	686,768.63	138,375,932.23	541,272.22	139,603,973.08	376,930,727.33
2018	755,445.50	152,213,525.45	595,399.44	153,564,370.39	414,623,800.06
2019	830,990.05	167,434,878.00	654,939.39	168,920,807.43	456,086,180.07
2020	914,089.05	184,178,365.80	720,433.33	185,812,888.17	501,694,798.07
2021	987,216.17	198,912,635.06	778,067.99	200,677,919.23	541,830,381.92
2022	1,066,193.47	214,825,645.87	840,313.43	216,732,152.77	585,176,812.47
2023	1,151,488.94	232,011,697.54	907,538.51	234,070,724.99	631,990,957.47
2024	1,243,608.06	250,572,633.34	980,141.59	252,796,382.99	682,550,234.07
2025	1,343,096.71	270,618,444.01	1,058,552.92	273,020,093.63	737,154,252.79

Source: Calculated by the authors

Table 15: CO_2 Emissions Simulation with 3% GDP Transformation

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO2 Emission
2011	324,514.21	64,072,889.11	262,948.14	64,660,351.46	174,582,948.94
2012	373,191.34	73,683,822.48	302,390.36	74,359,404.18	200,770,391.28
2013	429,170.04	84,736,395.85	347,748.91	85,513,314.80	230,885,949.97
2014	493,545.55	97,446,855.23	399,911.25	98,340,312.02	265,518,842.47
2015	567,577.38	112,063,883.51	459,897.93	113,091,358.83	305,346,668.84
2016	624,335.12	123,270,271.87	505,887.73	124,400,494.71	335,881,335.72
2017	686,768.63	135,597,299.05	556,476.50	136,840,544.18	369,469,469.29
2018	755,445.50	149,157,028.96	612,124.15	150,524,598.60	406,416,416.22
2019	830,990.05	164,072,731.85	673,336.56	165,577,058.46	447,058,057.84
2020	914,089.05	180,480,005.04	740,670.22	182,134,764.31	491,763,863.63
2021	987,216.17	194,918,405.44	799,923.84	196,705,545.45	531,104,972.72
2022	1,066,193.47	210,511,877.88	863,917.74	212,441,989.09	573,593,370.54
2023	1,151,488.94	227,352,828.11	933,031.16	229,437,348.21	619,480,840.18
2024	1,243,608.06	245,541,054.36	1,007,673.66	247,792,336.07	669,039,307.39
2025	1,343,096.71	265,184,338.70	1,088,287.55	267,615,722.96	722,562,451.99

Source: Calculated by the authors

Table 16: CO_2 Emissions Simulation with 4% GDP Transformation

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO2 Emission
2011	324,514.21	62,759,920.07	270,132.51	63,354,566.79	171,057,330.35
2012	373,191.34	72,173,908.08	310,652.39	72,857,751.81	196,715,929.90
2013	429,170.04	82,999,994.30	357,250.25	83,786,414.59	226,223,319.38
2014	493,545.55	95,449,993.44	410,837.78	96,354,376.77	260,156,817.29
2015	567,577.38	109,767,492.46	472,463.45	110,807,533.29	299,180,339.88
2016	624,335.12	120,744,241.70	519,709.79	121,888,286.62	329,098,373.87
2017	686,768.63	132,818,665.87	571,680.77	134,077,115.28	362,008,211.26
2018	755,445.50	146,100,532.46	628,848.85	147,484,826.81	398,209,032.39
2019	830,990.05	160,710,585.71	691,733.74	162,233,309.49	438,029,935.62
2020	914,089.05	176,781,644.28	760,907.11	178,456,640.44	481,832,929.19
2021	987,216.17	190,924,175.82	821,779.68	192,733,171.67	520,379,563.52
2022	1,066,193.47	206,198,109.89	887,522.05	208,151,825.41	562,009,928.60
2023	1,151,488.94	222,693,958.68	958,523.82	224,803,971.44	606,970,722.89
2024	1,243,608.06	240,509,475.37	1,035,205.72	242,788,289.16	655,528,380.72
2025	1,343,096.71	259,750,233.40	1,118,022.18	262,211,352.29	707,970,651.18
Source: Calculated by the authors					

