Energy Consumption and Carbon Emission in China

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Abstract

Concerned about the rising threat from climate change, this project looks into the data regarding energy consumption and carbon emission in China, the biggest carbon emitter in the world. According to the analysis, China is already making great effort in cutting its carbon emission but is still faced with huge challenge. The analysis reveals two underlying issues requiring enormous attention - the regional differences of development in China, as well as its problematic energy structure. Only by tackling the two key issues, can China realize the goal of low-carbon development. On the other hand, the two issues also embody huge economic and environmental potential, which offers China a great opportunity.

Ⅰ. Motivation

In the past years, the trend of global warming has been astonishing, and most of it can be ascribed to human activities, which emits greenhouse gases. The threats of climate change include but are not limited to the accelerating melting of cryosphere, the rise of sea level, increasing frequency of extreme weather patterns and the acidification of ocean. To avoid disastrous consequences of climate change, a lot of efforts has been made internationally, with United Nations Framework Convention on Climate Change (UNFCCC) adopted in 1992, Kyoto Protocol in 1997 and Paris Agreement signed in 2016 by 175 world leaders, including that of the two biggest carbon emitter - China and United States [1].

Since 2006, China has been the biggest emitter of carbon dioxide (CO2), the chief greenhouse gas [2]; and in 2015, its emission is 1.8 times that of US [3]. As US withdrew from Paris Agreement, the role of China became rather important in tackling climate change.

This project targets at gathering and analyzing the publicly available data on China's energy consumption in the form of fossil fuel and its carbon emission as a result. This project is aimed at figuring out the general features and driving factors of carbon emission in China and hopefully offer useful insights on feasible ways to reduce carbon emission and sustaining a healthy economy in China.

Ⅱ. Data

Ⅱ. a. Data Source

This project mainly relies on the panel data we found from Chinese National Bureau of Statistics. The data used covers the time period of 2001-2015, containing measurements on different energy consumption and CO2 emissions by 30 out of 34 provinces and by different industrial sectors. Besides, the data on national and provincial GDP, population and on provincial-level import & export, which are also obtained from Chinese National Bureau of Statistics, are used to facilitate analysis.

In total, we gathered and used 35 excel files as our raw data to facilitate our analysis on four layers: national level, provincial level, industry

sectoral level, and energy structural level. Their information is as follows:
15 excel files on Province energy inventory (energy consumption) from 2001 to 2015, each contains 30 spreadsheets by province.
15 excel files on Province sectoral CO2 emission from 2001 to 2015, each contains 30 spreadsheets by province.
1 excel file on national energy inventory from 2001 to 2015.
1 excel file on National sectoral CO2 emission from 2001 to 2015.
1 excel file on Population by province from 2001 to 2015.
1 excel file on National GDP by province 2001 to 2015.
1 excel file on Import and export by province from 2001 to 2015.

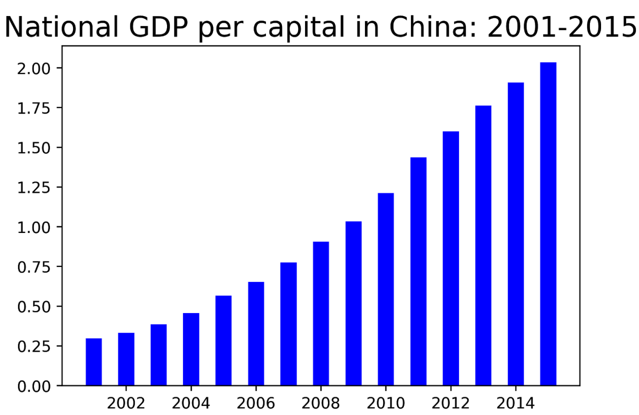
Ⅱ. b. Definition & Explanation of Measurement:

