Energy Intensity, Renewable Energy, and Economic Development: Examining Three Provinces in China

Ning Wu
Department of Urban Studies and Planning, MIT (ningwu@mit.edu)

Abstract
China has incurred a steady decrease of energy intensity (EI, energy consumption per unit of GDP) since the 1980s, for example, a decrease of 29.3% from 1995 to 2004. EI trends of individual provinces vary, although the whole country shows declining energy intensity. The energy-intensity trends in three provinces seem especially interesting, Inner Mongolia, Liaoning and Ningxia: they represent three typical EI trends in China, increasing, nearly constant, and decreasing. It brings forth a puzzle that Ningxia and Inner Mongolia, with developed renewable energy industry and clean energy technology, has increasing or almost constant EI, while Liaoning, which has a heavy industry base and does not have much renewable energy capacity, experienced an EI decrease. Whether or to what an extent does renewable energy development impact the energy intensity? What are other reasons driving the EI trends in these regions? How the economic development is interacting with energy intensity issues? This paper examines underneath reasons for differences in energy intensity trends. Furthermore it tackles that puzzle by analyzing determinants for EI trends and examining economic structures of these regions.

Keywords: energy intensity, renewable energy, economic structure, energy investment

1. Introduction

The People's Republic of China (China) has incurred a steady decrease of energy intensity (EI, energy consumption per unit of GDP) since the 1980s. This trend continued in the past decade. From 1995 to 2004, for example, the EI of China decreased from 163.25 to 115.42 kilogram standard coal equivalent (kgce) per thousand Yuan (1995 deflated value), a decrease of 29.3% (see Table1 and Figure 1).

Scholars have studied China's EI at the national level from the perspectives of structural change and real energy intensity (Smil 1990, Polenske & Lin 1993, Sinton & Levine 1994, Lin & Polenske 1995, Garbaccio 1999, Zhang 2003, Polenske 2007). Some of these analysts determined that structural change was a main factor responsible for EI decrease in the early 1980s when China started the "Open-door" policy, while others showed that it was technological change. The structural-change factor still works in decreasing China's EI in the late 1980s and 1990s, but its effect is less significant than the factor of real energy intensity which is caused by technology innovation. Based on firm-level data, Zhang (2003) further argues that 88% of the cumulative energy savings in the industrial sector was attributed to real intensity change, with approximately 80% of such savings from the four chief energy using sub-sectors (i.e., ferrous metals, chemicals, nonmetal mineral products, and machinery). Polenske & McMichael (2002) also find that technology innovation is the primary factor for EI decrease in those firms using large quantities of coal.

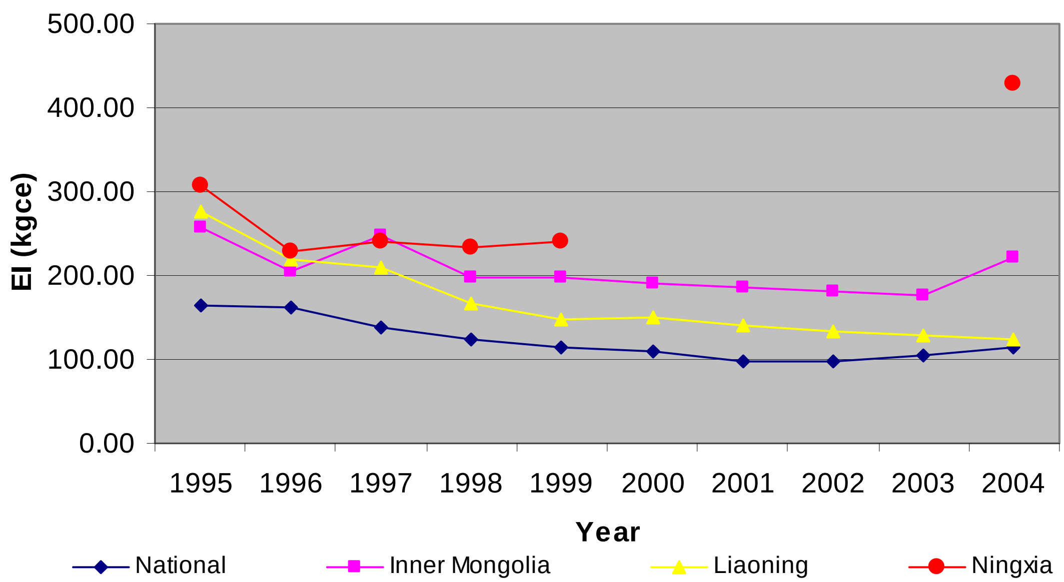
Few analysts have conducted studies concerning EI trends of individual provinces in China. In fact the EI trends of individual provinces vary, while the whole country shows declining energy intensity. Among all the 30 provinces or municipalities (not including Taiwan and Hong Kong Special Administration Region and Macau), the energy-intensity trends in three provinces seem especially interesting: Inner Mongolia, Liaoning and Ningxia (Table 1 and Figure 1). They represent three typical EI trends in China, increase, no significant change, and decrease. As shown in Table 1, Ningxia, a less-developed province in the northwest but with a well-developed solar-power industry, has experienced an EI increase over the past decades, from 308.24 in 1995 to 427.60 kgce (kilograms of coal equivalent) per thousand Yuan in 2004 (1995 deflated value), an increase of 38.7% over ten years. Inner Mongolia, famous for wind and solar-power and coal-gasification industries, exhibits a roughly constant EI over this period, from 258.26 kgce per thousand Yuan in 1995 to 220.53 in 2004 (1995 deflated value), but its EI basically fluctuated around 200. Liaoning, a province with considerable heavy industry, like most provinces, has a steadily decreasing EI trend, and its EI is at about the same level as that for China as a whole. Its EI decreased from 276.4 kgce per thousand Yuan in 1995 to 122.9 in 2004 (1995 deflated value), a decrease of 55.6%.

Table 1: Energy intensity, 1995-2004 (kilograms of standard coal equivalent per 1000 Yuan GDP

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
National	163.25	160.74	138.44	123.21	115.31	108.54	98.30	98.38	104.35	115.42
Inner Mongolia	258.26	204.39	248.58	198.75	197.29	191.16	186.73	181.53	175.84	220.53
Liaoning	276.39	218.62	208.69	167.77	148.65	150.86	140.38	132.56	128.40	122.86
Ningxia	308.24	227.73	240.68	233.61	241.20	*	*	*	*	427.60

Source: SSB&NDRC 1996-2005, SSB 1996-2005; edited by the author

Note: *: data of energy consumption by sector are unavailable from the sources given; therefore, I could not calculate the energy intensity. However, Polenske (2007) shows the energy intensity data of Ningxia for this period and indicates that Ningxia has a climbing curve of energy intensity over these 10 years.



