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The Economic Impacts of Carbon Tax and Its Income Distributional Effects in China: An Analysis Based on the CGE Model

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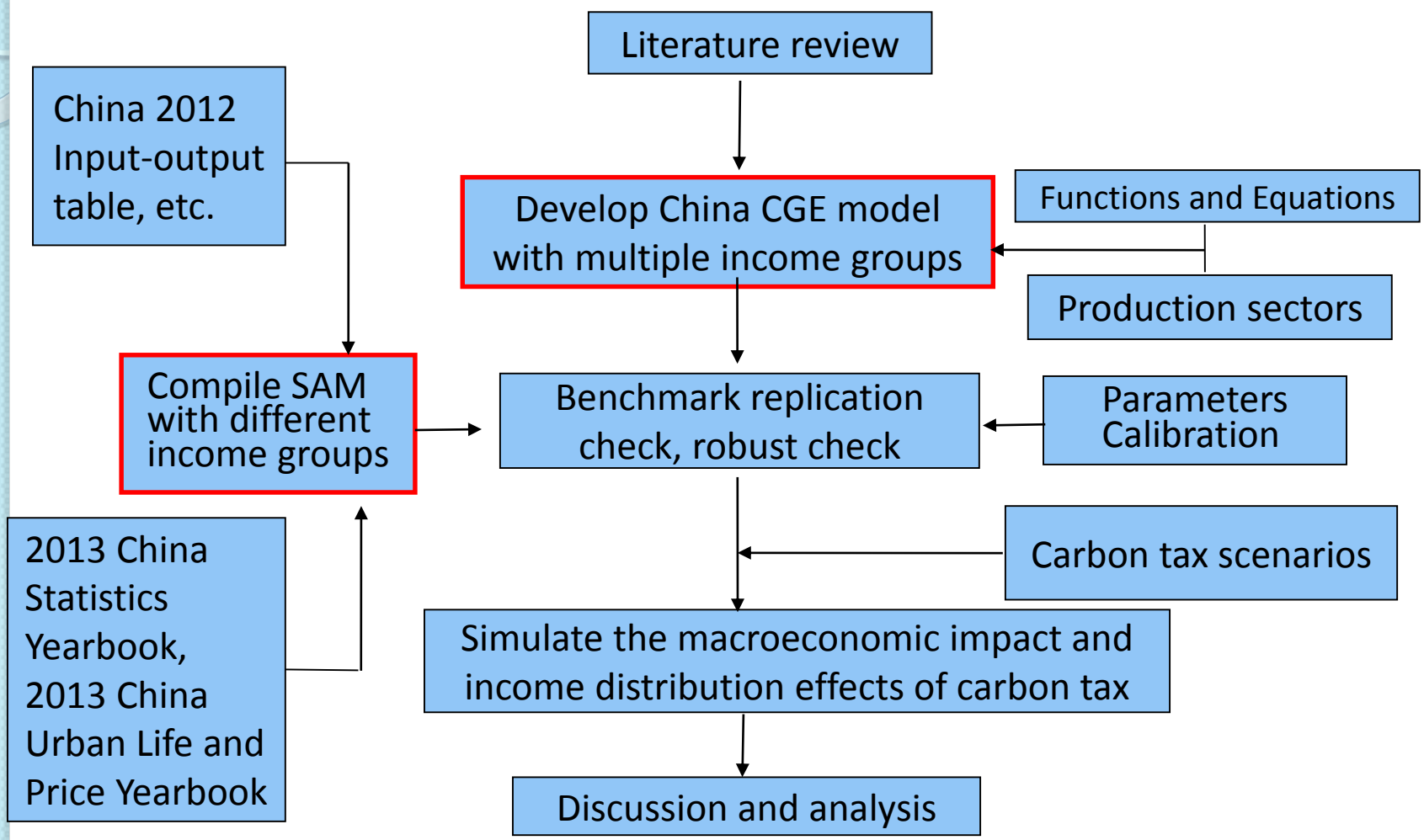
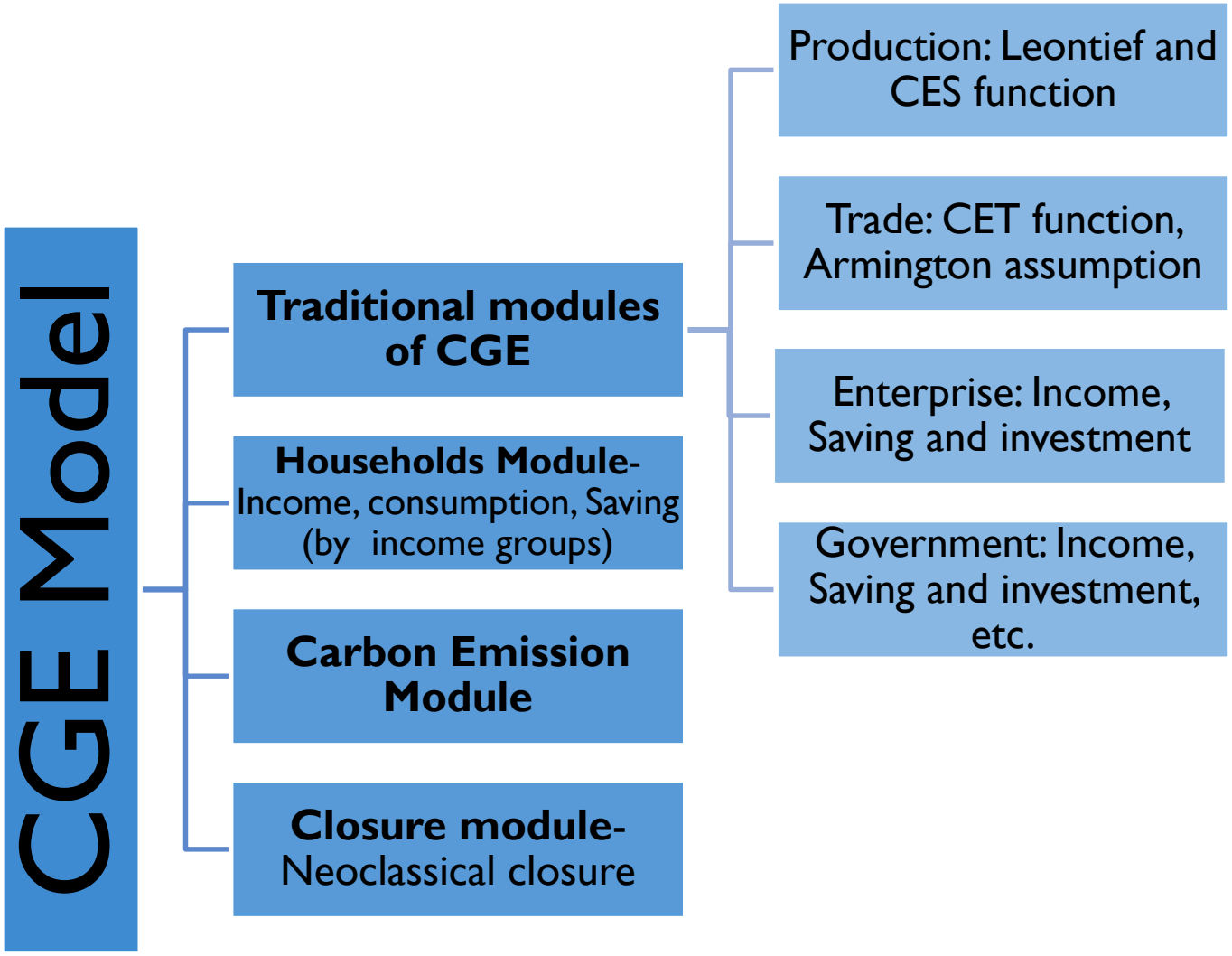
1. Background

