An LSTM-STRIPAT model analysis of China's 2030 CO2 emissions peak

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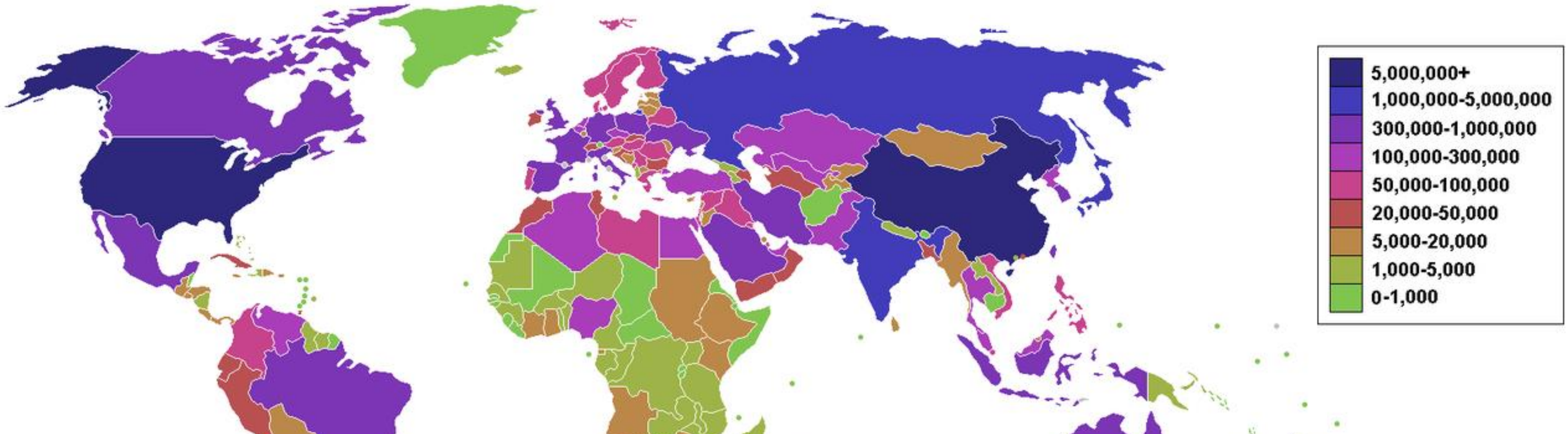
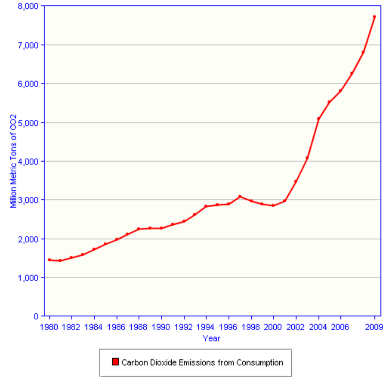
CO2 emissions background