Source: derived from Table 1

Figure 1: China's energy intensity from 1995 to 2004, national and provincial (from Table 1)

The past decades have also witnessed China’s development of renewable energy. China’s efforts for developing renewable energy date to 1982 when the central government issued “Suggestions to Reinforce the Development of Rural Energy.” More efforts were seen since 1995 when the State Planning Commission, together with other commissions, issued the Outline on New and Renewable Energy Development in (NREL 2004a&b, 2006). In 2001 the State Economic and Trade Commission (SETC) proposed its Tenth Five-Year Plan for Sustainable Development, including the Tenth Five-Year Plan for New and Renewable Energy Commercialization Development. Five years later, in 2006, China passed its Renewable Energy Law with a firm objective of boosting the use of renewable energy capacity up to 10 percent of the country's total energy consumption by the year 2020 (compared to 3% in 2003). Totally, since 1980s, China has issued more than 20 national policies or laws to promote renewable energy development and has achieved considerable progress (NREL 2004a&b, 2006). China’s renewable energy development has also received attention from multiple agencies. For example, the National Renewable Energy Laboratory (NREL) under the U.S. Department of Energy keeps track of China renewable energy policy. Wang (2005) concludes that renewable energy in China is still under utilized that it is even disregarded in official figures. Some reports also reflect that some provinces still rely on coal industries for economic growth (21 Century Economics 2005).

Renewable energy development is supposed to have a positive effect on EI decrease. Martinot (2001a, 2001b) reviews the World Bank’s renewable energy projects in China and finds that, on the one hand, these projects contribute to energy efficiency or decreasing EI in China by promoting the awareness of energy conservation. On the other hand, renewable energy development is supposed to help decrease EI as it brings forth technology innovation of energy use (NREL 1999, Martinot 2001a&b, Gao et al. 2005). For example, coal gasification, an innovation introduced in this period in Inner Mongolia, not only decreases energy intensity but reduces carbon-dioxide emissions (Moniz & Deutch 2007, SEPA 2004).

Given this background, Inner Mongolia has achieved significant growth in its renewable energy, especially wind power and solar power. Inner Mongolia has the highest wind power potential in the country, with a total wind power capacity by the end of 2005 of 166,000 kw, ranking 1st in China, with a projected capacity of 4,000,000kw by 2010 (North News 2006). Ningxia's solar industry dates to the 1970s, and the government plans to build up annual solar power capacity, which can substitute 432,000 tonnes of coal equivalents, about 5% of its coal consumption in 2004 (San 2004). Liaoning, which is a heavy industry base, so far does not have much renewable energy capacity.

It becomes a puzzle that Ningxia and Inner Mongolia, with developed renewable energy industry and clean energy technology, has increasing or almost constant EI, while Liaoning, which has a heavy industry base and does not have much renewable energy capacity, experienced an EI decrease. My hypothesis is that other factors, mainly technology innovation which improves the real energy intensity, still play key roles in changing energy intensity in these three provinces. Renewable energy also plays some role but it's at this stage too minimal to impact energy intensity.

To test the hypothesis, I explore what drives the changes of energy intensity in Liaoning, Inner Mongolia, and Ningxia. I also probe what factors prevent renewable energy from playing a role in decreasing energy intensity. My analysis sheds lights on what factors account for EI changes in those regions and what factors hinder or trade off the effect of renewable energy.

2. Three provinces

Inner Mongolia, Liaoning, and Ningxia are located in the north of China, as shown in Figure 2. Inner Mongolia has an area of 1.18 million kilometers (km) occupying about 12% of China's land area. In 2004, it had a population of about 24 million and its GDP was 271 billion Chinese Yuan (Yuan), which makes its rank 12th in GDP per capita all the provinces and municipalities in China. Its energy consumption was 3.9% of the national total, lower than Liaoning's, but two times more than Ningxia's amount of 2004. Liaoning has a larger population and smaller land area than Inner Mongolia. As of 2004, Liaoning achieved a GDP per capita of 16,300 Yuan, almost double the national average of 9,649 Yuan. Accordingly, its energy consumption is higher, claiming 5.7% of the national total. Ningxia, the smallest province of the three, consumed about 1.3% of the national total energy in 2004 for its GDP of 46 billion Yuan. Ningxia's GDP per capita is about 81% of China's average, placing 30th (the second smallest in China, higher than Tibet) in 2004 (SSB&NDRC, 2005, SSB, 2005).

Inner Mongolia is known for its abundance of coal and as an important coal base in north China. Also, it has other resources, such as cashmere, natural gas, and rare earth elements, and more deposits of naturally-occurring niobium, zirconium, etc. Inner Mongolia plans to double its annual coal production by 2010, from an annual 260 million tons in 2005 to 500 million tons by 2010 (PDO, 2005). Shenhua Group is the largest coal company in China (see the coming section), comparable to Peabody of the United States. Inner Mongolia growth depends upon coal, power generation, etc. The provincial government emphasizes the following six as competitive industries: energy, chemicals, metallurgy, equipment manufacturing, processing of farm produce, and hi-tech products (San, 2004).

Liaoning is one of China's most important industrial bases, covering a wide range of industries, such as machinery, electronics, metal refining, petroleum, chemical industries, coal, etc. Of provinces in China, it has the most iron, magnetite, diamond, and boron deposits. Its history of being a base for heavy industry in China since the birth of the People's Republic of China and its abundance of iron and other resources make Liaoning a key producer of steel in China. It has several large steel corporations, such as Anshan/Benxi Steel Group Corporation and Wushun Special Steel Corporation, Liaoning accounts for 1/6 of the total steel production in China (see http://www.ln.stats.gov.cn/jrln/gy.htm).

Ningxia is a relatively undeveloped region in China, which is shown by its low GDP per capita (SSB, 1997-2005). Coal is its key resource and the coal industry has become a base industry in Ningxia. East Ningxia Coal Basin is one of the 13 key huge coal production cases in China, with a proved reserve of 27.34 billion tonnes and a potential reserve of 139.43 billion tonnes. Developed by NingXia Coal Industry Corporation (merged by Shenhua Group from Inner Mongolia), this coal base will become an industrial park with mainly energy-intensive industries, including coal mining, coking, coal tar, petroleum products, etc. Ma Qizhi (2006), then the governor of Ningxia, stated that "The project of East Ningxia Coal Base is the key for ensuring our GDP growth of more than 10% per year until 2020".