Table 17: CO_2 Emissions Simulation with 5% GDP Transformation

Year	Primary Sector	Secondary Sector	Tertiary Sector	Total	CO2 Emission
2011	324,514.21	61,446,951.03	277,316.89	62,048,782.13	167,531,711.75
2012	373,191.34	70,663,993.69	318,914.42	71,356,099.45	192,661,468.52
2013	429,170.04	81,263,592.74	366,751.58	82,059,514.37	221,560,688.79
2014	493,545.55	93,453,131.65	421,764.32	94,368,441.52	254,794,792.11
2015	567,577.38	107,471,101.40	485,028.97	108,523,707.75	293,014,010.93
2016	624,335.12	118,218,211.54	533,531.86	119,376,078.53	322,315,412.02
2017	686,768.63	130,040,032.70	586,885.05	131,313,686.38	354,546,953.23
2018	755,445.50	143,044,035.97	645,573.56	144,445,055.02	390,001,648.55
2019	830,990.05	157,348,439.56	710,130.91	158,889,560.52	429,001,813.40
2020	914,089.05	173,083,283.52	781,144.00	174,778,516.57	471,901,994.74
2021	987,216.17	186,929,946.20	843,635.52	188,760,797.90	509,654,154.32
2022	1,066,193.47	201,884,341.90	911,126.36	203,861,661.73	550,426,486.67
2023	1,151,488.94	218,035,089.25	984,016.47	220,170,594.67	594,460,605.60
2024	1,243,608.06	235,477,896.39	1,062,737.79	237,784,242.24	642,017,454.05
2025	1,343,096.71	254,316,128.10	1,147,756.81	256,806,981.62	693,378,850.37
Source: Calculated by the authors					

Through the simulations, it is clear that an economic sector transformation is an effective way to reduce CO2 emissions. When one compares Tables 12 to 17, one can see that around 16.6% of CO2 emissions will be saved with a 5% transformation of provincial GDP from a secondary economic sector based economy (industry) to a tertiary economic sector driven one (services).

Results of Policy Modification

Through the simulations, the changes that would be likely under each policy change and the several selected options to reduce CO2 emissions while maintaining economic growth in Jiangxi Province are readily apparent and are summarized below.

Regarding electricity generation, policymakers should change some current strategies to increase electricity supply, while also reducing CO2 emissions. These changes include: (1) building natural gas electricity generation, (2) increasing the electricity supply through renewable energy forms such as solar power, wind power, biogas and nuclear power, and (3) importing zero emission technology for coal-fired power plants.

In the simulations, one can see that natural gas power generation could reduce the CO2 emissions of coal-fired power plants by around 50%. This is the preferred option before zero emission power plants can be utilized comprehensively. This is a popular policy in the world because electricity is produced reliably, consuming factories are able to operate stably, and the technical level is not really high. This means the province won’t have to import the technology from overseas. The provincial authorities could start to estimate how many natural gas-fired electrical generation units they could supply, and start to build them so that they could begin operation as early as 2015.

The province should also increase electricity production from renewable energy, which has zero emissions and would be more efficient in the future. This means per capita electricity production would be cheaper than previously. Nuclear energy is a higher risk alternative than the others, which is especially recognized in Asia after the disaster in Fukushima, Japan. As a consequence, the nuclear energy option is not considered.

In addition, the province could cooperate with other countries that have the technology for carbon storage and experience with that technology. However, the technology does not really reduce CO2 emissions; it just provides storage under ground. Therefore, this option is also not considered further.

Sectoral transformation of the provincial economy, however, is a workable strategy. The province should provide more incentives to attract private and international companies. For example, the government could open provincial-owned land to business investors or provide lower rent for a limited number of company types, while expanding public infrastructure to improve the environment. However, this transformation is not easy. Therefore, the goal of the province could be to implement sectoral transformation at a rate of 1% annually in the first five years, 3% annually from 2015 to 2020, and 5% annually from 2020 to 2025. This strategy is doable because when GDP keeps rising, the demand for services increases as well.