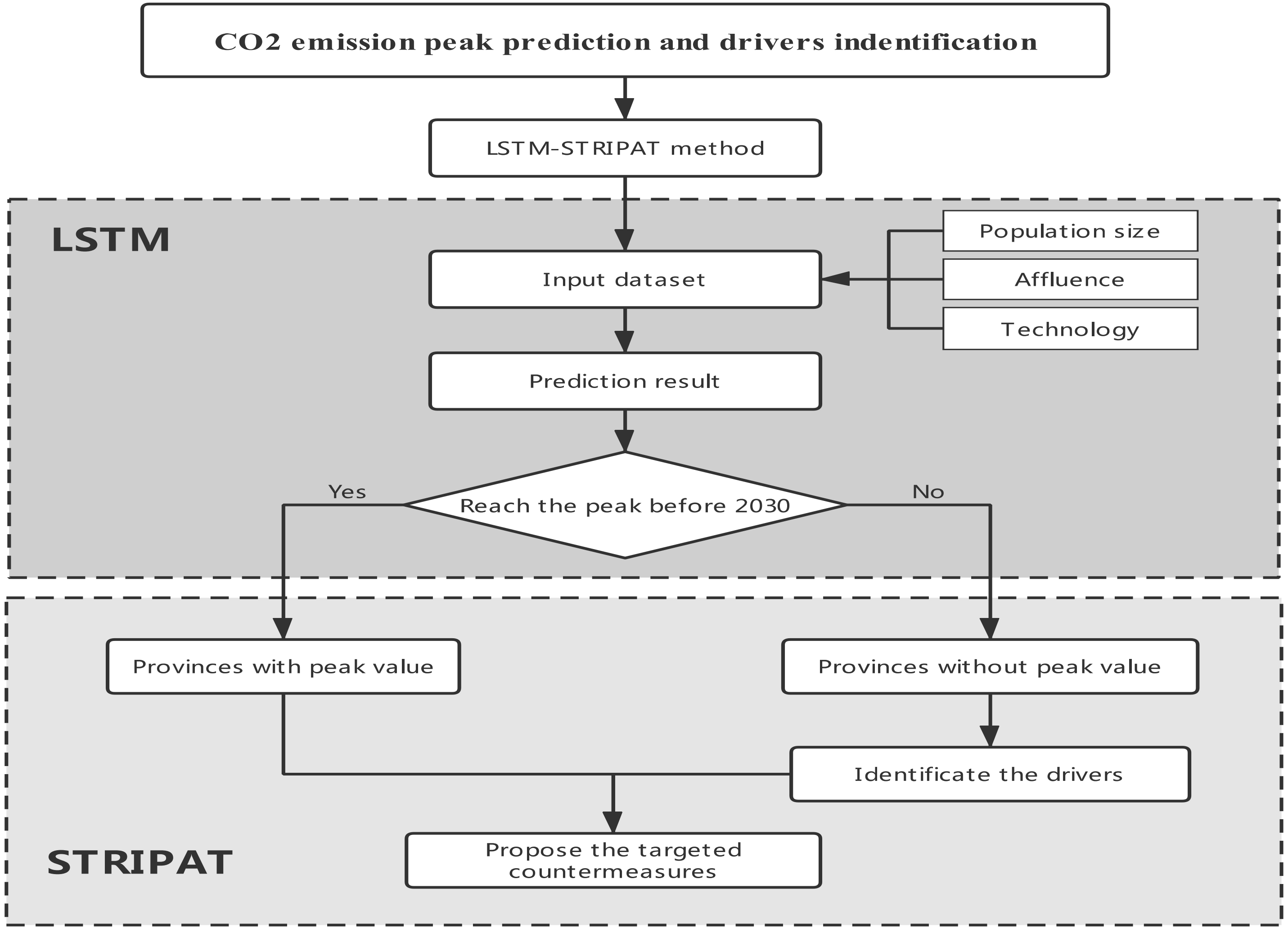




Key Problems

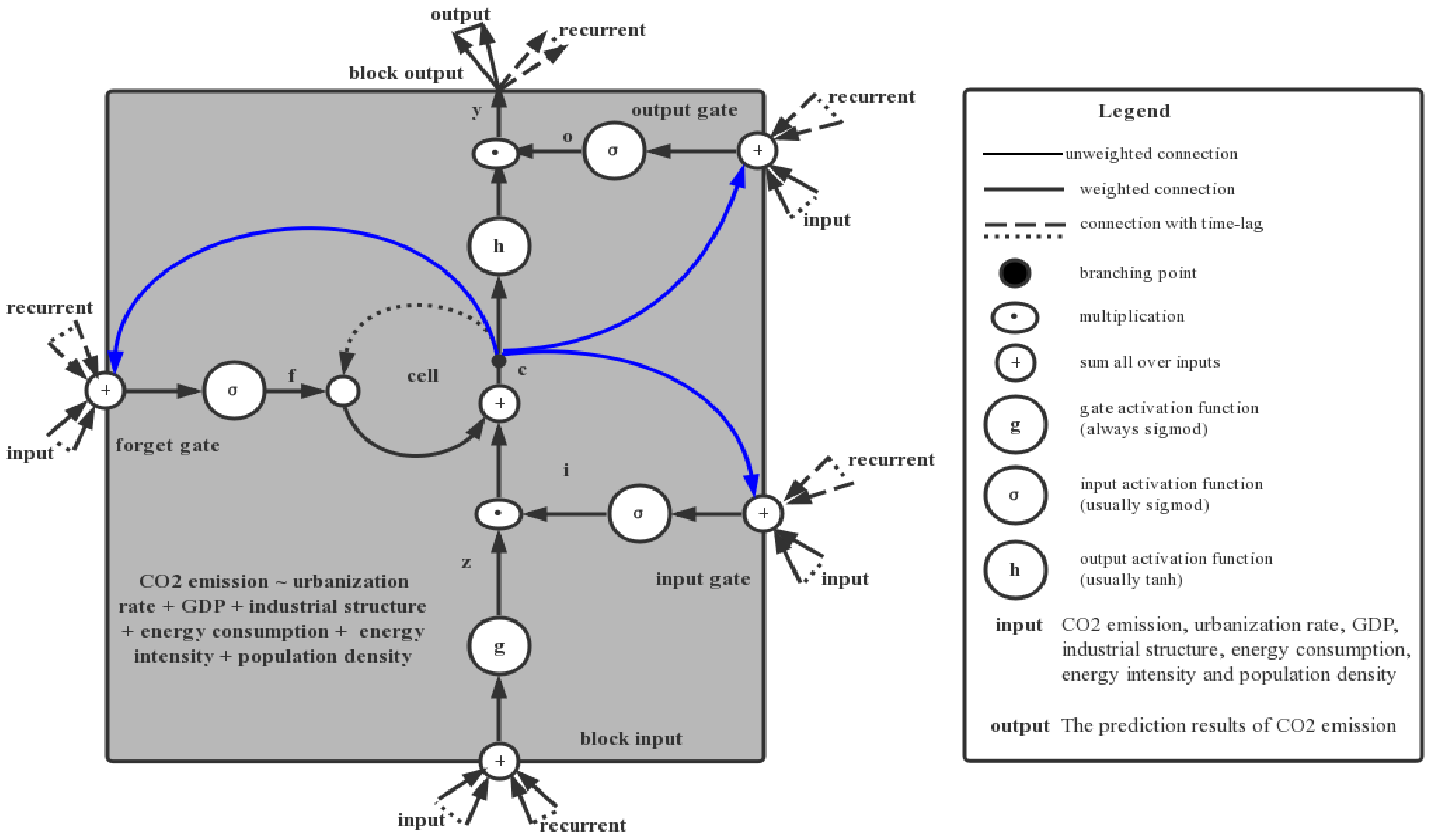
- **When** will China reach its peak CO_2 emissions?
- **What** are the factors that affect CO_2 emissions, taking into account the heterogeneity of each province?
- **How** to achieve the commitment of peaking before 2030?