Table 2: Introduction about three provinces, 2004 value

	Area (km²)	Population (person)	GDP (billion Yuan)	GDP per capita (Yuan)	Energy consumption (10,000 tons of standard coal equivalent)
Inner Mongolia	1,183,000	23,840,000	271	11,400	5,642
	(3rd)	(23rd)	(23rd)	(12th)	(3.9%)
Liaoning	145,900	42,170,000	687	16,300	8,180
	(21st)	(14th)	(8th)	(9th)	(5.7%)
Ningxia	66,000	5,880,000	46	7,830	1,844
	(27th)	(29th)	(30th)	(23rd)	(1.3%)
National	*9, 600, 000*	*1, 295, 330, 000*	*12496*	*9649*	*144, 227*

Source: SSB 2005, and Wikipedia (http://www.wikipedia.com); edited by the author.
Number in parenthesis indicates rank in nation;
Km = kilometer

Source: http://chinamash.com/wp-content/uploads/2006/08/china-map.jpg

Figure 2: Location of Inner Mongolia, Liaoning, and Ningxia: three study regions in China

3. Methodology

I define in this analysis energy intensity as the amount of energy consumption per unit of gross domestic product (GDP) or gross regional product (GRP). For energy consumption, I use the unit of 10,000 tonnes of standard coal equivalent (based on calorific value calculation). I deflate GDP to real GDP, based on 1995 values, as well as GRP using a current price index, which is calculated by the research group of Professor Karen Polenske at MIT. For energy consumption and GDP/GRP data (1995 through 2004), I use data from the China Energy Statistical Yearbooks and China Statistical Yearbooks for the relevant years.

I use shift-share analysis as the framework to explore energy intensity. There are different methods and analysts use the Laspeyres method extensively (Zhang 2003). Park (1992) proposes this method calculating changes in energy consumption with respect to a constant year. The change of energy consumption between two years, $\Delta E_{tot} = E_t - E_o$ is interpreted by three components: $\Delta E_{tot} = \Delta E_{out} + \Delta E_{str} + \Delta E_{\text{int}} + R$. ΔE_{out} is a change in aggregate production (output effect, the energy consumption of the second year based on the same energy intensity and industrial structure of the base year minor the energy consumption of the base year). ΔE_{str} represents a change of consumption due to changes in composition of aggregate production (structural effect) and ΔE_{int} is the intensity effect which shows the changed resulted from the adoption of more efficient technologies and techniques, and so forth (Detailed formulae about calculating these effects are presented by Zhang 2003, or Park 1992). R is the residual, which is not equal to zero and it will grow generally if t increases, which leaves part of the observed change in energy consumption unexplained. This constitutes a shortcoming of the Laspeyres methods and some scholars, such as Zhang (2003), derive their own equations to eliminate this residual.

Therefore, I adopt the method developed by Polenske and Lin (1993). Their method clearly decomposes the energy consumption into three parts each of which can be calculated and explained easily.

$$E_t = \quad e_0 \cdot O_t \quad + \sum_i [(e_{i,0} - e_0) \cdot O_{i,t}] \quad + \sum_i [(e_{i,t} - e_{i,0}) \cdot O_{i,t}] \qquad (1)$$

(constant share) (industrial mix) (efficiency change)

Where E_t is the total energy consumption in year t, O_t is the GRP (or GDP for the whole nation) in year t. $O_{i,t}$ is the GRP for each sector in year t. e_0 is the energy intensity for the whole region in the base year, and $e_{i,0}$ and $e_{i,t}$ are the energy intensity for industry i in the base year and year t.

The constant share is the energy consumption under the condition that the energy intensity in year t remains at the same level as that of the base year. The effect of industrial structure on energy use is illustrated by the industrial-mix component. A negative industrial mix means that the industrial structure has become less energy intensive compared with that in the base year, and, likewise, efficiency change is similar to the intensity effect discussed in the Laspeyres method, measuring the change of energy efficiency.

If we extend the items on the right-hand side of Equation (1) and add them, the sum is exactly equal to the item on the left side, which leaves no residual in the equation. In other words, the energy intensity can be fully explained by the three effects defined on the right-hand side of the equation. Furthermore, by dividing both sides of Equation (1) by O_t, Equation (2) describing the impacts on energy intensity is obtained.

$$e_t = \quad e_0 \quad + \sum_i [(e_{i,0} - e_0) \cdot O_{i,t}] / O_t \quad + \sum_i [(e_{i,t} - e_{i,0}) \cdot O_{i,t}] / O_t \qquad (2)$$

(constant share) (industrial mix) (efficiency change)

where $e_t = E_t / O_t$ is the energy intensity for the whole region in year t. e_t can be smaller or greater than e_0 depending on the simultaneous effects from industrial mix and efficiency change. Obviously the combined effect of industrial mix and efficiency change determines the level of energy intensity in a given year.

Energy efficiency is broadly defined as the introduction of new equipment, processes, and/or techniques, which can influence the amount of energy consumed per unit of output. A structural change reflects the shift in the industrial composition. Ideally, by using a finer industrial classification, an analyst can explain more about the shift and obtain a more reasonable explanation than for the courser detail data. But data availability remains a challenge. Similar to Polenske and Lin (1993), I use China's classification of six material production sectors: (1) Primary Industry (Farming, Forestry, Animal Husbandry, Fishery & Water Conservancy); (2) Industry; (3) Construction, (4) Transportation, Storage, Postal & Telecommunications Services; (5) Wholesale, Retail Trade & Catering Service; and (6) Others. The use of this classification is also determined by the data. I obtain energy consumption data for different sectors from the China Energy Statistical Yearbook, which designates seven sectors (the first five are the same with the above. The 6th and 7th sectors are Residential Consumption and Others, respectively). I obtain GRP data from the China Statistical Yearbook, which provides data for more sectors, but only the first five are same as those in the China Energy Statistical Yearbook. In this context, I use the first five sectors plus a six “others,” which includes all the other sectors.

4. Energy-intensity changes

In this section, I present the results of shift-share analysis both for China and for the three provinces. As shown in Table1, Ningxia Province energy-consumption data by sector for 2000, 2001, and 2002 are not available, which leaves the shift-share analysis of 2000-2003 blank for this province. For the convenience of the reader, I provide only the tables with results of the shift-share analysis, giving energy-consumption-by-sector, and GDP/GRP-by-sector tables in the Appendix.

