The carbon dioxide marginal abatement cost calculation of Chinese provinces

-based on stochastic frontier analysis

Kejia Yang, Yalin Lei

China University of Geosciences(Beijing)

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Background

- Commitment : 40%-45% reduction in carbon emissions per GDP by 2020 compared with 2005.
- Lack of central government's differential CO_2 reduction allocation, most provinces just follow the national commitment.

- Flaw: provinces have different attributes
- CO_2 Marginal Abatement Cost (MAC) varied

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Literature Review

- **Distance Function** was widely used in CO_2 marginal abatement cost calculation.
- **Parametric Distance Function**: needs to pre-establish a function form.

  easy to manipulate algebraically
- **Nonparametric Distance Function**

Studies	Method	Sample	MAC
Wang et al.	DDF/DEA	28 provinces, 2007	¥475/ton
Huang & Wei	DDF/LP	29 provinces, 1995-2007	¥1128/ton
Zhang et al.	DDF/LP	29 provinces, 2006-2010	¥80.19/ton
He	DF/LP	29 provinces, 2000-2009	¥104/ton
Liu et al.	DF/DEA	30 provinces, 2005-2007	¥1739/ton

- **Directional Distance Function(DDF)**: increase desirable output while decrease undesirable output.
- **Distance Function(DF)**: desirable & undesirable outputs are changed in same ratio.

- **Data Envelopment Analysis(DEA):** function needs to be differentiable everywhere.
- **Linear Programming(LP)**: cannot deal with isolated point

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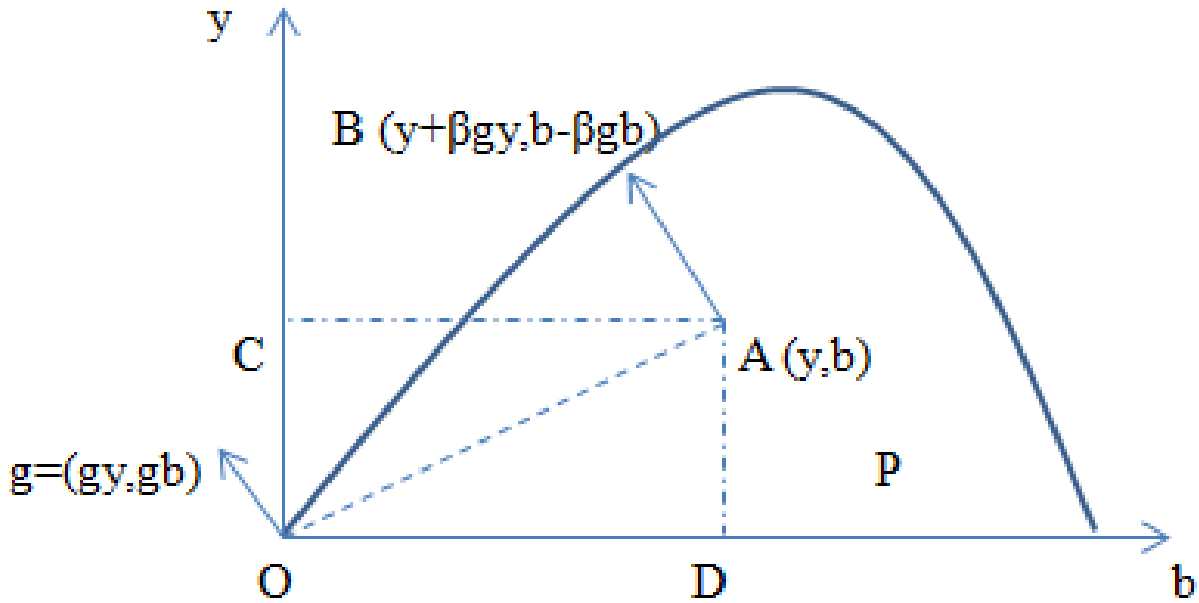

- P: production technology set

  P= {(y,b):X can produce (y,b)}
- A: region in P with desirable output y and undesirable output b
- B: Efficient point
- g: directional vector $g=(g_y,g_b)$
- DDF is measured by $\beta=AB/Og$.

