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Regional disparity and Mitigation cost for carbon policy in China ——Assessment based on multi-regional CGE model

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Abstract

Literature review shows that most economic analyses of climate change have focused on the international cross-section analysis on the impact of mitigation actions. This paper departs in disaggregating the impact by provinces in one country, focusing particularly on industrial structure and income disparities between different provinces in China. With different economic growth, there exists substantial difference for energy consumption and carbon emission between provinces in China. In 2008, the highest carbon emission per GDP is about six times of the lowest carbon intensity. Therefore, it is expected carbon mitigation will result in different effect on different provinces. This paper will build a multi-regional computable general equilibrium model for China, which contains 31 provinces. Uniform carbon tax is imposed across provinces to achieve different carbon mitigation. Different carbon policies will be simulated based on the multi-regional CGE model and its effect on regional disparity will be analyzed.

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Introduction and motivation

According to World Development Report, Business-as-usual could lead to temperature increases of 5°C or more this century and if all countries act together immediately, the incremental costs of keeping warming around 2°C are modest and can be justified given the likely dangers of greater climate change (World bank, 2009).

Global climate change has become a serious problem to all countries in the world. China, as a developing country, will face a greater impact compared with the developed countries due to the high dependence on natural resources and the lack of sufficient capital and technology to adapt to climate change.

In the run-up to the COP-15 negotiations for a post-kyoto Protocol climate agreement, China indicated it would unilaterally reduce its carbon intensity of GDP in 2020 by 40-50% relative to 2005 levels (Fu et al. 2009).

Therefore it can be expected in future years, Chinese government will carry out policies relating to CO2 emission in order to achieve its commitment to reducing carbon emission intensity.

Literature review shows that most economic analyses of climate change have focused on the international cross-section analysis on the impact of mitigation actions and obligation of mitigation for negotiation (IMF(2007), Nordhaus(2007), Stern(2007), UNDP(2007), World Bank(2009)). This paper departs in disaggregating the impact by provinces in one country, focusing particularly on industrial structure and income disparities between different provinces in China. With different economic growth, there exists substantial difference for energy consumption and carbon emission between provinces in China. In 2008, the highest carbon emission per GDP is about six times of the lowest carbon intensity. Therefore, it is expected carbon mitigation will result in different effect on different provinces.

Economic development, regional disparity and carbon emission

China is a vast country with more than 30 provinces or autonomous regions and so on. Many provinces are even larger than some European countries in term of population and land area. As the geographical positions and the natural resources are different among regions, there is a big different economic development between regions. The following mainly introduce regional disparity in the view of the resource distribution, economic structure, the income disparities and carbon emissions.

Energy resources are mainly concentrated in the central and western China; the regional distribution is extremely uneven. From the total amount of resource reserves point of view, China is one of countries having rich primary energy sources, abundant water and coal resources but poor oil and gas resources. From a perspective of the resource distribution, coal resources is distributed widely and the resources in storage is relative concentrated, but generally uneven, with characteristics of abundance in the West and little in the East, poor in the South and rich in the North.

According to the 1997 Third National Coal forecasts, the total of the coal resource is 5.58 trillion tons. Two autonomous regions with more than trillion tons are Xinjiang and Inner Mongolia; there are 6 provinces having more than one hundred billion tons including Shanxi, Shaanxi, Ningxia, Gansu, Guizhou and Henan. The above 8 provinces (or autonomous regions) totally account for 91.3% of the amount of coal resources.

Water resources are mainly concentrated in 12 western provinces including Yunnan, Guizhou, Sichuan, Chongqing, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, Tibet, Guangxi, Inner Mongolia (autonomous regions and municipalities), whose water resource account for 77% of the national total. Especially, five southwest provinces, including Yunnan, Guizhou, Sichuan, Chongqing and Tibet, account for 60% of the national total.

Oil resources are mainly distributed in the Northwest, North, Northeast China and the marine continental shelf; natural gas resources are mainly distributed in the Northwest Territories, followed by the Northeast, North China and Southeast coastal shallow continental shelf.