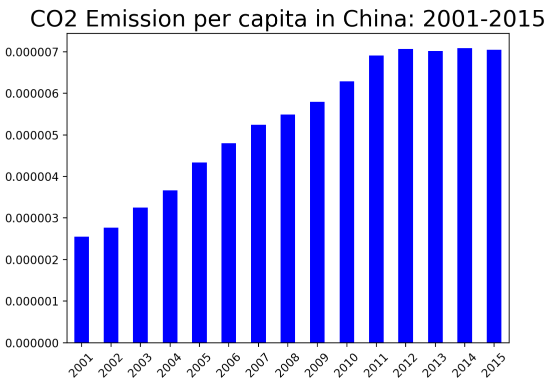
1. Living standard measurement: We adopted the international consensus and defined it as:
   GDP / Number of population
2. Environment-friendly economic development measurement: It seems unfair to judge a nation's economic development only by standard of total CO2 emission. So we decided to adopt the carbon cost per GDP to measure whether the GDP is produced in an environmentally friendly way. And this measurement is defined as:
   CO2 emission volume / GDP
3. Energy structure: There are differences among different energies. Some are finely processed while others are not, and they differ in their contribution to CO2 emission. We were very interested to explore how China's energy structure changed over years and how such shifts might help reduce CO2 emission. So we categorized energies into Raw and Clean and define the measurement as:
   Raw energy consumed / Clean energy consumed
4. Trade activeness measurement: It is suggested by some scholars that the existence of carbon market may help reduce the CO2 emission. China indeed has carbon market yet data about its distribution or activeness is nowhere to be gathered. So we decided to compromise and attempted to use the total trade activeness of a region as a proxy for it. Worrying about the bias of GDP volume differences, we generated an index adjusting for GDP volume. So the trade activeness index is defined as:
   (Import + Export) / GDP [all data on provincial level]

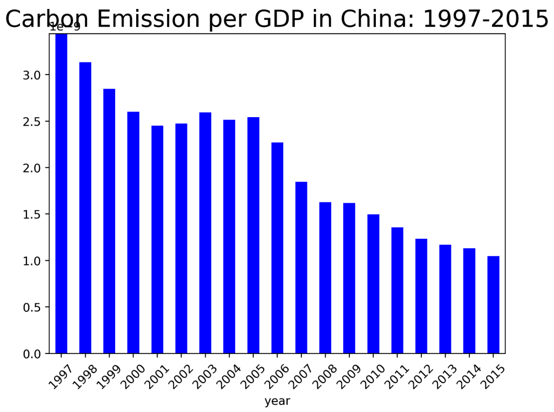
Ⅲ. Analysis Process

Ⅲ. a. General National-Level Indexes

To start with, we first looked into the general national-level data in relate to population, GDP and carbon emission. Graphs are made to demonstrate the change of their interrelation - GDP per capita, CO2 emission per capita and carbon emission per GDP.



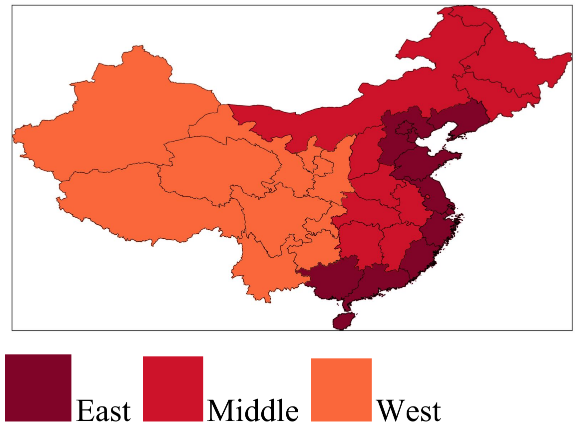




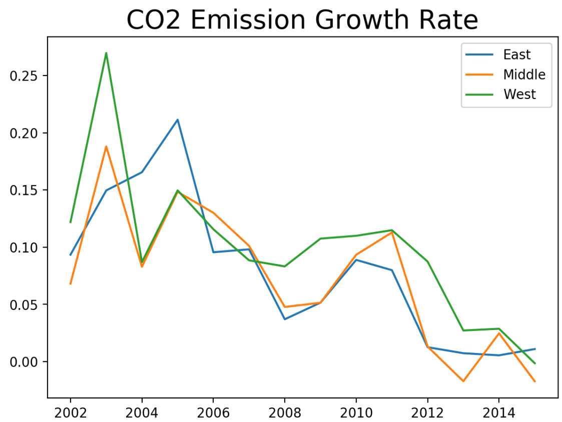
It can be clearly seen that population, GDP and carbon emission all increased dramatically in China over the time. However, the good news is that as China keeps developing, CO2 emission per capita reaches a plateau: recent increase in development (shown in GDP per capita) was and is expected to continue being driven more by efficiency. Such interpretation is also supported by the decrease shown in the trend of carbon emission per GDP.