- Directional Distance Function

$$\vec{D}(X, y, b; g) = \sup\{\beta : (y + \beta g_y, b - \beta g_c) \in P\}$$

- Parametric Directional Distance Function

  X: inputs (capital X_k, laborX_l, energyX_E)

  y:desirable output (GDP)

  b:undesirable output (CO_2 emission)

  Quadratic form of production function:

$$\vec{D}(x, y, b; g_y, -g_b) =$$

$$\alpha_0 + \sum_{i=K,L,E} \alpha_i x_i + \alpha_y y + \alpha_b b + \frac{1}{2} \sum_{i=K,L,E} \sum_{j=K,L,E} \alpha_{ij} x_i x_j + \frac{1}{2} \alpha_{yy} y^2 + \frac{1}{2} \alpha_{bb} b^2 + \sum_{i=K,L,E} \alpha_{iy} x_i y + \sum_{i=K,L,E} \alpha_{ib} x_i b + \alpha_{yb} yb$$

- Stochastic Frontier Analysis(SFA) method which can manage random error was applied.

$$\vec{D}_0(x^n, y^n, b^n; g_y, -g_b) + v^n - u^n = 0$$

- v: noise, satisfies normal distribution $v^n \sim N(0, \sigma_v^2)$
- u: random error, satisfies half-normal distribution $u^n \sim N^+(0, \sigma_u^2)$

$$R = p[y + (1 - \vec{D}_0) g_y] - p_b[b - (1 - \vec{D}_0) g_b]$$

- R: revenue of a certain region
- p: price of GDP, p=1
- P_b: price of CO_2 (Marginal abatement cost)

$$p_b = -\frac{y}{b}\left(\frac{\partial \ln D_0}{\partial \ln b} / \frac{\partial \ln D_0}{\partial \ln y}\right)$$

$$= -\frac{y}{b}(\gamma_b + \gamma_{bb} \ln b + \eta_k \ln x_k + \eta_l \ln x_l + \eta_e \ln x_e)$$

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Data

- Data resource

  2013 China Statistic Yearbook:

  capital stock, labor, GDP

  2013 China Energy Statistic Yearbook:

  energy consumption

- Energy sources:

coal, coke, kerosene, gasoline, fuel oil, diesel and natural gas

- CO_2 EMISSION:

$$C = E_{ij} \times \delta_j$$

$$= E_{ij} \times M_j \times \beta_j \times \varepsilon_j \times \omega$$

- E_{ij}: consumption of energy j in province i
- δ_j: coefficient of CO_2 emissions of energy j
- M_j: net calorific value of energy j
- β_j: carbon content of the unit heat value of energy j
- ε_j: carbohydrate oxidation of energy j
- ω: gasification coefficient of CO_2 , has constant value of 44/12