Resource-rich provinces heavily depend on exploitation and export of energy and resources. Table 1 shows the industrial structure in China in 2006. According to the data, agriculture in eastern region account for lower proportion than the developed provinces. More and more rural residents transferred to City and engaged in non-agricultural industries due to faster economic development in the eastern region. Thus, the proportion of the agricultural economy is becoming less and less in the whole economy. The proportion of secondary industry in the eastern region is relatively higher than the central and western regions; but their share of service sector is also slightly higher than resource-rich province in the Middle and Western China. At present, China is still in the stage of rapid industrialization, manufacturing industry is still the main driving force for economic growth, and thus the development of the manufacturing sector has also become one of important determinants of economic growth.

Figure 1 shows the proportion of GDP of the mining and the manufacturing industry in the share of total regional GDP. In the figure, the horizontal axis from left to right reflects the proportion of mining industries from low to high; the vertical axis from bottom to top reflects the manufacturing sector rising from low to high. Intersection of the two-axis denotes the national average. Thus the all regions are divided into four groups according to the national average. As can be seen from the chart, five resource-rich provinces including Shanxi, Xinjiang, Shaanxi, Ningxia, and Inner Mongolia are at the lower right area, characterized by above-average proportion of mining industries and the manufacturing sector with low on average.

East China also belongs to this group. But East and South China are in upper left area, namely, the proportion of mining industries is relatively low, while the manufacturing sector is high in these regions. So, it could be that economic development of the resources- and energy -rich provinces simply rely on resource and energy extraction, but processing and manufacturing industries fell behind and even shortage. In other words, these provinces will only be at the most low-end of value-chain, lacking of deep processing of products with high added value, thus it lack of dynamic for long-term economic growth; the high-end of value-chain is controlled by the economically developed eastern region to promote the long-term rapid growth of those regional economy.

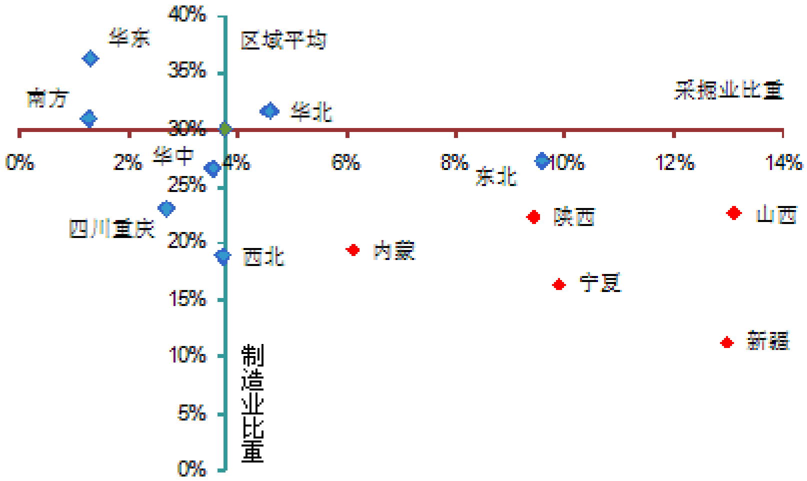

Fig 1 Share of mining and manufacturing in 2002 (%)

Energy- and resource-rich areas are poorer than coastal provinces; the regional income disparity was large. Figure 2 shows the level of per capita GDP of the 30 regions in 2007, which indicated the difference between regions in 2007. Per capita GDP in many provinces in Eastern China was significantly higher than the regional average. In recent years the growth rate of GDP of Inner Mongolia Autonomous Region has been even more than 20%, per capita GDP in Inner Mongolia Autonomous Region in 2007 was 19% higher than the regional average level, because high resource prices were driving the rapid development of related industries,. But regret is that the level of per capita GDP of other energy-rich provinces is lower than the regional average, particularly in Shanxi and Ningxia. In 2007 per capita GDP of the two provinces were 20% and 35% lower than the regional average respectively. Overall, the level of development of energy- resource-rich provinces fell relatively behind.