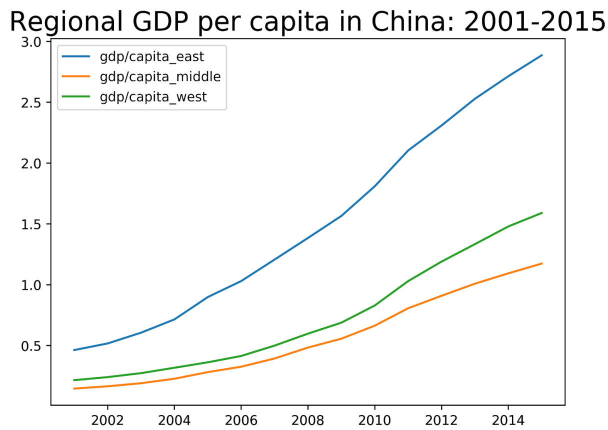
Ⅲ. b. General Regional-Level Indexes

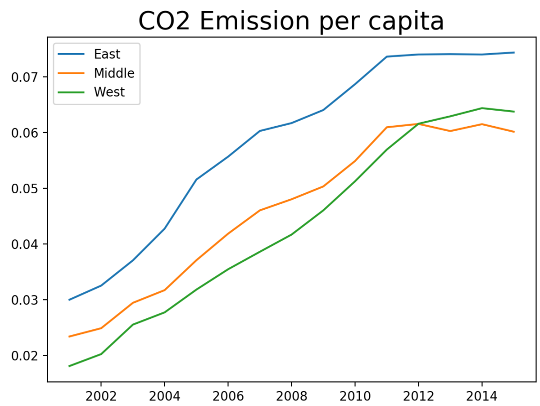
Considering the fact of regional difference in China, we decided to look into the regional level of these indexes. To do that, we divided the provinces of China into three regions: East, Middle and West, which can be clearly seen in the map we created below.

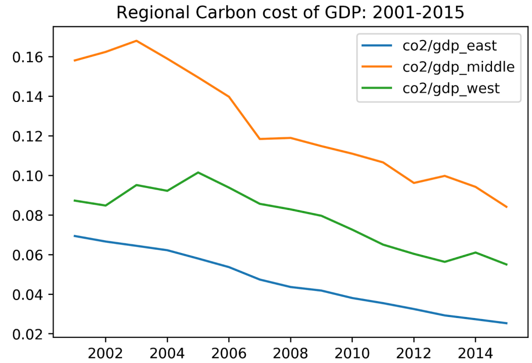


We then looked at the growth rate CO2 emission over the years - it’s inspiring to see that the rate got quite low at the end of the period. The graphs for indexes analyzed on the national level are also shown on regional level as follows.





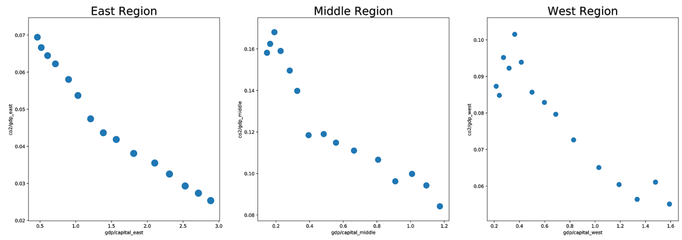




The result is intuitive in general - the richer region (East) emits more carbon per capita, corresponding to the fact that they consumed more resources. While at the same time, the richer region is where energy is used more efficiently to generate wealth, as shown by CO2 per GDP. Moreover, CO2 emission per capita got to level off in all three regions, which might be the result of a desired positive "technology spillover" from East to Middle and West. From this, it's reasonable to expect efficiency, especially in the form of CO2 per GDP, would improve further in Middle and West in a relatively short period.