In these ways, the above tables indicate CO2 emissions will be reduced by a total of 23,771,064 tons, equal to 2% per year during first five years; by a total of 280,954 739 tons, equal to 15.5% per year, which include 5.7% from industry and 9.8% from electricity in the second five year period; and by a total of 728,169,246 ton, equal to 24.2% per year, which include 9.5% from the industrial upgrade and 14.7% from electricity in the third five year period.

Conclusions

From the previous sections, it is apparent that CO2 emissions of China present major issues that need to be dealt with. Jiangxi Province is an excellent example of how balancing economic growth and global warming in Chinese provincial development needs reformulation. Although this study only consists of the energy consumption and economic structure of the province, the case still provides significant insight into the problem of coal consumption. The main topic of interest is to determine how to reduce coal consumption, but still retain a high economic growth rate.

However, it also can be understood that the ability to reduce CO2 emissions in absolute terms is not likely, especially in a developing country. Even though China can be much more efficient in dealing with most of the issues involved in C02 production, CO2 emissions will continue to grow in China and Jiangxi Province along with GDP. While reducing CO2 emissions in absolute terms is the long-term goal, it is now necessary to focus on how much CO2 emissions can be reduced per unit of GDP as a first step to move closer to the goal.

The simulation runs of this study demonstrate that CO2 emissions would decline if Jiangxi Province would adopt new technology for electricity generation and increase the GDP role of the service sector. The CO2 emissions per unit of GDP would decline from 171 tons/million RMB to 136 tons/million RMB in 2025 without zero emissions technology being adopted. This is almost 21% less than if the province didn't do anything until 2025. If zero emissions technology were to be adopted, however, the CO2 emissions per unit of GDP would decline from 171 tons/million RMB to 121 tons/million RMB in 2025, a 30% decline in CO2 emissions.

From the energy consumption analysis, over 45% of total coal consumption was used in electricity generation in 2010. In order to reduce this consumption, natural gas-fed electricity generation and hydro power plants (including renewable energy) instead of coal-fired power plants were built into the simulation. The results, then, show that the CO2 emissions would decline to 156,894,977 tons in 2025, when compared to building more coal-fired power plants to increase supply, which would produce 238,027,535 tons. Thus, this policy, if adopted, would reduce CO2 emissions by 81,132,558 tons, or 34%.

From the industry transformation simulations, it was demonstrated that if 1% of provincial GDP is transformed from the industry to services, CO2 emissions would be reduced by 1.9% in that year; with a 2% transformation, the emissions would decline by 3.9%; with a 3% transformation, CO2 emissions would be reduced by 5.7%; with a 4% transformation, emissions would decline by 7.6%; and with a 5% transformation,, the reduction would be 9.5% in that year. This means if Jiangxi could implement the transformation of the industrial sector to services by 5%, the provincial CO2 emissions would decline to 693,378,859 tons in 2025, which would be a savings of about 76,290,132 tons in 2025. This number is almost equal to the total CO2 emissions of Jiangxi Province in 2005!