Table 3 shows the shift-share analysis for China’s energy intensity during the past ten years (1995-2004). This country’s energy intensity continues to decrease from 1995 to 2001/2002, from 163.25 to 98.3 kg of standard coal equivalent (SCE) per 100 Yuan. Its EI shows an increasing trend in 2003 and 2004. In 2003, China’s EI increases by 6 EI units, while in 2004 this increase is accelerated to 11 EI units. I note that the industrial mixes are all positive (except the value of 1998) in these ten years. This indicates that China’s industrial structure in these ten years actually increases its energy intensity. Also, this might suggest that it is hard for China to reduce its energy intensity by changing its industrial structure. One explanation for the negative industrial mix value of 1998 (-0.64) is that in 1998, China started its so-called “laid-off” reform, duing which many employees of state-owned enterprises (SOEs) were laid off, and some old, inefficient or unprofitable SOEs were closed, which had a great impact on China’s industrial structure. Except for 2003 and 2004, the efficiency shift has played a role in decreasing energy intensity. During this period, the efficiency shift accounts for the decrease of energy intensity, while industrial mix mostly increases the energy intensity of China.

Table 3: Shift-share analysis of energy intensity in China's material production sector (kilograms of standard coal equivalent per 1000 Yuan of Output)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Constant share		163.25	160.74	138.44	123.21	115.31	108.54	98.30	98.38	104.35
Industrial mix		0.92	2.71	−0.64	0.95	2.39	0.34	0.34	1.10	0.29
Efficiency shift		−3.42	−25.02	−14.59	−8.85	−9.16	−10.58	−0.26	4.88	10.77
Total EI	163.25	160.74	138.44	123.21	115.31	108.54	98.30	98.38	104.35	115.42

Source: calculated from related tables in the Appendix.

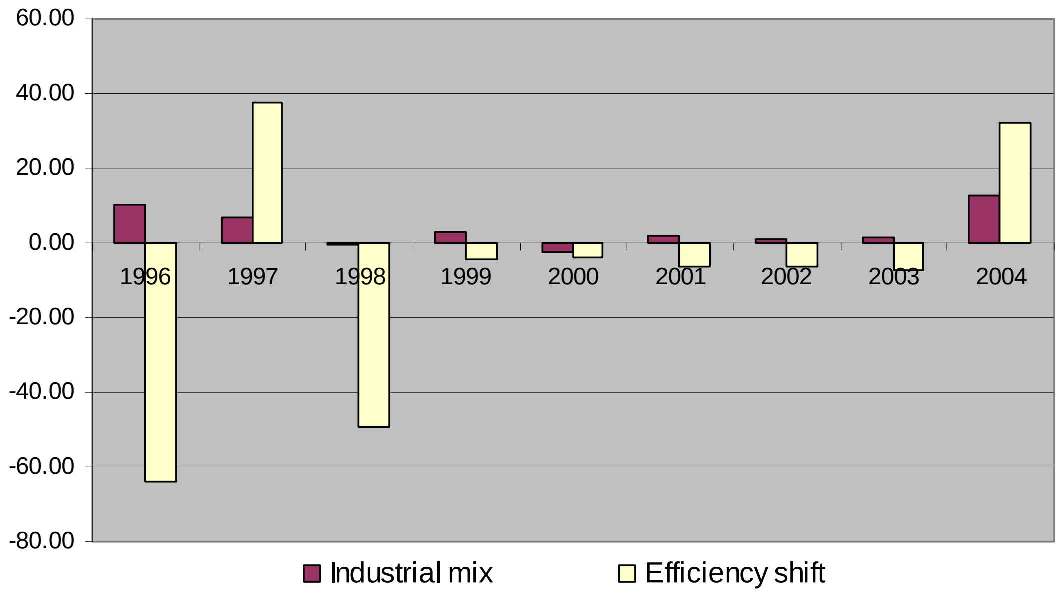
In the case of Inner Mongolia, the effect of efficiency shift is still significantly larger than that of industrial mix (see Table 4 and Figure 2). In the past decade, the EI of Inner Mongolia has decreased and then increased, fluctuating by roughly 200 EI units. Industrial mix, in general, does not contribute to energy efficiency except in 1998 and 2000. In contrast, for most of the years, the efficiency shift is negative, decreasing the energy intensity. This effect is especially noticeable in 1996 and 1998. In the early 2000s, the effect of efficiency shift is relatively minute, and in 2004, this effect on energy intensity actually is positive. Figure 2 shows an explicit comparison between these two effects. Regardless of being negative or positive, the efficiency shift always has a larger influence on the total EI than the industrial mix does, which matches the trend at the national level discussed above.

Table 4: Shift-share analysis of energy intensity in Inner Mongolia's material production sector, 1996-2004 (kilograms of standard coal equivalent per 1000 Yuan of Output)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Constant share		258.26	204.39	248.58	198.75	197.29	191.16	186.73	181.53	175.84

Industrial mix		10.06	6.77	−0.51	3.00	−2.36	2.06	1.13	1.62	12.50
Efficiency shift		−63.93	37.42	−49.32	−4.45	−3.78	−6.50	−6.33	−7.31	32.19
Total EI	258.26	204.39	248.58	198.75	197.29	191.16	186.73	181.53	175.84	220.53

Source: calculated from related tables in the Appendix.



Source: derived from Table4

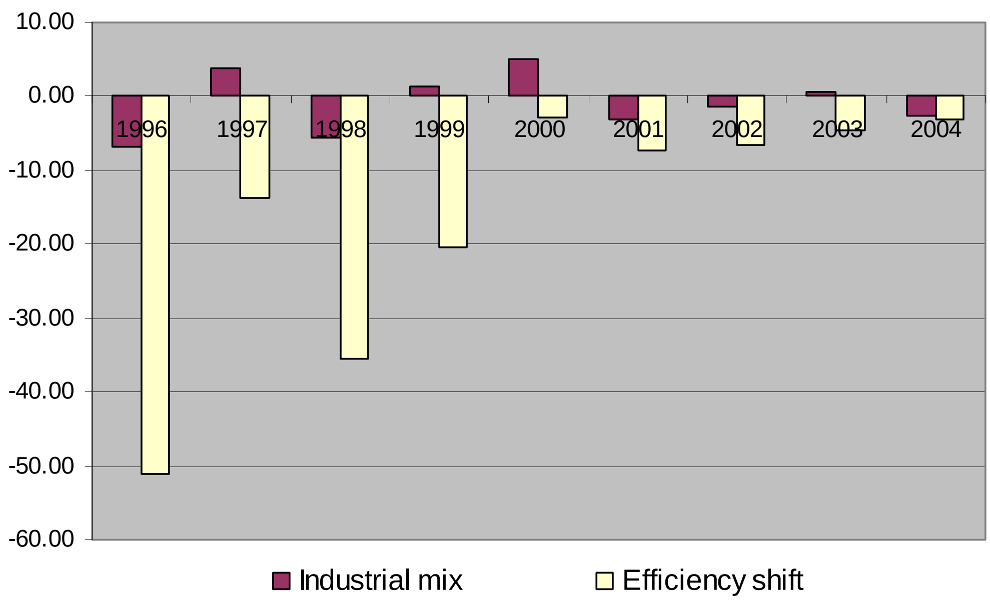
Figure 2: Inner Mongolia's industrial mix and efficiency shift, 1996-2004