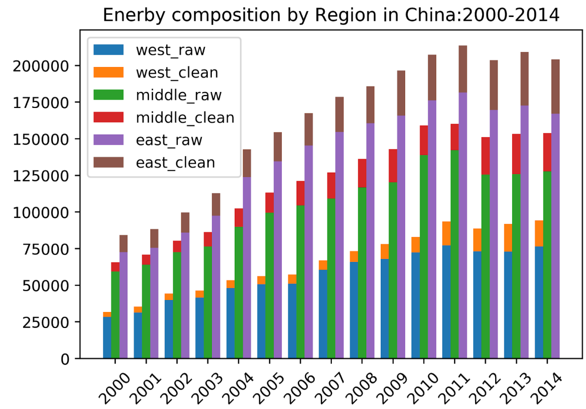
What surprised us is that CO2 emission per capita in Middle region was higher than West region before 2012, despite the fact that it was the region with the lowest GDP per capita. We consider the two explanations as reasonable: 1. The process of consuming resources and generating wealth is too inefficient in Middle region before 2012; 2. A large amount of CO2 emitted in Middle region before 2012 was not used for local people's benefit and was instead used to support economic development in East region. However, due to the limited availability of relevant data, we didn't get a chance to look into the real reason.

We also examined the the relationship between Carbon cost per GDP and People's living standard by checking the correlation of GDP per capita with CO2 emission per GDP in each region using scatter plot, with the size of points representing the size of population. As it shows, the trend in Middle and West region is much less smooth than the East, which supports our belief that the two region enjoyed a benefit from technology spillover, and probably governmental support as well. We consider it a good sign that the Chinese government was taking action.

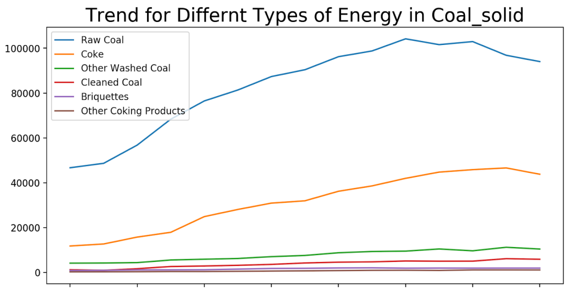


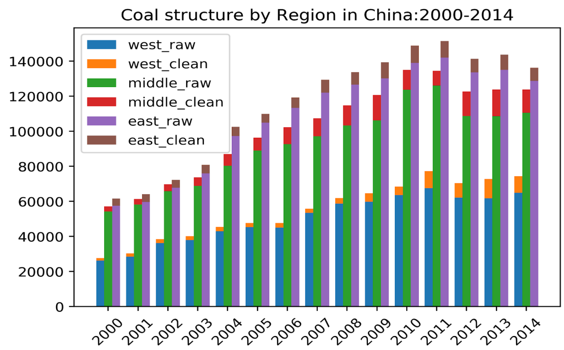
Ⅲ. c. Consumption of Different Types of Fossil Fuels

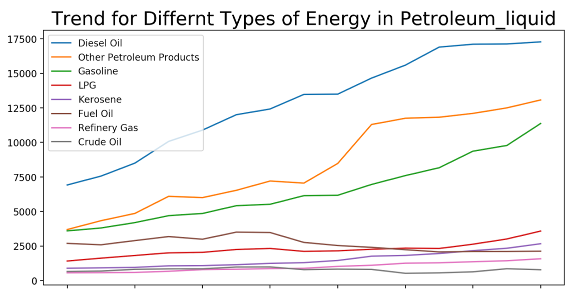
To get an understanding of the source of carbon emission, we looked into China's consumption of different types of fossil fuels. The data we use contains consumption of both primary (fossil fuels) and secondary (e.g. heat and electricity) energy sources, so we first dropped the secondary and unknown (named as "others" in the data) sources. We then divided them roughly into two groups: raw and clean based on how polluting they are to the environment, and plotted the graph for regional energy composition regarding the two types. The result is quite worrying in terms of how small the proportion of relatively clean energy is. But it’s also inspiring to confirm the decrease of raw energy in all three regions.