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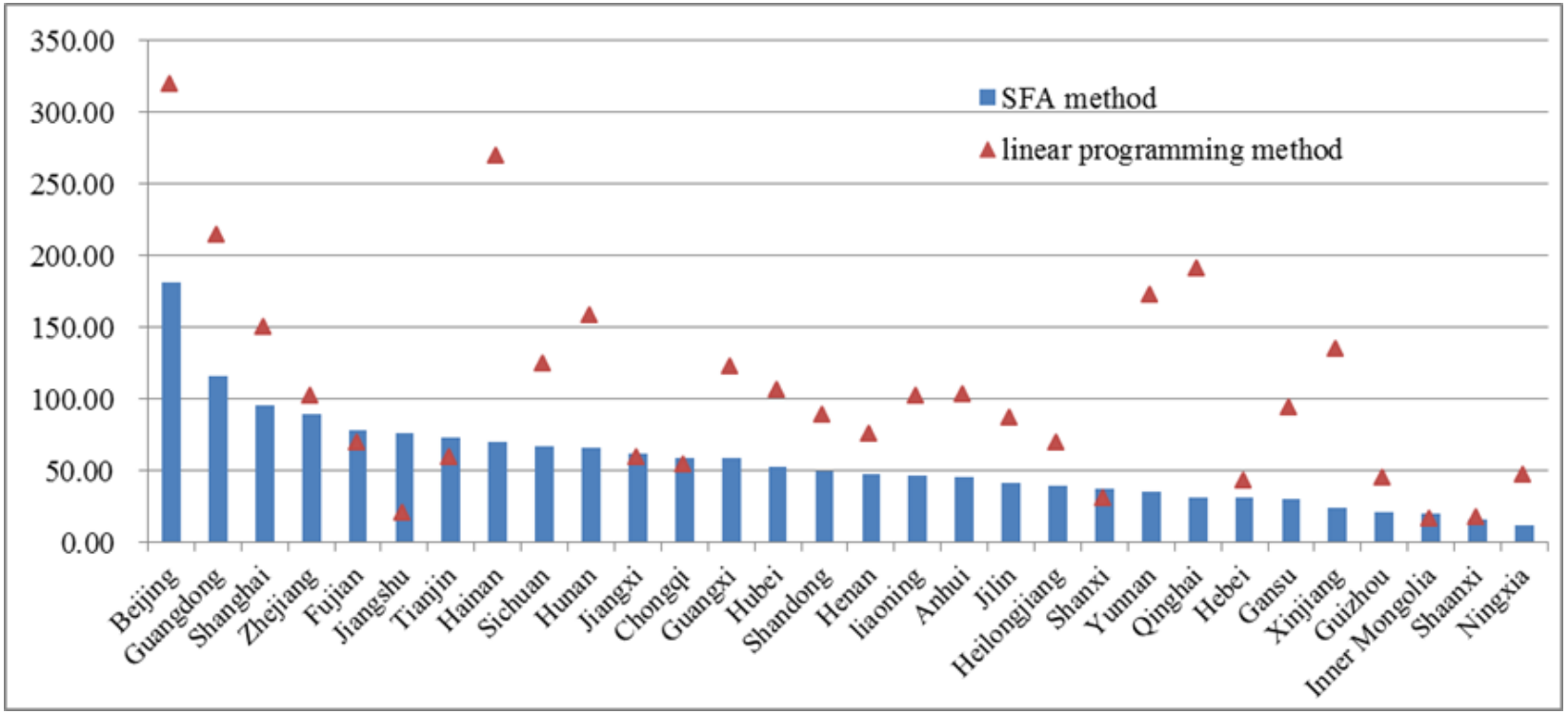
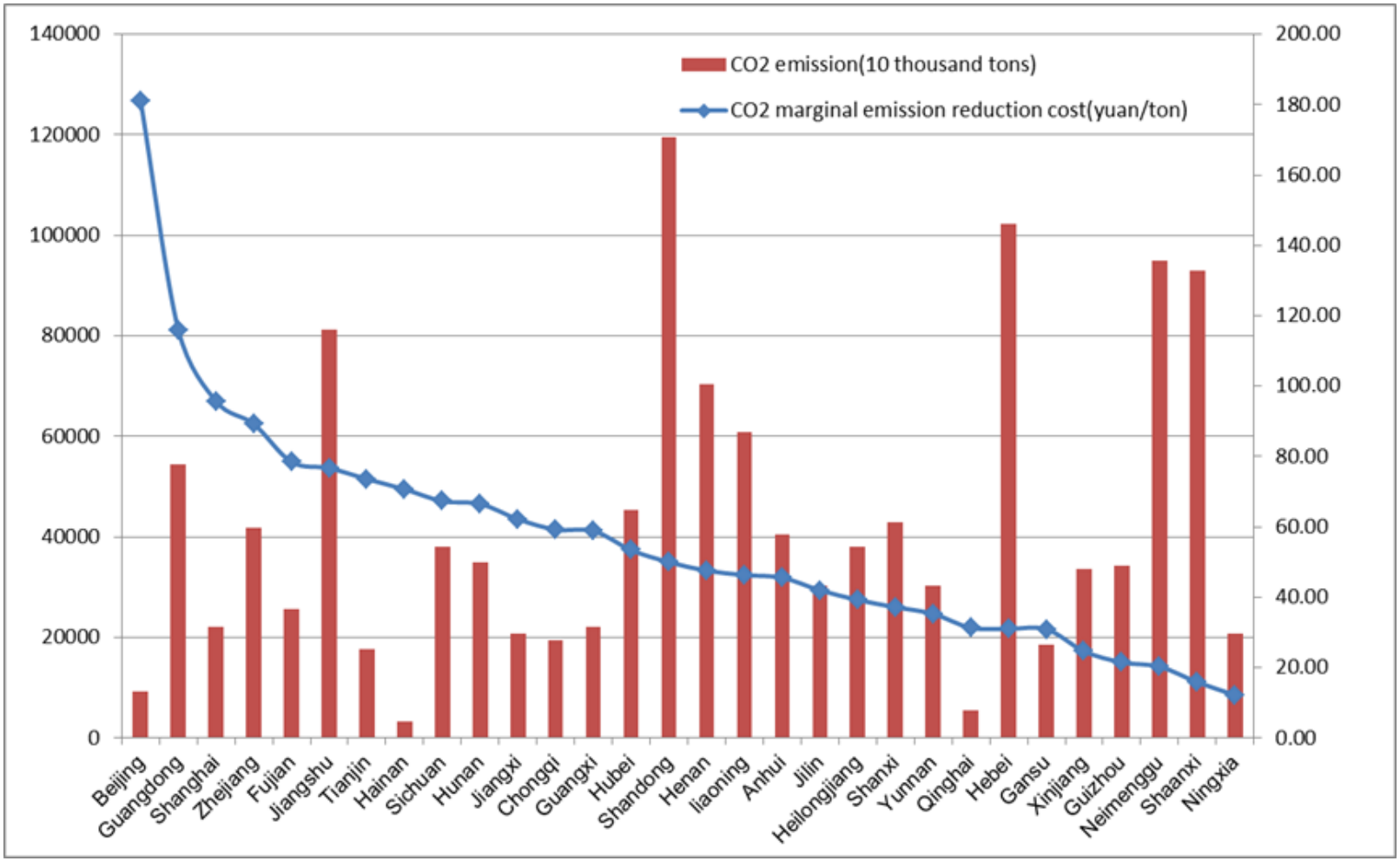
Results