Liaoning shows a constant decrease of energy intensity except in the year 2000, in which the EI is slightly higher than the previous year then returning to a lower level. This indicates that this province has made progress in improving its energy efficiency. Examining from the effects of industrial mix and efficiency shift, we can easily find that its efficiency shift has been continuously negative, while the industrial mix varies above and below zero. The efficiency shift trend clearly tells that, Liaoning, in the past ten years, has introduced new energy technology or other techniques that improve energy efficiency. In contrast to Inner Mongolia, Liaoning also makes more progress in optimizing its industrial structure: in five of the nine years, the industrial mix is negative. Still, efficiency shift has higher values than industrial mix, thus, it remains a main force in changing energy intensity, as shown both in the table and the figure

Table 5: Shift-share analysis of energy intensity in Liaoning's material production sector, 1996-2004 (kilograms of standard coal equivalent per 1000 Yuan of 0utput)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Constant share		276.39	218.62	208.69	167.77	148.65	150.86	140.38	132.56	128.40
Industrial mix		-6.76	3.72	-5.47	1.32	5.16	-3.09	-1.35	0.50	-2.53
Efficiency shift		-51.01	-13.65	-35.44	-20.44	-2.96	-7.39	-6.48	-4.66	-3.01
Total EI	276.39	218.62	208.69	167.77	148.65	150.86	140.38	132.56	128.40	122.86

Source: calculated from related tables in the Appendix.



Source: derived from Table5

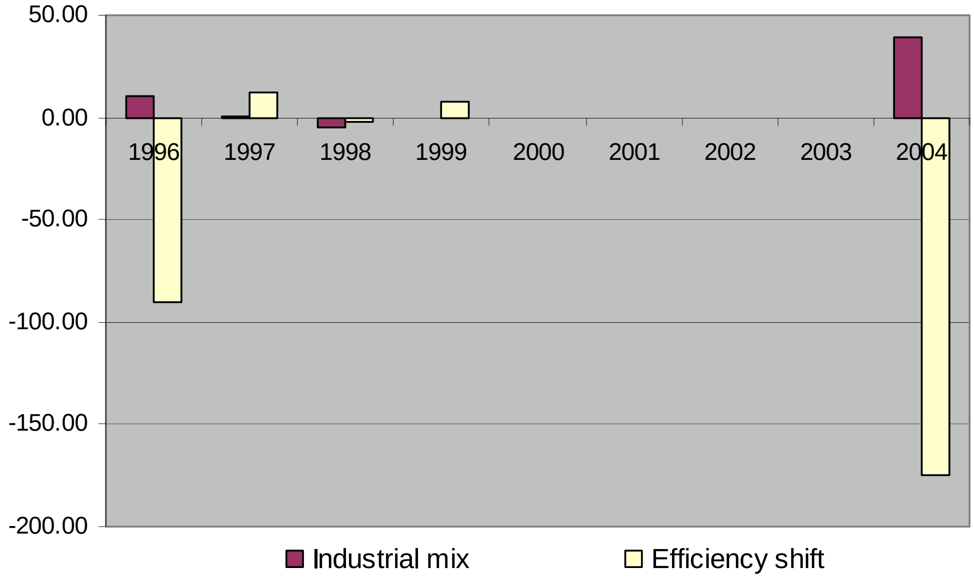
Figure 3: Liaoning's industrial mix and efficiency shift, 1996-2004

For Ningxia Provicne, due to data unavailability, I have only five years' data about shift and mix effects. Based on the available information, I find that, as a whole, energy intensity climbed in Ningxia Province from 1995 through 2004. Although its EI in 1996 decreases to 227.7 from 308.2 in 1995, the coming three years actually have increasing energy intensity. EI of 1997, 1998 and 1999 stays basically at the same level (around 240 EI units), and then in 2004, it soars to 427.6, almost doubling that of 1996. To go further, the efficiency shift does not stay constant, changing between positive and negative. The years of 1996 and 2004 witness significant negative efficiency shift compared to other years; meanwhile, the industrial mix also presents a large trade-off with a positive effect on energy intensity. On the one hand, I infer that, Ningxia, a relatively undeveloped region in China, has not improved its technology of utilizing energy significantly in the past ten years. On the other hand, its industrial structure still remains energy-intensive. I explain this in detail in the coming section.

Table 6: Shift-share analysis of energy intensity in Ningxia's material production sector, 1996-2004 (kilograms of standard coal equivalent per 1000 Yuan of output)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Constant share		308.24	227.73	240.68	233.61					563.56
Industrial mix		10.06	0.48	-4.92	0.01					38.86
Efficiency shift		-90.57	12.47	-2.15	7.58					-74.83
Total EI	308.24	227.73	240.68	233.61	241.20					427.60

Source: calculated from related tables in the Appendix.



Source: derived from Table 6

Figure 4: Ningxia Province's industrial mix and efficiency shift, 1996-2004

5. Energy investment, efficiency and renewable energy

In the previous section, I showed that the energy-efficiency shift is the main factor explaining the change of energy intensity in China as a whole as well as in each of the three selected provinces. As defined, I assume this efficiency effect is triggered by technological innovations. To help understand the underlying factors causing the efficiency effect, I examine energy-technology investments in China and in the three provinces.