- China is the largest GHGs emission country in the world, and Chinese government set up ambitious targets for decarburizations.
- Carbon tax is an option for GHGs emission control in China and is under discussion among different stakeholders.
- What is the economic impact of carbon taxation on China? – many publications
- What is the Income distributional effects of carbon taxation for different income groups in China? –only several papers

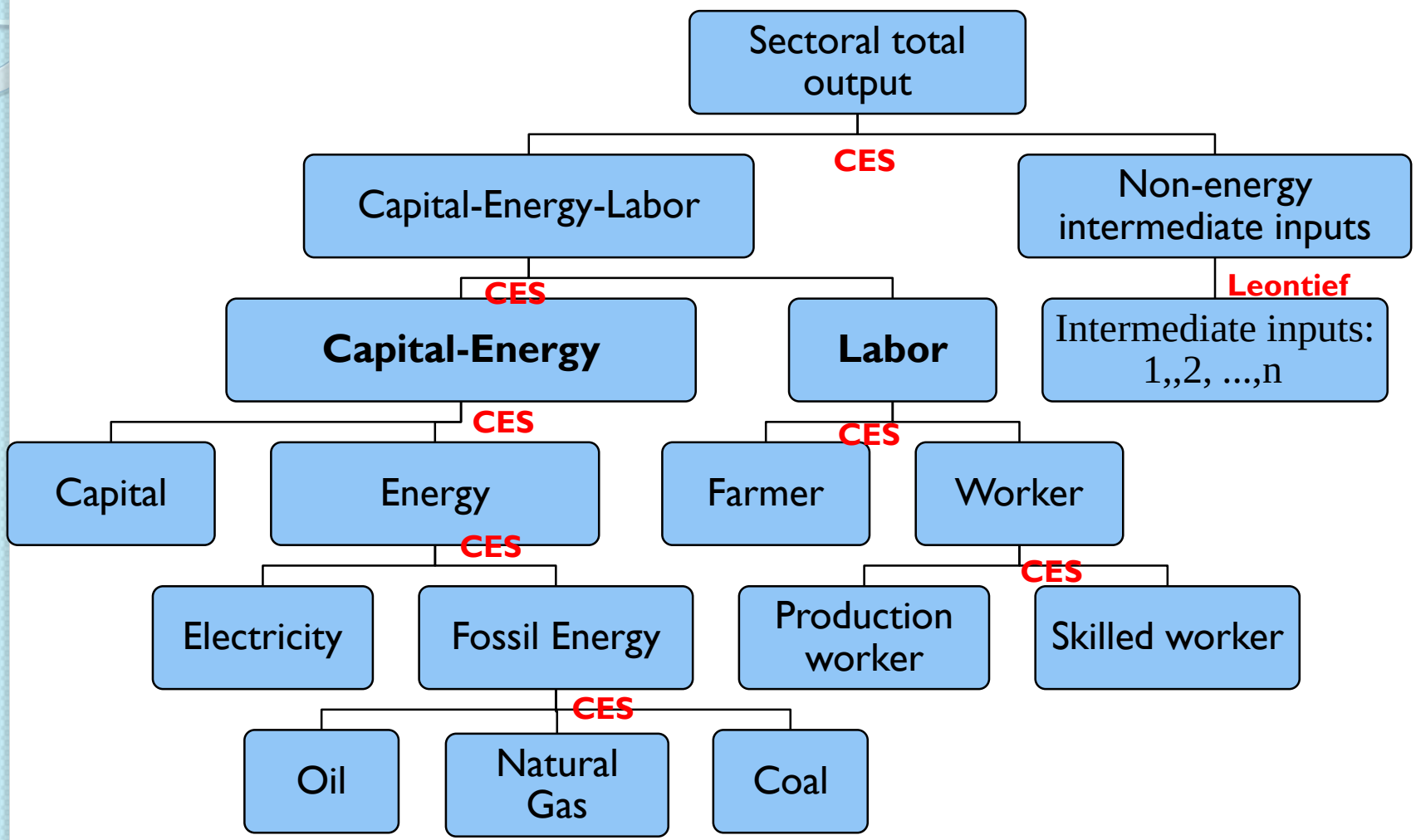
2. Methodology



3. CGE model Structure



4、Nested Structure of Production Function



5、Production Sectors

No.	Productions Sector	Abbreviation
1	Agriculture	AGR
2	Coal mining and supply	CMI
3	Oil exploration and supply	OES
4	Natural gas production and supply	GPS
5	Electricity and Heating production and supply	EHP
6	Heavy industry	HIN
7	Light industry	LIN
8	Construction	CON
9	Transportation, storage and postal services	TSP
10	Services	SER

6. Households divided by income

Urban households	
hc1	Lowest income households (first decile)
hc2	Low income households(second decile)
hc3	Lower middle income households(second quintile)
hc4	Middle income households(third quintile)
hc5	Upper middle income households(fourth quintile)
hc6	High income households(ninth decile)
hc7	Highest income households(tenth decile)
Rural households	
hv1	Low income households(first quintile)
hv2	Lower middle income households(second quintile)
hv3	Middle income households(third quintile)
hv4	Upper middle income households(fourth quintile)
hv5	High income households(fifth quintile)

7.The Structure of SAM

		output										
		1.Activity	2.Com-modity	3.Labor	4.Capital	5.House-holds	6.Enter-prise	7.Govern-ment	8.Carb on tax	9.Investment and saving	10.ROW	Total
input	1.Activity		Domestic supply								Export	Total output
	2.Commo-dity	Intermed-iate input				household consump-tion		Government consumption		Inventories increases		Domestic demand
	3.Labor	income										Income_L
	4.Capital	Depreciati on										Income_C
	5.House-holds			Labor income	Capital income		Transfer payment	Transfer payment			Income_ FR	Income_R
	6.Enter-prise				Depreciation			Transfer payment				Income_E
	7.Govern-ment	Indirect tax	Import tariffs			income tax	Direct tax				Income_ FG	Income_G
	8.Carbon tax											
	9.Invest-ment and saving					Household saving	Enterprise saving	Government saving		Inventories investment	Foreign net saving	Total saving
	10.ROW		import		Investment income			Output_GF				Income_F
	Total	Total input	Domestic expend.	Factor expend.	Factor output	household expend.	Enterprise expend.	Government expend.		Total investment	Foreign expend.	

8. Mapping matrix between 10 production sectors and 8 consumer goods

	Foods	Clothes	Living	Household equipment and services	Transportation and communication	Education and Entertainment	Medical and Health	Others
AGR	0.308	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CMI	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000
OES	0.000	0.000	0.038	0.000	0.055	0.000	0.000	0.000
GPS	0.000	0.000	0.065	0.000	0.000	0.000	0.000	0.000
EHP	0.000	0.000	0.047	0.000	0.068	0.000	0.000	0.000
HIN	0.000	0.000	0.014	0.361	0.372	0.095	0.177	0.344
LIN	0.462	0.741	0.026	0.257	0.000	0.022	0.214	0.054
CON	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TSP	0.000	0.000	0.000	0.001	0.225	0.000	0.000	0.001
SER	0.229	0.258	0.804	0.382	0.279	0.883	0.609	0.602

9. Coefficient of CO_2 emission

CO_2 Emission= Consumption (Yuan) of fossil energy (coal, oil and gas) × CO_2 Emission Coefficient of this fossil energy (t CO_2/Yuan).