MAC of Chinese provinces



- MAC： ¥12.21/ton-¥181.1/ton
- The average result of MAC calculated by SFA method is 46% lower than LP method.



- There are no distinct correlation between CO_2 emission and MAC.

Discussion

- Reliability Test of the MAC Results

(1) Is SFA necessary?

$$\gamma^2 = \sigma_u^2 / \sigma^2 = 0.8 .$$

80% of error was caused by random error.

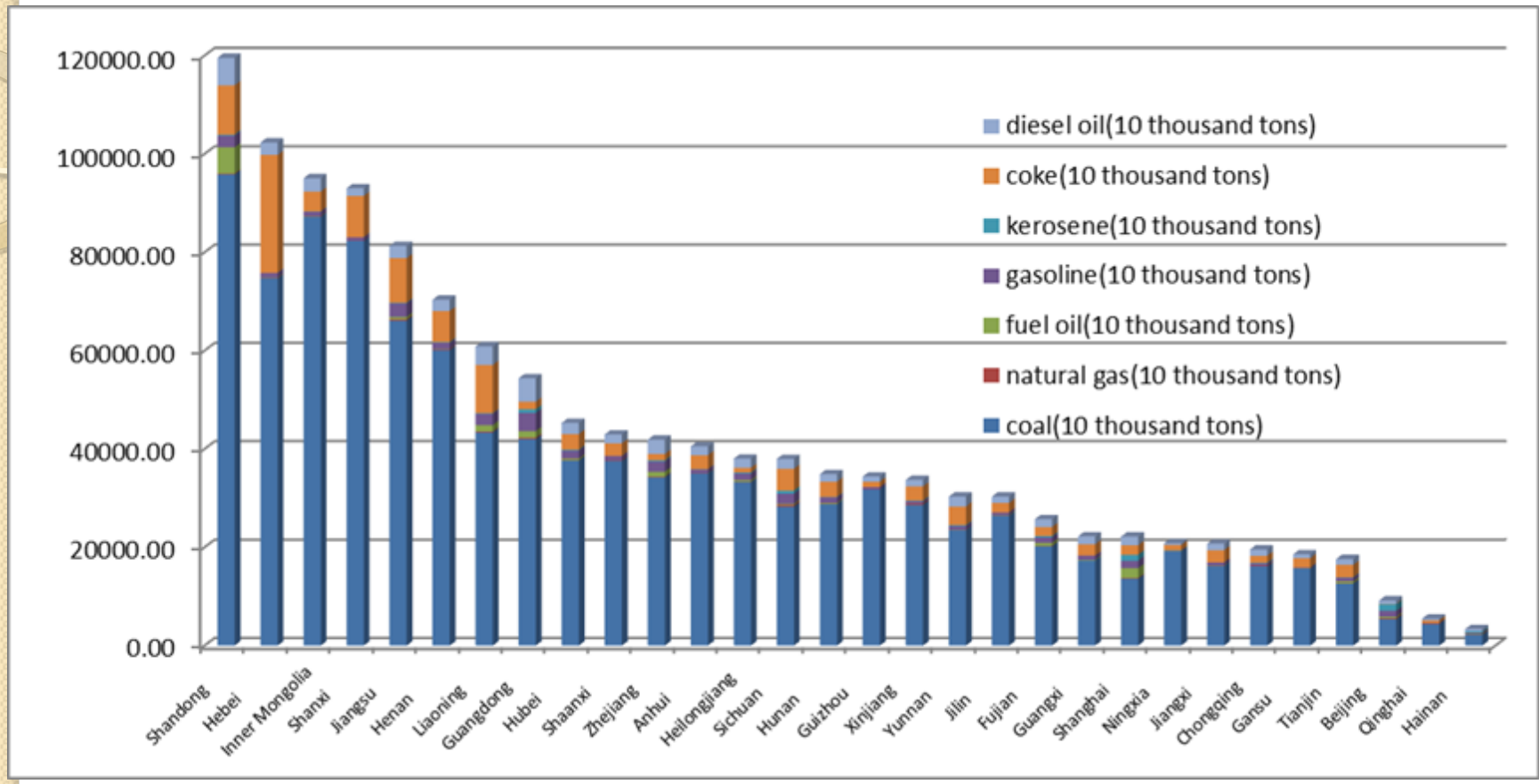
(2) Is DDF's coefficient reliable?

|t ratio|> critical value

coefficient	coefficient value	T ratio
η_b	-0.038	-1.825
η_{bb}	0.068	3.376
η_k	-0.031	-2.319
η_l	-0.019	-1.923
η_e	0.008	-7.082