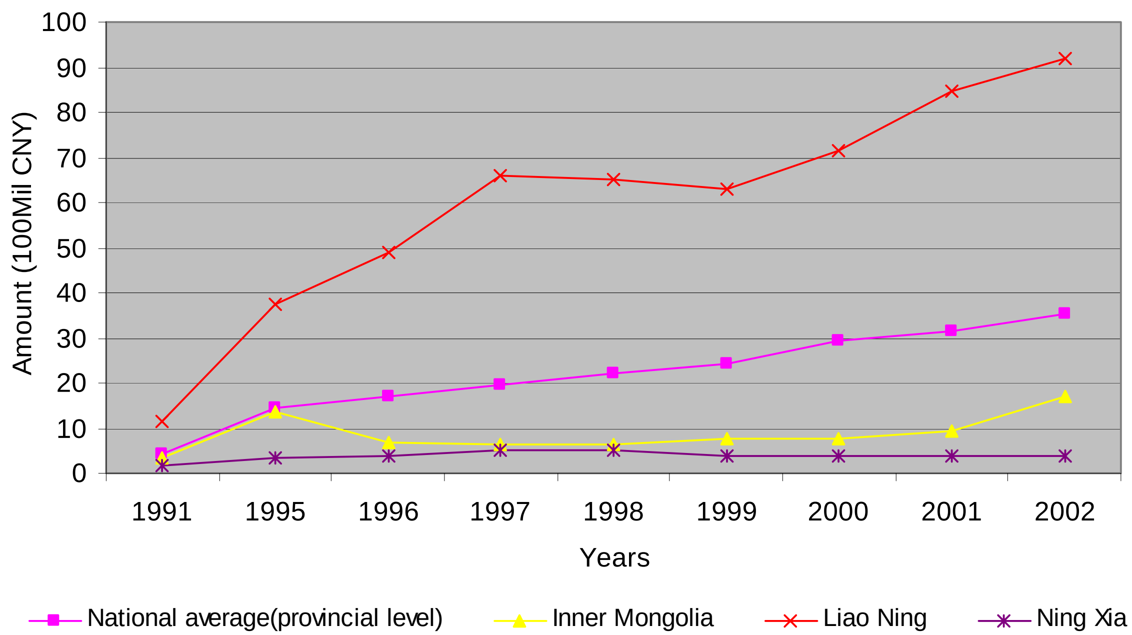
Table 7 describes the investment in technology updates and transformation in the energy industry by region in China. On average, China's investment in this field has increased steadily in those years, from 0.441 billion yuan in 1991 to 3.549 billion yuan in 2002, with an average annual growth rate of 66.4%. Compared to this national average, both Inner Mongolia and Ningxia Provinces have underinvested. Ningxia's investment remains roughly at the level of 400 million yuan during this period. Its investment in 2002 is only 367 Million Yuan, considering the factor of deflation, lower than that of 1995, which is 353 million yuan. Ningxia has experienced a long-term underinvestment in technical updates and transformation in energy industry. This underinvestment naturally cannot contribute to increasing energy efficiency and can cause the efficiency shift to be insignificant in decreasing energy intensity, which might well explain why this province, unlike many provinces in China, has increasing energy intensity in the past ten years. Inner Mongolia (Figure 5) also underinvests in technology during this period. Since 1996, its investment has been always less than half that of the national average, and from 1996-2000, Inner Mongolia invests about the same amount for technologies in the energy industry, around 700 million yuan (roughly 90 million US dollars). Inner Mongolia's energy intensity basically has remained constant or only slightly decreased during 1996 through 2003, which is shown by this investment profile.

In contrast to the other two provinces, Liaoning Province, in general, has increased its annual technology investment. In 1991, Liaoning Province invested only 1,160 million yuan for technology innovation in the energy industry, but this value tripled to 3.75 billion yuan after four years. Then, from 1995 to 2002, this investment continues to climb, reaching 9.2 billion yuan in 2002. The investments for years around 1998 stay almost the same or only slightly decrease, which might be connected to the "laid-off" reform around 1998 when a lot of heavy industrial or some other SOEs were shut down, which could lead to the non-increase in energy technology investment. Figure 5 well illustrates this trend. For each year, Liaoning's investment is more than double that of the provincial average. These large amounts of investment benefit Liaoning Provicne by decreasing its energy intensity remarkably. As discussed earlier, in 1995 Liaoning's energy intensity was 276.4 units, which was almost double that of the national value (163.4 units), but in 2004, Liaoning had decreased its EI to 122.86, very close to the national 115.42 EI units. This achievement, although we cannot illustrate it strictly at this stage, can be reasonably attributed to the continuously increasing investments in energy technology innovation in Liaoning Province.

Table 7: Investment in technical updates and transformation in energy by region, 1991-2002, (100 million yuan, current price)

	1991	1995	1996	1997	1998	1999	2000	2001	2002
National (provincial average)*	*4.41*	*14.59*	*17.03*	*19.38*	*22.21*	*24.38*	*29.47*	*31.63*	*35.49*
Inner Mongolia	3.55	13.82	6.93	6.49	6.38	7.85	7.84	9.31	17.05
Liaoning	11.60	37.51	48.92	65.92	65.18	62.77	71.39	84.49	91.94
Ningxia	1.88	3.53	3.95	5.15	5.12	4.00	3.97	3.96	3.67

Source: *China Energy Statistics Yearbook* (1992-2005)
*: the average of 31 of China's provinces and municipalities (not including Hong Kong, Macau and Taiwan), calculated from the national total divided by 31; 1992/1993/1994, and 2003/2004 data unavailable.



Source: derived from Table 7.

Figure 5: Investment in technical updates & transformation in energy industry (edited from Table7)

However, these investments in the energy industry are not necessarily directed to renewable energy development. Due to China's long push and policy motivation for developing renewable energy, I believe that these provinces have some renewable energy that might benefit from technology investments and contribute to energy efficiency to a certain degree. In the following, I discuss the development of renewable energy in these regions.

Unfortunately, due to data limitations, I cannot analyze in detail the renewable energy development in the three provinces, but I can give a brief description about their general status with respect to renewables. Ningxia Province, based on its geographic location, has a good potential of developing the solar industry. Its solar industry development dates to 1970s, with technologies including solar stoves, solar water heaters, solar-powered houses, and household solar PV systems. Yinchuan, the capital of Ningxia, ranks the 3rd, after Lasha and Hohhot, among all the 31 capital cities in China in terms of solar power potential capacity. San (2004) shows that the 2003-2010 planning of Ningxia solar power utilization will reduce annual energy consumption by 432,000 Tonnes of Coal Equivalent (TCE), about 5% of its 2004 coal consumption. However, the investment in the solar industry is still minimal: government investment for rural energy has accumulatively amounted only to 28 million RMB (about 3.7 million USD) up to 2003. Although having a relatively long history, the solar industry, the main renewable industry in Ningxia, remains at its infant stage, and its minimal scale keeps it from playing a noticeable role in bringing energy technology innovation or reducing energy intensity.