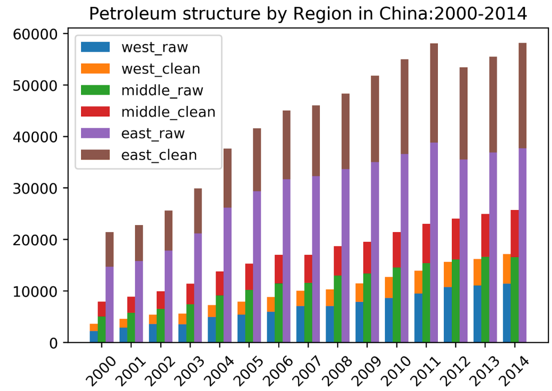


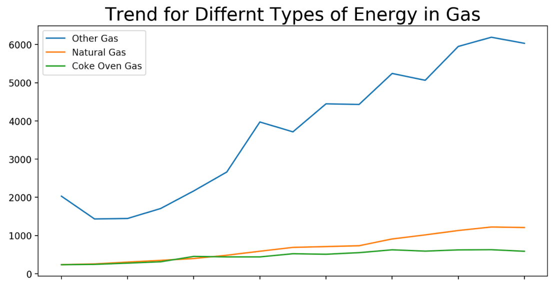
However, we later found that there might be a problem in our analysis that created certain bias - the units of different energy types are also different. Therefore, we added another dimension which categorizes the fuels into three groups: Coal_solid, Petroleum_liquid and Gas, each with the same unit.

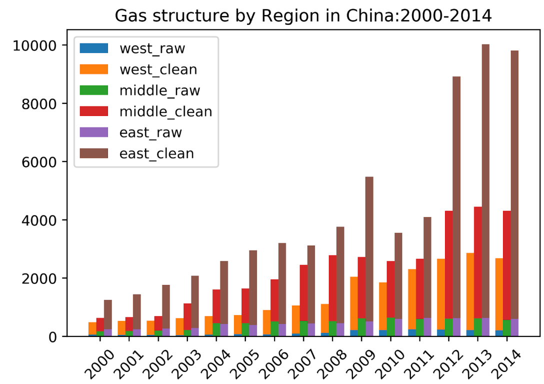






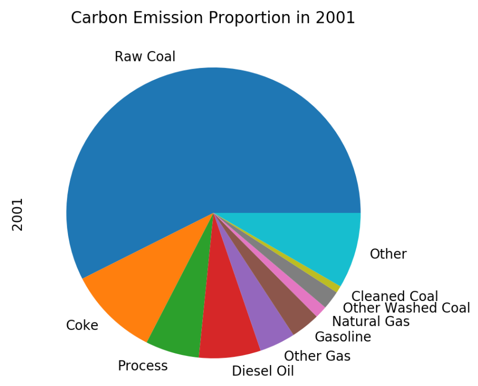


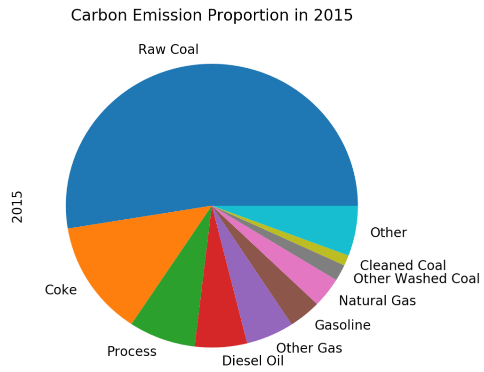




There’s not much we can tell from the category of Gas due to the limited variety, but Coal_solid and Petroleum_liquid already reveals meaningful facts - China does consume a lot of raw fossil fuels instead of cleaner ones, especially in terms of coals. We consider this a big problem for China, but also an area where it can and should improve without hurting economic development much.

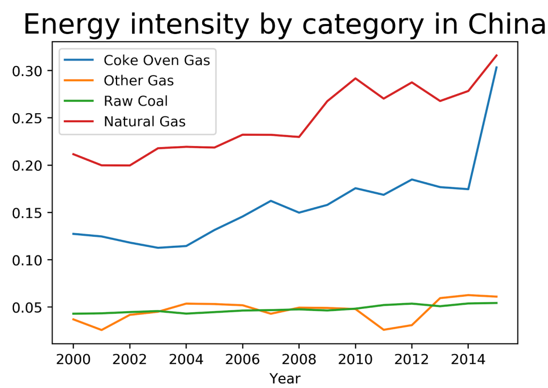
The observation is also supported by the data regarding carbon emission.