Table: The CO_2 emission coefficients of coal, oil and natural gas

	Data in this study (2012)			Data in other analyzes(2007)		
	CO_2 Emission (Mt)	Final demand (10^9 Yuan)	Coefficient (t CO_2/yuan)	CO_2 Emission (Mt)	Final demand (10^9 Yuan)	Coefficient (t CO_2/yuan)
Coal	6512.70	29251.57	2.23E-03	5139.86	12531.92	4.10E-03
Oil	1305.65	54588.29	2.39E-04	986.63	31674.96	3.06E-04
Natural Gas	281.32	11596.79	2.43E-04	138.06	3391.34	4.07E-04

10. Main Data Sources

- China 2012 Input-output table.
- 《China Statistical Yearbook 2013》、《China Finance Yearbook 2013》、《China Population and Employment Statistics Yearbook 2013》,etc.
- 《China Urban Life and Price Yearbook 2013》、《China Yearbook of Household Survey 2013》,etc.
- Endogenous parameters in the CGE model are derived by calibration method from the SAM data
- Exogenous parameters (including the elasticity of CES functions, Armington and CET functions) in the CGE model are obtained from public publications of other researches.

11. Carbon tax policy scenarios

	Carbon tax rate（Yuan/t CO_2）
Baseline	0
Low tax rate	10
Middle tax rate	30
High tax rate	70

12. Impacts on Macroeconomic indicators, Energy Consumption and Carbon Emission

		10yuan/tCO_2	40yuan/tCO_2	70yuan/tCO_2
GDP	Real GDP	-0.07%	-0.29 %	-0.51%
Total output, consumption, import and export	Total output	-0.16 %	-0.60 %	-0.96 %
	Total consumption	-0.17 %	-0.60 %	-0.98 %
	Total import	0.17%	0.72%	1.29%
	Total export	0.15%	0.62%	1.11%
Energy Consumption and Carbon emission	Energy consumption	-1.24%	-4.51%	-7.28%
	Total carbon emission	-3.85 %	-13.26 %	-20.43 %
	CO_2 emission intensity	-4.05 %	-12.84 %	-20.27 %
Income	Household income	-0.43%	-1.71 %	-2.95 %
	Urban household income	-0.47 %	-1.86 %	-3.20 %
	Rural household income	-0.32 %	-1.27 %	-2.22 %
	Government income	0.43 %	1.52%	2.40 %
Consumption	Household consumption	-0.19%	-0.77%	-1.36 %
	Government consumption	-0.32 %	-1.22 %	-2.05 %
	Enterprise investment	-0.09 %	-0.36 %	-0.63%

13.Impacts on the output and price of production sectors

Production Sectors	10yuan/tCO_2		40yuan/tCO_2		70yuan/tCO_2	
	Output	Price	Output	Price	Output	Price
AGR	0.11%	-0.22%	0.42%	-0.89%	0.73%	-1.55%
CMI	-5.56%	3.52%	-19.18%	13.99%	-29.59%	24.41%
OES	-0.11%	0.68%	-0.80%	2.72%	-1.87%	4.75%
GPS	-0.26%	0.46%	-1.37%	1.83%	-2.84%	3.17%
EHP	-0.33%	1.39%	-1.27%	5.31%	-2.13%	8.93%
HIN	-0.25%	0.08%	-0.93%	0.31%	-1.55%	0.50%
LIN	0.24%	-0.24%	0.95%	-0.93%	1.64%	-1.59%
CON	0.00%	-0.13%	0.00%	-0.50%	0.00%	-0.87%
TSP	-0.06%	-0.15%	-0.24%	-0.57%	-0.40%	-0.93%
SER	0.01%	-0.39%	0.04%	-1.48%	0.07%	-2.48%

14.Impacts on the import and export of production sectors

Production Sectors	10yuan/tCO_2		40yuan/tCO_2		70yuan/tCO_2	
	Import	Export	Import	Export	Import	Export
AGR	-0.66%	1.01%	-2.53%	4.01%	-4.26%	6.93%
CMI	4.79%	-17.67%	19.84%	-51.99%	35.81%	-70.49%
OES	2.02%	-2.89%	7.85%	-11.33%	13.43%	-19.27%
GPS	1.09%	-2.12%	4.02%	-8.47%	6.56%	-14.67%
EHP	0.89%	-1.00%	3.37%	-3.75%	5.62%	-6.19%
HIN	0.00%	-0.52%	0.04%	-1.98%	0.10%	-3.32%
LIN	-0.88%	1.48%	-3.31%	5.78%	-5.51%	9.93%
CON	-0.46%	0.58%	-1.75%	2.23%	-2.91%	3.75%
TSP	-0.51%	0.48%	-1.86%	1.72%	-2.98%	2.74%
SER	-0.92%	1.26%	-3.44%	4.86%	-5.68%	8.22%