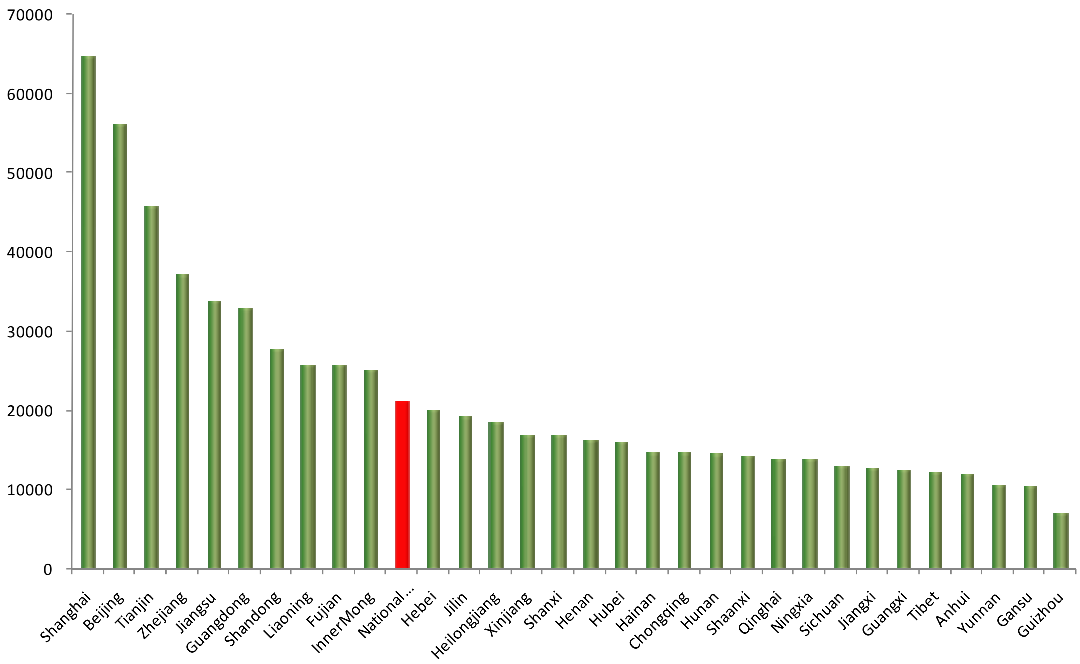

Fig 2 Regional GDP per capita in 2007 (Yuan)

Both coal reserves per capita and GDP per capita are drawn in Fig 3. It is clearly to see the inverse relationship between this two issues, that is the level of the economic development of provinces with a good endowment of coal resources is more backward, and the provinces with scarcity of coal is relatively advanced.

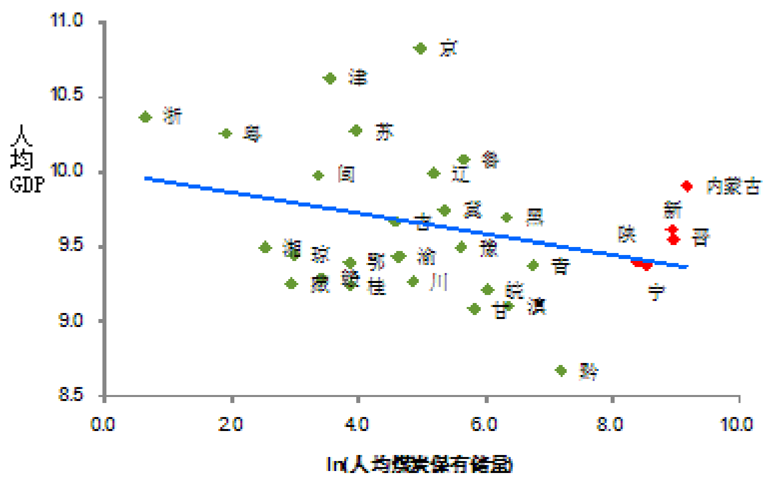

Fig 3 Coal reserve per capita and GDP per capita

Carbon emissions mainly come from the use of fossil energy. There are two main factors impacting carbon emissions. One factor is the economic scale, the other is the carbon emission intensity. The CO_2 emissions in Shandong, Guangdong and Jiangsu provinces had been more than 200 million tons in 2002 mainly *due to the* larger economy; on the other hand, the CO2 emissions in provinces like Shanxi, Inner Mongolia were also large and up to 150 million tons mainly due to the high carbon emission intensity per unit GDP .