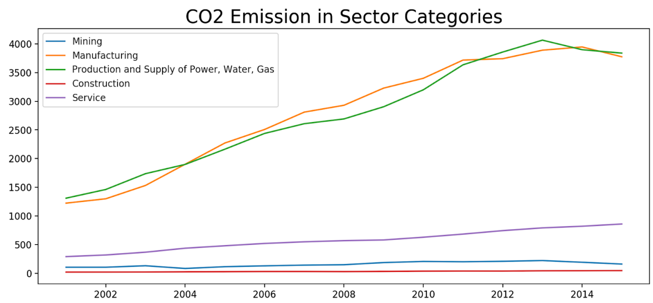
As we can see from the two pie charts above showing the composition of carbon sources in both 2001 and 2015, over half of the CO2 emitted was related to the consumption of Raw Coal, which is one of the least clean energy. Although China has reduced its reliance on Raw Coal over the 15 years, it still has a long way to go.

We further looked into the property of these energy types by calculating its carbon intensity, which we defined as Total CO2 Emission divided by the Units Consumed. The top four energy types with highest carbon intensity are shown in the graph below.



Ⅲ. d. Energy Consumption & Carbon Emission in Different Industrial Sectors

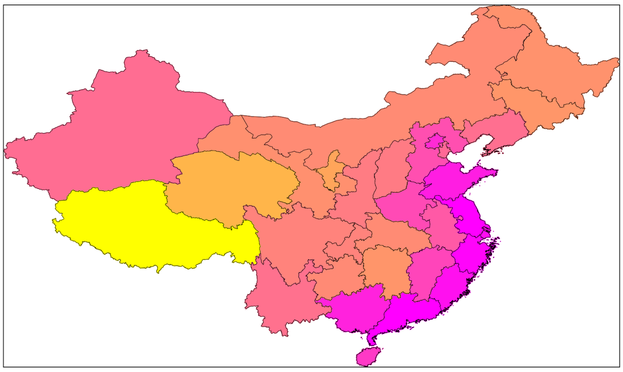
We also dived into the carbon emission by different industrial sectors to learn what the energy was consumed for. As the data we have covers mainly the secondary industry, with a small portion for service industry, we further divided the secondary industry into different categories: Mining, Manufacturing, Production and Supply of Power, Water, Gas, AND Construction, according to the official classification of Chinese government [4].



From our analysis, it's easy to tell that Manufacturing, along with Production and Supply of Power, Water, Gas, was the major emitter of CO2. And their emission was declining at the end of the target period, coinciding with the trend we saw when analyzing energy consumption in general. We also applied sectoral analysis to energy consumption. However, as some major sectors relies heavily on secondary energy source such as electricity, the data we have is biased, making the result meaningless.

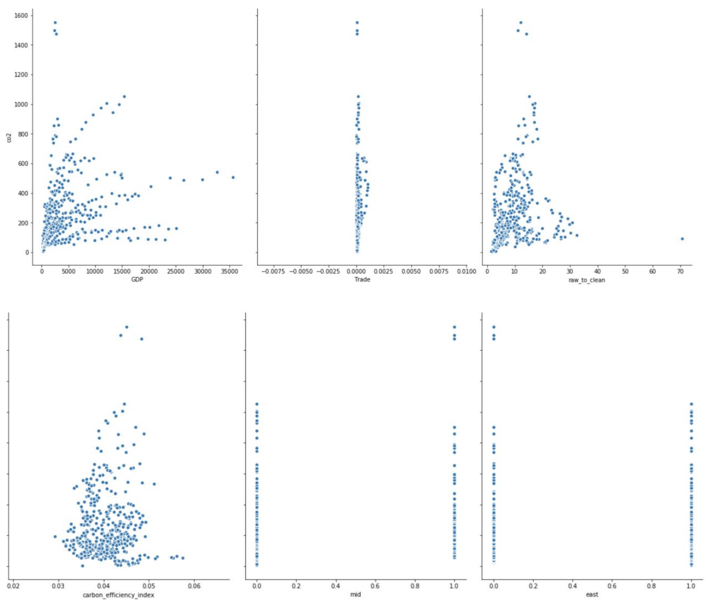
Ⅲ. e. Regression

Finally, to make our analysis more comprehensive, we read some research papers and listed several potential factors that can affect carbon emission and ran regression on them [5]. After several trials, we identified the following factors as significant: GDP, trade (import and export on provincial level), energy structure (raw energy relative to clean), as well as carbon intensity (amount of CO2 emitted per unit of energy), and region (East, Middle, West), which grabs all other regional factors such as technology levels that's unmeasurable. Before the regression, let's first take look at the unmentioned trade pattern in China's different provinces, which suggests the coastal East region has the highest trade activeness.