15.Impacts on the demand of production factors

Production Sectors	10yuan/tCO_2			40yuan/tCO_2			70yuan/tCO_2		
	Labor	Capital	Energy	Labor	Capital	Energy	Labor	Capital	Energy
AGR	0.13%	0.26%	-0.24%	0.50%	0.99%	-0.90%	0.86%	1.65%	-1.50%
CMI	-5.26%	-4.94%	-6.51%	-18.16%	-17.18%	-22.10%	-28.07%	-26.68%	-33.64%
OES	0.11%	0.21%	-0.20%	0.06%	0.42%	-1.15%	-0.40%	0.15%	-2.46%
GPS	-0.09%	0.01%	-0.54%	-0.69%	-0.37%	-2.41%	-1.69%	-1.23%	-4.53%
EHP	0.07%	0.32%	-0.70%	0.27%	1.15%	-2.58%	0.45%	1.84%	-4.22%
HIN	-0.12%	0.01%	-0.91%	-0.42%	0.01%	-3.35%	-0.66%	-0.02%	-5.43%
LIN	0.33%	0.37%	-0.45%	1.29%	1.40%	-1.61%	2.24%	2.37%	-2.56%
CON	0.12%	0.17%	-0.41%	0.49%	0.61%	-1.54%	0.86%	1.00%	-2.55%
TSP	0.03%	0.09%	-0.35%	0.15%	0.33%	-1.32%	0.28%	0.53%	-2.23%
SER	0.06%	0.07%	-0.45%	0.25%	0.25%	-1.70%	0.46%	0.39%	-2.83%

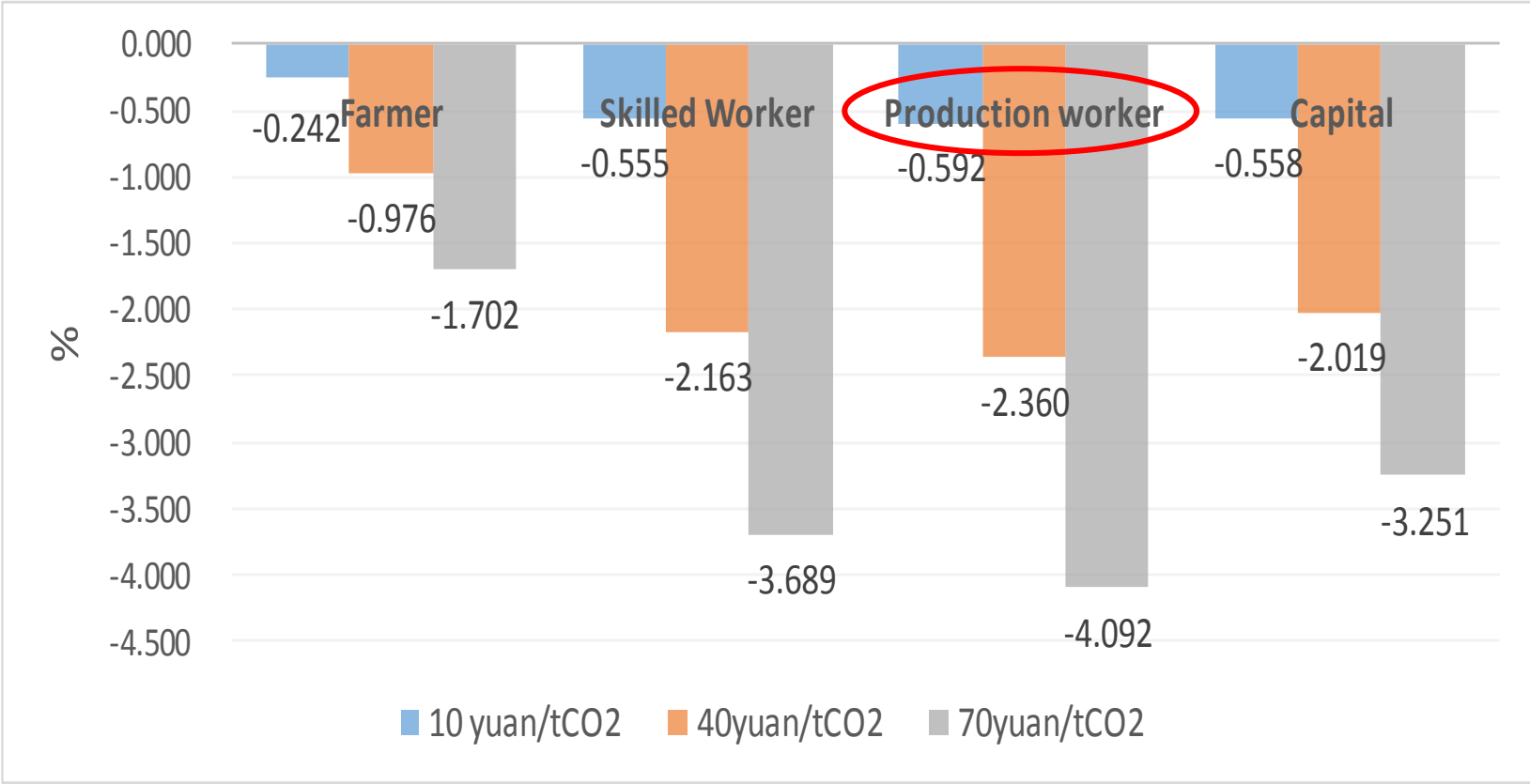
16. Impacts on Energy consumption of production sectors