Inner Mongolia has the largest wind power potential in China. Up to 2005, the total capacity of wind power was 166,000kwh (kilowatt hours), the top one in China. However, only 1% of this potential has been developed so far. Up to 2004, there were 158,000 mini wind turbines, which supply 150,000 households with electricity. In 2010, this wind capacity will reach 4,000,000kwh, about 25 times that of 2005. However, even this planned amount, only accounts for 0.0075% of the electricity consumption by Inner Mongolia in 2004, which is 53.6 billion kwh. Apparently, although Inner Mongolia has a well-developed wind-power industry, it is still too little to contribute to its energy efficiency.

Due to the data unavailability for Liaoning Province, I cannot discuss much about its renewable energy industry. Renewable energy is less developed compared to the other two provinces. Although the provincial government issued some policies and laws, on the one hand, these regulations mainly affect renewable development in rural areas, and the scale is minimal. On the other hand, things are changing. In Liaoning Province, energy conservation and developing renewable energy were on the agenda in the provincial 11th Five-Year Plan (Liaoning, 2006).

6. Industrial structure

To play a role in decreasing energy efficiency, officials need to promote the renewable energy industry more than they do at present. The minimal scale of renewable energy in the provinces explains why this industry cannot show the expected effect of improving energy efficiency. Althoguh Investments in energy technology updates and transformation help analysts understand why there is a difference in the energy-shift effect among these provinces, I note that the industrial mix usually plays a minimal role in changing energy intensity.

As mentioned before, the coal industries, energy-intensive sectors, are the main force driving the

Inner Mongolian and Ningxia economies, and in Liaoning Province, the energy-intensive steel industry, plays a similar role. Table 8 shows two supporting companies in Inner Mongolia and Ningxia, Shenhua and Ningxia Coal. Each of them is regarded as the main power fueling the GDP growth in the host province. As the economy relies on these energy-intensive industries for growth, it may face internal challenges of adjusting the industrial structure to a better level for decreasing energy intensity. To understand the importance of such a company, for example, Shenhua Corporation, we can compare it with Peabody, the largest coal company in the United States, which made a total revenue of 3.6 billion USD in 2004. Shenhua's 2004 revenue was 56.5 billion Yuan, about 7 billion USD, almost double that of Peabody.

Table 8: Shenhua and Ningxia Coal

Rank	Corporation	Assets (billion RMB)	Proved Reserve (billion tonnes)	Annual coal production (million tonnes)	Province
1	Shenhua Corporation	188.8	＞223.6	121	Inner Mongolia
8	Ningxia Coal Corporation	25.1	24.1	33	Ningxia

Source: Multiple, edited by the author

Note: Ningxia Coal Corporation merged with Shenhua in 2006.

7. Conclusion and discussion

Conducting a shift-share analysis, I have proved my hypothesis proposed at the first section. My analysis shown that the energy-efficiency shift, the key 'other' factor rather than the development of renewable energy, plays a main role in changing the energy intensity of China, and three of its provinces (Inner Mongolia, Liaoning, and Ningxia) from 1995-2004. Although Liaoning province has a heavy industry base, it still decreases its energy intensity during those years. Inner

Mongolia and Ningxia, although having better developed renewable industry than Liaoning, have experienced flat or increases in energy intensity. Renewable energy development supposedly brings in new energy technology that can decrease energy intensity, but this does not appear to occur in Inner Mongolia and Ningxia. This can be mostly explained by the minimal scale of this industry in both regions. I show that technical update and transformation investments in the energy industry can partially explain the effect of efficiency shift in the three study provinces.

However, due to the data limitations, I cannot at present understand the exact role of renewable energy development in China and, in particular, in these three provinces. This prevents me from examining what exactly renewable energy industry has brought to technology innovation. This remains a problem for future research.

Another puzzle also occurs. The fact that the energy-intensive coal industry remains a base industry for both Inner Mongolia and Ningxia seems to explain partially why they cannot realize an energy-intensity decrease. However, Shanxi, the largest coal production province in China, has decreased its energy intensity successfully in the past decades (Polenske 2007). Then, why can Shanxi Province do this while Inner Mongolia and Ningxia cannot? This can also be a question for future research. Both questions call for field trips to China to collect data and to interview companies and government officials to find appropriate information.

Appendix

Note1.

All these data come from *China Energy Statistics Yearbook 1996-2005*, and *China Statistical Yearbook 1996-2005*.

Note2.

Energy consumption data are edited by the author from *China Energy Statistics Yearbook 1996-2005*. The total consumption is composed of the following ten sub-categories and is the sum of these ten after converting into standard coal equivalent via calorific value calculation: (1) coal total, (2) coke, (3) coke-oven gas, (4) other gas, (5) other coking products, (6) petroleum products total, (7) natural gas, (8) heat, (9) electricity, and (10) other energy.

These data tables with sub-categories are not attached here but are available upon request from the author.

Note3.

Sectors:

1. Farming, Forestry, Animal Husbandry, Fishery, & Water Conservancy
2. Industry
3. Construction
4. Transportation,Storage, Postal, &Telecommunications Services
5. Wholesale, Retail Trade, & Catering Service
6. *Residential consumption*
7. *Others*

67. Sum of 6 and 7 to match the classification of GDP/GRP sectors

Table 1. Energy consumption in China's Material Production Sector, 1996-2004
(10,000 tonnes standard coal equivalent based on calorific value calculation)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	3914.02	4124.20	4080.69	4076.28	4239.55	4286.98	4331.86	4593.60	4754.12	5818.18
2	69930.63	74726.76	69823.12	66687.98	64390.11	64735.67	62488.43	68161.68	80398.58	98384.39
3	897.41	978.75	842.26	1091.69	1599.52	1736.29	1090.17	1203.09	1316.25	2741.89
4	5159.18	5245.47	6550.95	7249.47	8325.87	8977.14	9128.13	9909.21	11476.24	13732.18
5	1472.05	1690.08	1630.31	1738.90	1975.12	1993.65	2048.23	2219.21	2612.87	3098.56
67	16765.29	19160.07	16296.37	14385.74	14935.93	15378.63	15379.76	16379.92	18216.19	20452.03
Total	98138.58	105925.33	99223.70	95230.06	95466.10	97108.36	94466.58	102466.71	118774.25	144227.23