Then we take a look at how all the regressors were distributed:

For the distribution of GDP, raw_to_clean(energy structure), carbon_efficiency_index, we saw diffusing patterns, which suggested a use of log to contract its distribution.

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                            OLS Regression Results
==============================================================================
Dep. Variable:           np.log(co2)   R-squared:                       0.504
Model:                           OLS   Adj. R-squared:                  0.497
Method:                Least Squares   F-statistic:                     74.56
Date:               Fri, 30 Nov 2018   Prob (F-statistic):           5.98e-64
Time:                       00:28:25   Log-Likelihood:                -416.70
No. Observations:                447   AIC:                             847.4
Df Residuals:                    440   BIC:                             876.1
Df Model:                          6
Covariance Type:           nonrobust
=================================================================================================
                                   coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------------------
Intercept                        3.2510      0.979      3.319      0.001       1.326       5.176
np.log(GDP)                      0.4228      0.028     14.904      0.000       0.367       0.479
trade_adj                        0.0142      0.002      6.133      0.000       0.010       0.019
np.log(structure)                0.4225      0.047      8.914      0.000       0.329       0.516
mid                              0.2666      0.082      3.254      0.001       0.106       0.428
east                            -0.3895      0.093     -4.210      0.000      -0.571      -0.208
np.log(carbon_efficiency_index)  0.7182      0.302      2.379      0.018       0.125       1.312
==============================================================================
Omnibus:                       0.785   Durbin-Watson:                   1.703
Prob(Omnibus):                 0.675   Jarque-Bera (JB):                0.680
Skew:                         -0.093   Prob(JB):                        0.712
Kurtosis:                      3.040   Cond. No.                         721.
==============================================================================

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
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After refining for the functional form, the regression is presented as strong in terms of the total data fitness and the statistical significance of all the regressors. We find from the P value that all the regressors are statistically significant at a 95% confidence interval. And this strong fitness, as 50.4% data is on the predicted line, tells us that the model we generated can be used to perform substantially strong prediction.

Looking at the regression coefficient, we can see:

1) The GDP contribution to the CO2 emission is rather substantial, so that we probably would not expect to see a decline in the total co2 emission as long as the economics keeps growing.
2) Parallel to GDP, the effect of the energy structure makes huge contribution to the CO2 emission, which urges China to have a fundamental adjustment in the energy structure, such as using more refined & washed coal instead of the raw coal.
3) It's not surprising to see that the coefficient of the dummy variable east is negative. As being more advanced in policy adoption and having better technology, keeping other things constant, being in the east region reduced CO2 emission by 0.3895 unit.

Ⅳ. Conclusion and Suggestion

From our analysis above, it's safe to conclude that China did make certain achievement in limiting its carbon emission, but is still facing a great challenge in the years ahead. As the Middle and West region of China catch up, the absolute volume of energy consumption and carbon emission of the country will increase without doubt. However, the effect can be mitigated through technology advancement supported by governmental policies, which has the potential to help the Middle and West region to leapfrog.

Furthermore, regarding China's future development, we consider the key issue to be cutting its direct consumption of raw and unclean materials, especially raw coal. China has a rich reserve of coal, so its reliance on coal is reasonable, and to some extent inevitable. But it can make better use of coal by processing it before consumption. This not only helps with reducing carbon emission by increasing efficiency, but also contributes to solving air pollution. In this area, government support is needed to facilitate the upgrading of equipment and switching to cleaner form of coal. In a broader sense, changing the consumption pattern of coal is just part of the change of China's energy structure. In the future, more use of clean as well as sustainable energy sources is expected.

We only have one planet, and climate change is connecting everyone together closely. China, as the world's biggest carbon emitter, is expected to take its responsibility in the battle against climate change.

Ⅴ. References

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5. Wang, Qunwei, Yung-Ho Chiu and Ching-Ren Chiu. "Driving factors behind carbon dioxide emissions in China: A modified production-theoretical decomposition analysis." *Energy Economics* 51 (2015) 252–260.

Link to Github:
https://github.com/QianchunKaye/Data-Bootcamp-final-project
https://github.com/GoEvelynZhang/Data_Bootcamp