Prod. Sectors	10 yuan/tCO$_2$				40 yuan/tCO$_2$				70 yuan/t CO$_2$			
	Coal	Oil	Gas	Electri-city	Coal	Oil	Gas	Electri-city	Coal	Oil	Gas	Electri-city
AGR	-6.7%	-0.1%	0.3%	-0.5%	-22.4%	-0.3%	1.3%	-1.8%	-33.6%	-0.5%	2.2%	-2.9%
CMI	-7.1%	-0.5%	-0.1%	-4.4%	-24%	-2.3%	-0.7%	-15.3%	-36.2%	-4.4%	-1.8%	-24%
OES	-6.9%	-0.3%	0.1%	-0.6%	-23.3%	-1.4%	0.2%	-2.7%	-35.2%	-2.9%	-0.2%	-4.9%
GPS	-6.6%	0.0%	0.4%	-0.7%	-22.5%	-0.4%	1.2%	-2.9%	-34.3%	-1.5%	1.2%	-5.4%
EHP	-3.4%	3.5%	3.9%	0.2%	-11.9%	13.3%	15.1%	0.6%	-18.7%	21.9%	25.2%	0.8%
HIN	-4.8%	2.0%	2.4%	-0.2%	-16.6%	7.2%	8.9%	-1.0%	-25.7%	11.5%	14.5%	-1.7%
LIN	-4.2%	2.7%	3.1%	0.0%	-14.5%	9.9%	11.6%	-0.1%	-22.5%	16.2%	19.4%	-0.1%
CON	-6.5%	0.2%	0.6%	-0.5%	-21.7%	0.7%	2.3%	-1.8%	-32.7%	0.9%	3.7%	-3.0%
TSP	-7%	-0.3%	0.1%	-0.7%	-23.2%	-1.2%	0.4%	-2.7%	-34.7%	-2.1%	0.6%	-4.4%
SER	-6.8%	-0.1%	0.3%	-0.7%	-22.7%	-0.6%	1.0%	-2.4%	-34%	-1.1%	1.6%	-4.0%

17. Impacts on CO_2 Emissions of production sectors

Production Sectors	10 yuan/tCO_2	40 yuan/tCO2	70 yuan/tCO_2
AGR	-0.28%	-1.00%	-1.60%
CMI	-7.10%	-23.88%	-36.07%
OES	-0.52%	-2.17%	-3.95%
GPS	-3.36%	-11.66%	-18.10%
EHP	-3.18%	-11.18%	-17.49%
HIN	-4.13%	-14.24%	-21.91%
LIN	-3.74%	-12.95%	-19.97%
CON	-2.76%	-9.30%	-14.04%
TSP	-0.62%	-2.22%	-3.54%
SER	-1.66%	-5.66%	-8.64%

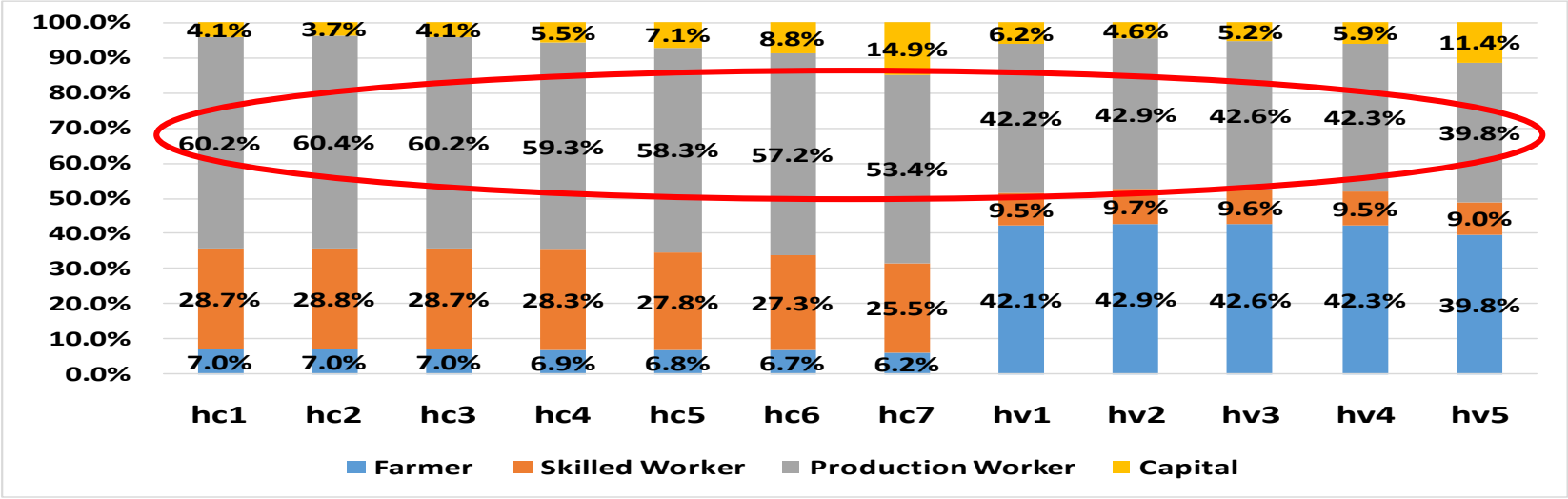
18. Impacts on price of labors and capital factors



- Prices of labor and capital are both decreased, and more significant when the carbon tax rate get higher.
- The Wage of farmers has the smallest decrease, and the wage of production workers has the biggest reduction.