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

Table 2. China's Real GDP/GRP, 1996-2004
(100 million renminbi in 1995 constant prices)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	12328.80	13438.94	13678.95	14356.88	14599.82	14628.20	15219.34	15962.03	16591.76	18960.57
2	25410.41	28231.27	31198.16	32939.31	35397.10	39047.30	41845.43	45532.28	51538.72	57348.07
3	3926.55	4397.88	4630.43	5161.11	5518.92	5888.00	6295.78	6937.51	7941.81	8739.00
4	3140.23	3391.72	3654.98	4065.93	4499.69	5408.60	5893.77	6358.45	6519.01	7024.54
5	5070.40	5397.53	5928.90	6490.71	6971.33	7316.00	7819.91	8395.04	8967.67	9219.59
67	10239.09	11040.08	12582.32	14278.64	15805.47	17180.00	19025.31	20973.77	22260.62	23671.30
Total	60115.49	65897.42	71673.74	77292.58	82792.34	89468.10	96099.53	104159.08	113819.60	124963.08

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

Table 3. Energy consumption in Inner Mongolia's Material Production Sector, 1996-2004 (10,000 tonnes standard coal equivalent based on calorific value calculation)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	87.46	117.64	136.73	120.71	118.13	126.59	154.56	159.42	184.66	216.67
2	1381.03	1363.18	1780.24	1529.41	1798.66	1969.51	2116.30	2326.02	2766.82	3605.16
3	35.85	46.05	63.97	62.28	53.09	54.82	50.85	57.52	68.69	88.11
4	150.86	154.17	184.36	187.11	137.29	144.16	149.75	164.12	174.14	329.35
5	62.81	89.23	122.86	105.83	100.68	89.29	89.12	93.26	106.39	252.77
67	269.93	341.28	443.20	390.28	326.78	293.79	308.60	322.95	369.79	1150.06
Total	1987.95	2111.54	2731.36	2395.63	2534.62	2678.16	2869.18	3123.29	3670.48	5642.12

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

Table 4. Inner Mongolia's Real GDP/GRP, 1996-2004

(100 million Renminbi in 1995 constant prices)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	235.39	328.17	323.78	345.37	347.37	350.80	356.75	371.71	407.79	477.40
2	232.51	338.36	375.80	403.80	433.90	455.21	503.67	568.74	700.44	958.11
3	63.00	67.94	71.44	80.99	88.26	101.07	119.07	153.81	244.96	298.86
4	60.46	87.52	98.43	107.21	118.16	142.59	161.82	186.59	210.41	229.19
5	54.35	74.62	80.59	96.54	104.33	133.45	147.30	162.82	175.49	191.84
67	124.04	136.49	148.75	171.46	192.67	217.89	247.97	276.86	348.31	403.01
Total	769.75	1033.11	1098.79	1205.37	1284.69	1401.01	1536.57	1720.53	2087.40	2558.41

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

Table 5. Energy consumption in Liaoning's Material Production Sector (10,000 tonnes standard coal equivalent based on calorific value calculation)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	128.50	147.32	145.53	144.88	148.41	143.18	148.09	145.83	144.75	151.08
2	5938.14	5454.32	5540.41	5011.22	4759.76	5483.66	5251.18	5411.11	5837.28	6005.13
3	45.86	40.98	68.96	64.79	64.19	65.67	68.13	68.75	73.53	77.91
4	245.12	195.10	304.37	290.10	289.98	442.32	653.91	637.74	594.25	635.94
5	61.41	67.15	49.53	51.00	54.92	58.61	62.95	66.77	69.47	99.96
67	984.55	1056.68	1015.11	852.90	877.94	850.21	881.23	985.58	943.30	1140.78
Total	7403.59	6961.56	7123.91	6414.89	6195.21	7043.64	7065.49	7315.78	7662.58	8110.80

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

Table 6. Liaoning's Real GDP/GRP (100 million Renminbi in constant 1995 prices)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	347.05	478.09	474.76	523.50	520.28	503.44	544.44	596.76	612.24	739.57
2	1207.67	1390.71	1533.26	1639.11	1793.91	2114.89	2190.12	2357.89	2542.04	2721.37
3	162.31	159.95	172.45	188.31	205.56	229.51	250.43	280.99	340.09	428.33
4	174.31	196.20	219.13	267.88	314.17	350.46	394.50	430.14	492.81	588.88
5	312.95	394.55	428.72	525.16	575.20	631.64	696.51	768.72	798.57	860.70
67	474.38	564.84	585.37	679.60	758.39	839.12	957.08	1084.43	1182.10	1263.03
Total	2678.68	3184.34	3413.69	3823.56	4167.52	4669.06	5033.08	5518.93	5967.85	6601.86

Source: *China Statistics Yearbook, 1996-2005*.

Table7. Energy consumption in Ningxia's Material Production Sector (10,000 tonnes standard coal equivalent based on calorific value calculation)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	23.64	19.55	21.19	20.06	21.15	*	*	*	9.83	9.73
2	307.17	321.19	359.34	380.11	428.40	*	*	*	1851.69	1365.95
3	2.65	1.41	3.14	2.83	3.04	*	*	*	2.68	7.33
4	39.41	31.92	35.72	34.52	27.86	*	*	*	113.82	37.33
5	0.75	0.68	0.36	5.79	12.46	*	*	*	15.86	18.58
67	76.40	75.18	79.29	79.06	87.24	*	*	*	120.51	409.26
Total	450.02	449.93	499.04	522.37	580.15	*	*	*	2114.40	1848.19

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

*: data unavailable

Table 8. Ningxia's Real GDP/GRP, 1996-2004 (100 million renminbi in 1995 constant prices)

Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	32.62	44.12	44.06	47.86	47.82	45.95	48.79	52.32	54.04	61.15
2	50.01	69.02	71.94	74.78	80.38	93.00	100.62	113.67	139.53	174.92
3	10.78	12.35	14.22	17.64	21.89	27.04	31.63	36.00	47.41	49.87
4	6.69	11.93	14.09	15.84	17.96	19.31	22.59	25.33	27.11	28.07
5	12.77	17.38	18.17	18.71	20.44	21.60	23.08	25.04	27.22	29.81
67	33.13	42.78	44.87	48.78	52.04	58.67	66.97	73.68	79.88	88.40
Total	146.00	197.57	207.35	223.61	240.52	265.57	293.68	326.05	375.18	432.22

Source: *China Energy Statistics Yearbook 1996-2005*, *China Statistical Yearbook 1996-2005*.

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