- Influence factor analysis of MAC

CO2 emission of Chinese provinces

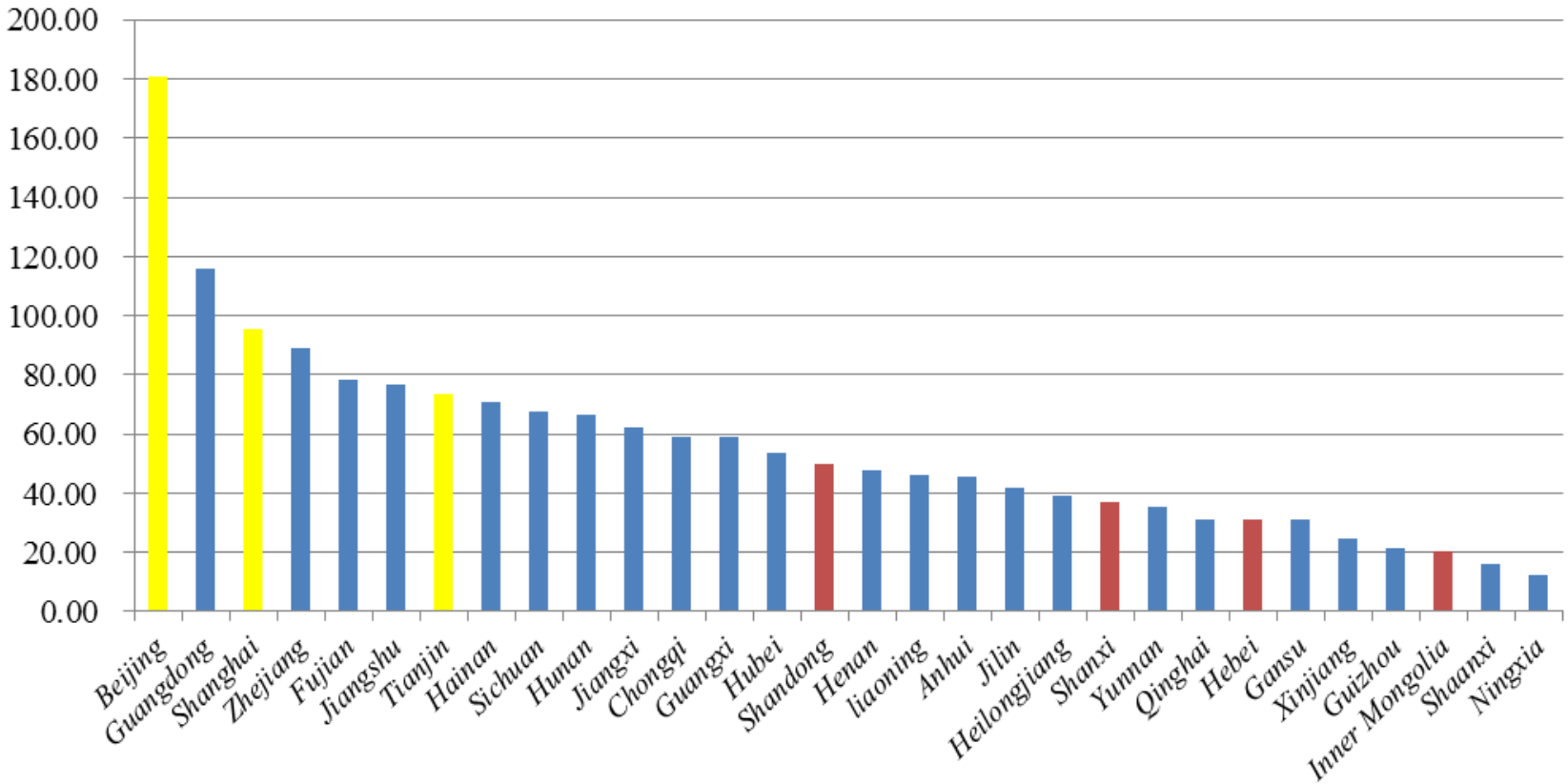


Energy Consumption Structures:

Coal: main emitter used for: power generation, production of building materials and domestic-use

Coke: Hebei, Shandong, Liaoning provinces used for: metal smelting

Fuel oil: Shandong, Shanghai, Zhejiang provinces used for: ship fuel



MAC of each Chinese provinces

Industrial Structures:

Beijing, Shanghai and Tianjin: The ratios of low-carbon industry in those provinces are more than half of total ratio of tertiary industry.

Shandong, Hebei, Shanxi and Inner Mongolia: the ratios of secondary industry of large emitters are more than 50%

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Conclusion

- (1) Applying SFA method, MAC results are precise but are 46% less than LP method in this paper as random errors were taken into concerned.
- (2) There are no distinct correlation between CO_2 emission and MAC.
- (3) Because of different industrial structures, and energy consumption structures among Chinese provinces, the CO_2 emission and MAC of each province varied.

Policy suggestions

- **Change energy consumption structures**

Coal is the main consumption energy . 68.4%

Natural Gas: 5% of total energy consumption

Clean Energy: 8% of total energy consumption

Hydro-power: Hubei, Sichuan and Yunnan

Wind power: Inner Mongolia, Hebei and Liaoning

Solar power: start-up Ningxia, Gansu, Xinjiang and Tibet

- **Synergetic development in industry structure and economy among provinces**

(1) Economic development of low MACs provinces will be destructed if simply reduce CO_2 emission of those provinces.

(2)During the development, pollutions are transfer into the low MACs provinces while secondary industry is the leading industry in those provinces.

- Thank You!