19. Income structure of different income groups and change of the factor income proportion

- The factor income structure of different income groups at the baseline scenario.

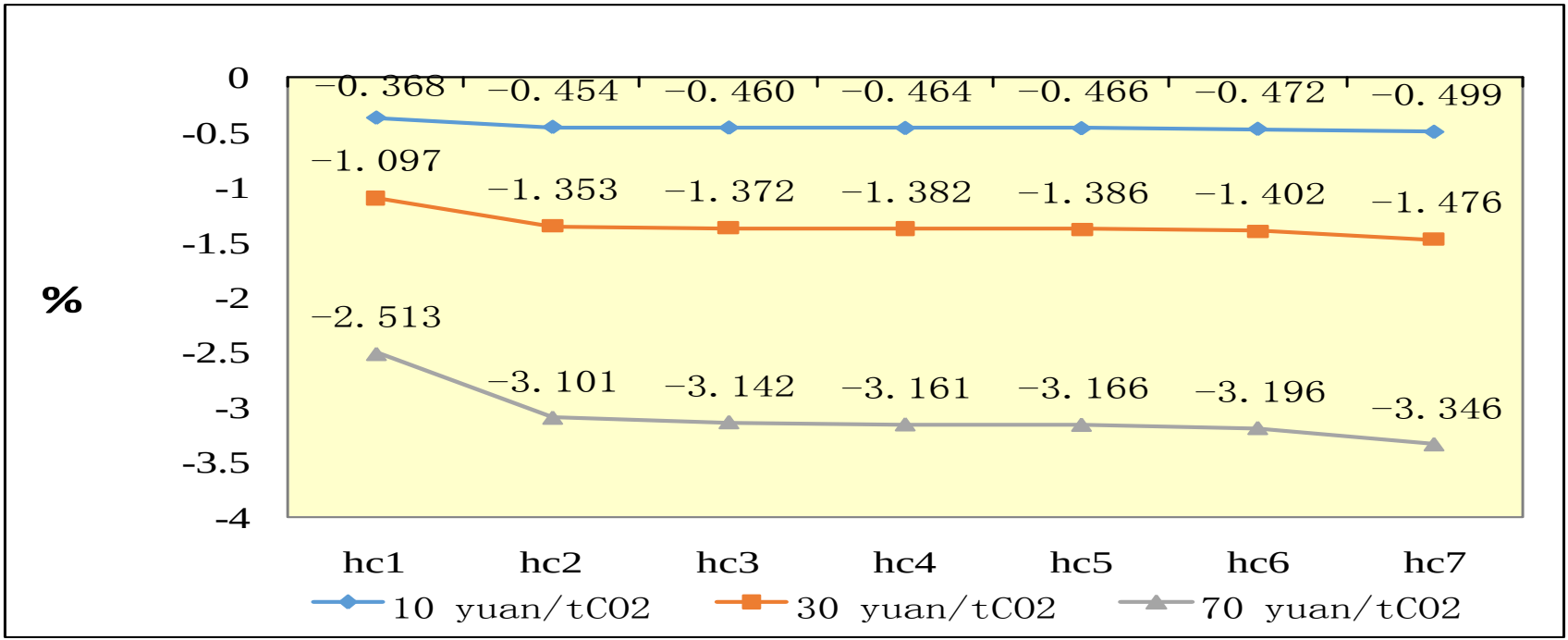


- The change percentage of different factor income proportion when levying carbon tax rate at 70 yuan/tCO_2