Figure 4 shows the per capita GDP and CO_2 emissions intensity per unit GDP. From the figure, we can see clearly that the CO_2 emission intensity in energy- and resource-rich provinces such as Guizhou, Shanxi, Inner Mongolia and Ningxia were very high; the provinces which have the high level of economic development rate and lack of energy resources such as Guangdong, Zhejiang and Jiangsu, its carbon emission intensity is very low. Overall, the regions with abundant energy resources were characterized by low level of economic development and high carbon intensity.

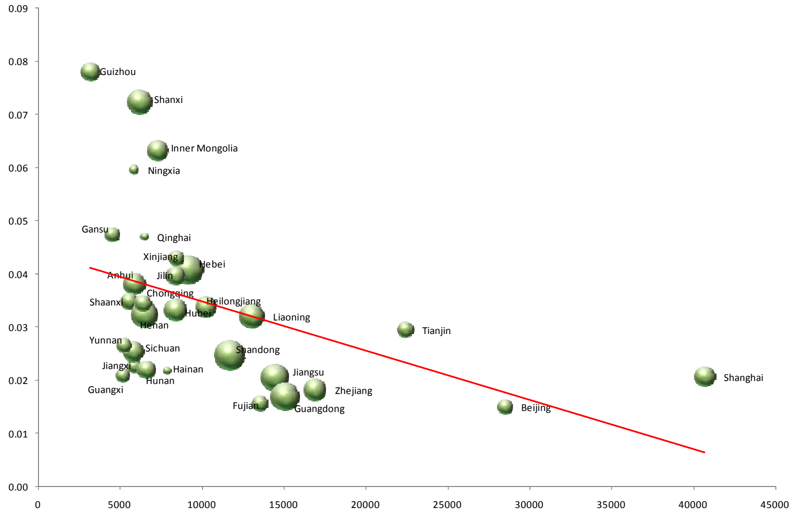

Fig 4 Carbon intensity and GDP per capita

Notes: the size of bobble denotes total emission of carbon dioxide.

China's Multi-regional Computable General Equilibrium Model

The model in this paper belongs to a family of DRC-CGE-models used extensively over the past two decades to analyse environmental policy and other policy reforms, and maintained at the Development Research Center of the State Council in China. In China the model is used in regional development planning and macroeconomic planning for the State Council, including the five year plans.

The model has 30 region and 23 sectors (including 1 agricultural sectors, 3 mining sectors, 7 manufacturing sectors, 8 utility sector, and 4 services sectors). There are 4 production factors: land, resource, labor, and capital. Labor is disaggregated into 3 types by occupation. There are 2 representative households by area. In addition, electricity activity is divided into different sub-sector by source (Thermal-, hydro-, nuclear and renewable power generation). The model is calibrated to DRC multi-regional Social Accounting Matrix with a 2002 base year[1]. For a detailed description see Appendix 2.

Carbon mitigation and its regional impact

In general, there are many ways to mitigate carbon emission from a point of regional view, e.g carbon tax, cap and emission trading. All these three types of policies can be simulated in this multi-regional CGE model. As for carbon tax and cap, regional specific carbon tax or cap on emission can be imposed. Different from carbon tax, the model will provide the shadow price of carbon according to emission cap. The emission quotas should be assigned in advance for emission trading policy. In this paper, the aggregate emission cap policy will be simulated and total regional carbon emission will be reduced by 20%, i.e a uniform shadow carbon price will produced by model endogenously.

Figure 5 shows changes of the welfare for all regions under the carbon emission reduction scenarios, in which the horizontal axis from left to right shows the level of per capita GDP from low to high; the vertical axis reflects carbon emission intensity, namely, CO2 emissions per unit GDP; The size of the bubble indicates the degree of the welfare losses suffered. The bigger the bubble is and the severer their loss is. According to per capita GDP and the carbon emission intensity, all the regions are divided into three groups as the following.

The first group includes those regions, which have the high level of per capita GDP, but its carbon emission intensity is very low.

[1] The latest regional Input-Output tables are in 2002.