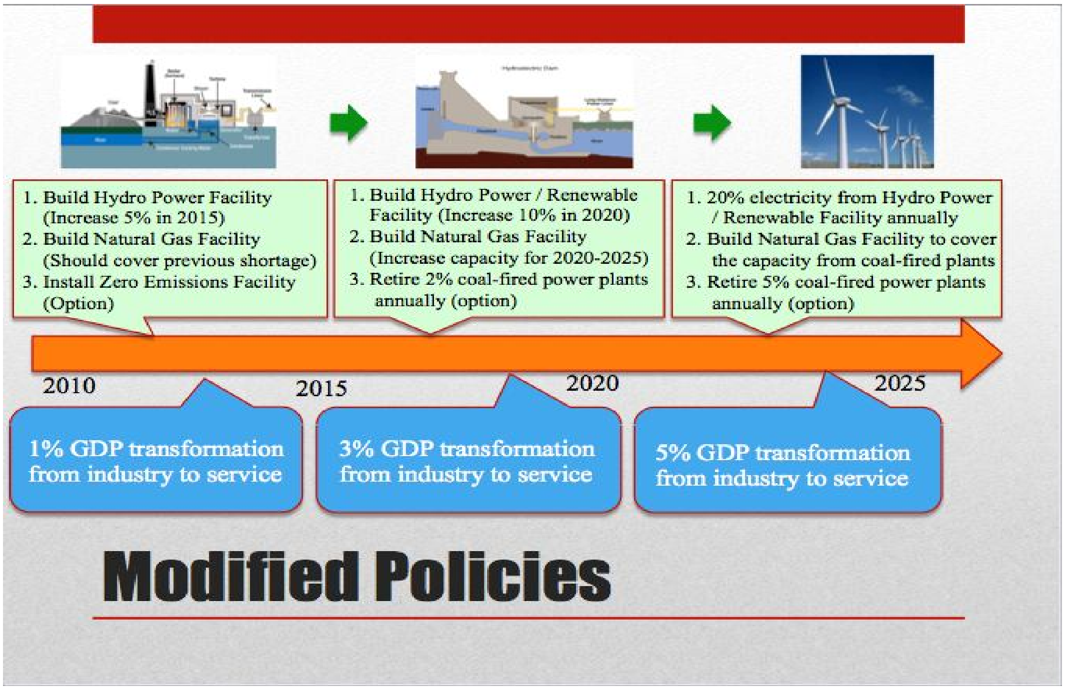
Two conclusions can be drawn from these simulation results. First, the upgrading of electricity generation can reduce CO2 emissions, especially in coal-dominated China and Jiangxi Province. Second, not only can industrial to service transformation reduce coal consumption and CO2 emissions, but it can also maintain the provincial economic growth rate. In China, over 80% of electricity is produced from coal-fired power plants and the total is still increasing. This is one of the reasons why China has passed the U.S. as the largest emissions-producing county in the world. While as a developing county, it faces more of a challenge to reduce its coal consumption, nevertheless, halting the building of coal-fired power plants is something China can and should do. From the results of the simulations, around 30% of emissions of the province can be saved in 2025, which also suggests around 34% of China's total CO2 emissions can be saved in electricity generation. To build more natural gas and hydropower/renewable energy electricity generation will not conflict with coal-fired power plants. China has several gas fields, which are located in Changqing and Qinghai that can produce the supply. China also has rich renewable power potential, include hydropower (Yellow River), wind power (Tibetan plateau and coastal area) and solar power (desert areas and the southern region of China), and, therefore, it has a high potential for building renewable electricity generation.

Moreover, the simulations show that Jiangxi Province would save around 10% of total CO2 emissions from an industrial transformation policy, which is suitable for second level Chinese cities. Compared with first level cities, for instance, Beijing, Shanghai, Tianjin, Xiamen, etc., the industrial GDP of Jiangxi is much higher than in these cities, which have been upgraded to business centers. Therefore, the policy effects of a transformation policy would not be as significant as in second level cities. In third level cities, most GDP still comes from primary industry (agriculture), which has lower coal consumption, so the policy would not be as effective here as well. Even if the policy is only suitable in second level cities with their high coal consumption, if it is assumed that all second level cities adopt the policy, there would be a nationwide reduction of around 9% of total CO2 emissions with a 5% GDP transformation.

Through the previous paragraphs, it can be seen that a modified policy of electricity generation and industry upgrading has the ability to reduce CO2 emissions while still maintaining economic growth in China.

In addition, if the Chinese government would prepare related policies, for instance, increasing the public transportation utilization rate in coastal cities, improving the specifications of industrial facilities, and retiring facilities in industrial areas that are over 20 years of age, these policies would be even more powerful. The recommended policy modifications are summarized in Figure 10 below.

Figure: Recommended Modified Policies



Source: Created by the authors

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