20. Impacts on annual income per capita of urban households

Unit: Yuan

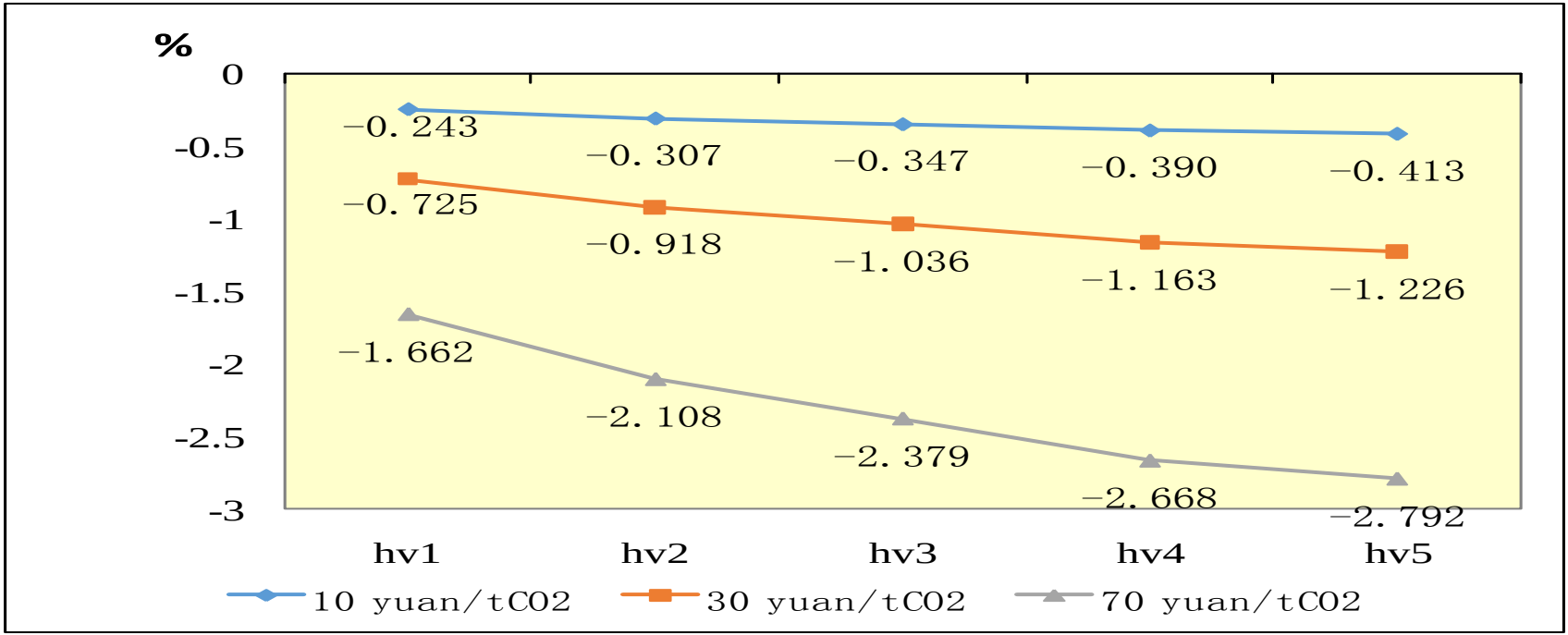
	10Yuan/tCO_2	30Yuan/tCO_2	70Yuan/tCO_2
hc1	-51.8	-154.3	-353.4
hc2	-78.3	-233.6	-535.3
hc3	-101.5	-302.7	-693.2
hc4	-136.0	-405.1	-926.5
hc5	-181.5	-540.1	-1233.5
hc6	-247.4	-735.3	-1676.6
hc7	-441.2	-1305.7	-2959.8



21. Impacts on annual income per capita of rural households

Unit: Yuan

	10Yuan/tCO2	30Yuan/tCO2	70Yuan/tCO2
hv1	-11.9	-35.5	-81.3
hv2	-25.7	-76.8	-176.4
hv3	-38.4	-114.6	-263.0
hv4	-55.9	-166.8	-382.6
hv5	-110.2	-327.3	-745.7



22. Impacts on income equality of households

- MT index(Musgrave and Thin,1948) has been adopted here, if MT>0, promoting income equality; if MT<0, promoting income inequality.
- MT index = Gini coefficient before levying carbon tax - Gini coefficient after levying carbon tax

Households	Baseline (no carbon tax)	Gini Coef. (10Yuan/tCO2)	Gini Coef. (30Yuan/tCO2)	Gini Coef. (70Yuan/tCO2)
Urban households	0.2978512	0.2977393	0.2975 335	0.2971738
Rural households	0.3035669	0.3033021	0.3027833	0.3017864
All households	0.3900091	0.3897559	0.3892643	0.38735

Households	MT index (10Yuan/tCO2)	MT index (30Yuan/tCO2)	MT index (70Yuan/tCO2)
Urban households	0.000112	0.000318	0.000678
Rural households	0.000265	0.000784	0.001781
All households	0.000253	0.000745	0.001681

- The income distributional effects of carbon tax in China is **progressive**, it can improve the income equality of both urban household and rural household.
- The higher the tax rate is, The more obvious the progressive effect is.
- Comparing to urban households, carbon tax is more effective in promoting the income equality of rural households.

23. More about the Income Distribution effects of Carbon Tax

- The distributional effects of a China carbon tax: A Rural-Urban Assessment. (Wenjun Sun and Kazuhiro Ueta. 2011.The Kyoto Economics Reviews 170(2),188-204)
  - 2007 China I-O table
  - Using Input-output method, no CGE model
  - Rural – Progressive, Urban - Regressive
- Can carbon taxes be progressive? (Yazid Dissou,etc. 2014.Energy Economics(42), 88-100)
  - 2004 Canadian national economic accounts.
  - Carbon taxes tend to reduce inequality through the changes in factor prices and tend to increase inequality through the changes in commodity prices.
  - Find a non-monotonic (U-shaped) relationship between carbon taxes and inequality

24. Main conclusions

- Carbon tax in China will reduce the carbon emissions and the carbon emission intensity.
- Carbon tax in China can reduce the consumption of coal significantly, and increase the consumption of natural gas.
- Energy-intensive sectors of China will face greater challenges when levying carbon tax.
- Carbon tax will reduces the factors return. Production workers will have the biggest reduction and farmers will have the smallest decrease.
- The income distributional effects of carbon tax in China is progressive
- The higher the tax rate is, the more obvious the progressive effect is.
- Comparing to urban households, carbon tax is more effective in promoting the income equality of rural households.

25. The next steps

- Further investigate the income distributional effects of carbon tax by using input-output method based on 2012 China I-O table.

- Carbon tax V.S Carbon trading ? Simulating by using CGE model.

Thanks for your attention!