This group includes three municipalities (Beijing, Shanghai and Tianjin) and three coastal provinces (Zhejiang, Guangdong and Jiangsu). No doubt are these currently the most developed areas. The lowest level of per capita GDP in these regions has exceeded more than 5000 U.S. dollars. From the figure, we can see that compared with other regions, the welfare loss in these areas is lower. Among them, Guangdong has the least welfare loss, only 0.02%. At the same time, it is not difficult to find Guangdong is also characterized by the least carbon emission intensity per unit GDP in all 30 regions. Conversely, Tianjin has the largest loss, with highest carbon intensity in this group. Besides Tianjin, other five developed regions have relatively same carbon emission intensity, but it is clear that the welfare losses for the three municipalities are significantly higher than that of the three coastal provinces.

There are two main reasons for this: firstly, when imposed with the carbon tax, it is easier for the energy-intensive industrial capital to move into other capital-intensive manufacturing industries due to that the three coastal provinces have developed manufacturing industries compared with the three municipalities; these municipalities, energy-intensive industries are not easy way out with more service industry, especially labor-intensive and technology-intensive service industries; Secondly, electric power is the major direct source for carbon emissions. The electricity demand in the three municipalities mainly comes from residential and commercial sector, which is more unchangeable than demand mainly from manufacturing in three coastal provinces

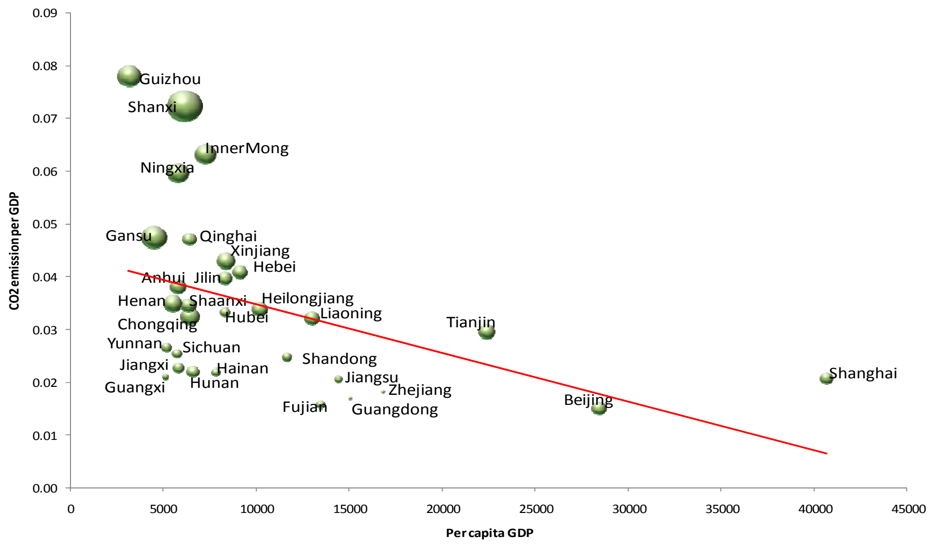

Fig 5 Welfare loss due to uniform carbon tax

Notes: the size of bobble denotes the loss of real income.

The second group includes provinces, with slow economic development and rather high carbon emission intensity.

This group includes Guizhou, Shanxi, Inner Mongolia, Ningxia, Gansu, Qinghai and Xinjiang. Except Inner Mongolia Autonomous Region, per capita GDP in other provinces in the central and western regions are lower than the national average. Another important feature of all these provinces is that they are full of very rich coal resources, especially in Xinjiang and Inner Mongolia. As a whole, these provinces will suffer more welfare losses than other regions if the uniform carbon tax is imposed. The largest welfare loss will happen in Shanxi province, which welfare will decline by 3.5%. According to 2002 Shanxi Social Accounting Matrix, 20% of its GDP comes from the coal industry and power industry which generate 40% of the industrial added value for Shanxi. Coal combustion is the main source of carbon emissions and the emission factors of coal are higher than crude oil and natural gas. Therefore, Shanxi will be the first to be affected when the carbon tax is imposed.

The least welfare loss will occur in Qinghai in this group. We can see that the loss of Qinghai (less than 0.5%) is significantly less than other provinces in this group. Qinghai decrease in the benefits level by less than 0.5%, while other provinces have reached about 1% or more than 1%. The main reason is that the water resource in Qinghai Province is abundant and it plays an important role in the entire electricity production. According to the 2008 Energy Statistics Yearbook, the data showed that hydroelectricity account for 70% of the total electricity production in Qinghai Province in 2007. This also explains why carbon emission intensity of unit GDP in Qinghai is just higher than that of Xinjiang.

Another special province is Guizhou. It has the highest carbon emission intensity in all 30 provinces; CO2 emissions per GDP reached to about 3 times of national average. However, according to simulation results, their welfare loss of Guizhou is not the highest one and less than half of that of Shanxi Province.

It could be understood by analyzing its energy structure. Firstly, from the energy composition point of view, primary energy source just includes coal and hydro-electricity, and coal accounts for nearly 90% of the total primary energy, while coal consumption accounts for only about 70% of the total national primary energy consumption in the corresponding period. This is one of the reasons why Guizhou Province on the carbon emission intensity ranks first in China.

In terms of energy use, coal consumption for resident accounted for about 25% of all the final coal consumption, while industrial consumption accounted for only about 60% in 2007; meanwhile the amount of coal consumption for resident in the whole country accounted only for about 10% of the total final coal consumption, while industrial consumption accounted for 80%. In general, the higher the proportion of primary energy consumption for resident is, the smaller the indirect effect of the carbon tax is; oppositely, the higher the proportion of the industrial consumption is, the greater the indirect effect of the carbon tax is. It is because of these two points that the welfare loss of Guizhou province with the largest carbon emission intensity is not the biggest.

The third group includes provinces, characterized by the lower level of economic development and lower carbon emission intensity.

All remaining provinces are attributed to this group. We can see from the figure that the level of welfare loss of provinces is usually higher than first group, but lower than the second group. In this group, it is also easy to see that the higher the carbon emission intensity is, the bigger the welfare loss is.

Provinces such as Anhui, Jilin, Hebei, Chongqing, Henan, and Shaanxi in this group have so relatively high carbon emission intensity that the corresponding welfare losses are big. But the welfare losses of Hubei province having nearly same carbon emission intensity with the other six provinces are relatively small, mainly because of its abundant hydropower resource, resulting in half of the electricity production of Hubei. The eight provinces such as Yunnan, Sichuan, Jiangxi, Guangxi, Hunan, Hainan, Shandong and Fujian have lower carbon emission intensity, their welfare losses are smaller.

Conclusion

This paper built a multi-regional computable general equilibrium model including 30 provinces of China to simulate the regional effect of reducing 20% of carbon emissions. The paper mainly focuses on change of the regional welfare level and some conclusions are followed:

1. Energy resources in china are mainly located in western and central regions with relatively poor economy, but their carbon emission of unit GDP are relatively high.
2. Imposing a uniform carbon tax on all regions to achieve the reduction of carbon emissions, the welfare losses of energy- and resource-rich provinces in central and western regions is much bigger than that of developed coastal provinces. If without other support measures, the carbon policy will expand the regional gap.

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Appendix 1 Economic structure in 2006 (%)

	Primary Industry	Secondary Industry	Tertiary Industry
Beijing	1.1	26.8	72.1
Tianjin	2.2	57.3	40.5
Hebei	13.2	52.8	34.0
Shanxi	4.7	60.0	35.3
Inner Mongolia	12.5	51.8	35.7
Liaoning	10.3	53.1	36.6
Jilin	14.8	46.8	38.3
Heilongjiang	13.0	52.3	34.7
Shanghai	0.8	46.6	52.6
Jiangsu	7.1	55.6	37.4
Zhejiang	5.3	54.0	40.7
Anhui	16.3	44.7	39.0
Fujian	10.8	49.2	40.0
Jiangxi	16.5	51.7	31.9
Shandong	9.7	56.9	33.4
Henan	14.8	55.2	30.1
Hubei	14.9	43.0	42.1
Hunan	17.7	42.6	39.8
Guangdong	5.5	51.3	43.3
Guangxi	20.8	40.7	38.4
Hainan	29.5	29.8	40.7
Chongqing	11.7	45.9	42.4
Sichuan	19.3	44.2	36.5
Guizhou	16.3	41.9	41.8
Yunnan	17.7	43.3	39.1
Tibet	16.0	28.8	55.2
Shaanxi	10.8	54.2	34.9
Gansu	14.3	47.3	38.4
Qinghai	10.6	53.3	36.0
Ningxia	11.0	50.8	38.2
Xinjiang	17.8	46.8	35.4