LSTM-STRIPAT model



LSTM-STRIPAT model

☐ Long short-term memory



$$i_t = \sigma(W_i x_t + R_i h_{t-1} + b_i)$$

$$f_t = \sigma(W_f x_t + R_f h_{t-1} + b_f)$$

$$o_t = \sigma(W_o x_t + R_o h_{t-1} + b_o)$$

$$g_t = tanh(W_g x_t + R_g h_{t-1} + b_g)$$

$$c_t = f_t * C_{t-1} + g_t * i_t$$

$$h_t = o_t * \tanh(c_t)$$

LSTM-STRIPAT model

☐ STRIPAT model

$$I = \alpha P^{a} A^{b} T^{c} e$$

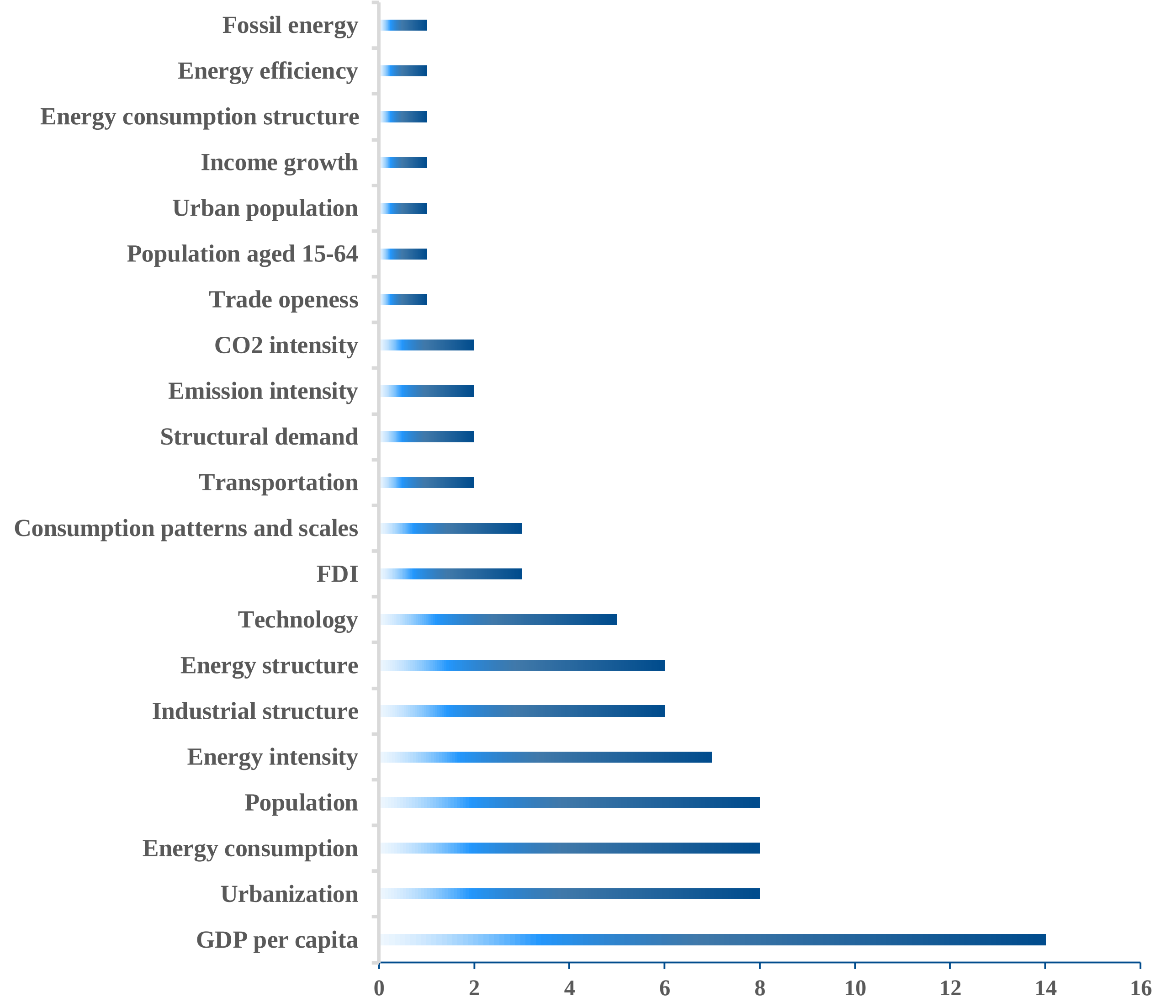
$$\ln I = \ln\alpha + a \ln P + b \ln A + c \ln T + \ln e$$

where I, P, A and T are same as in the IPAT framework, a, b, c represent the elasticity of I, P, A and T, and e is the residual error.

$$\ln CE_{i,t} = \alpha + a\ln UR_{i,t} + b\ln GDPi_{i,t} + c\ln SEC_{i,t} + d\ln EC_{i,t} + e\ln EI_{i,t} + f\ln PD_{i,t} + e$$

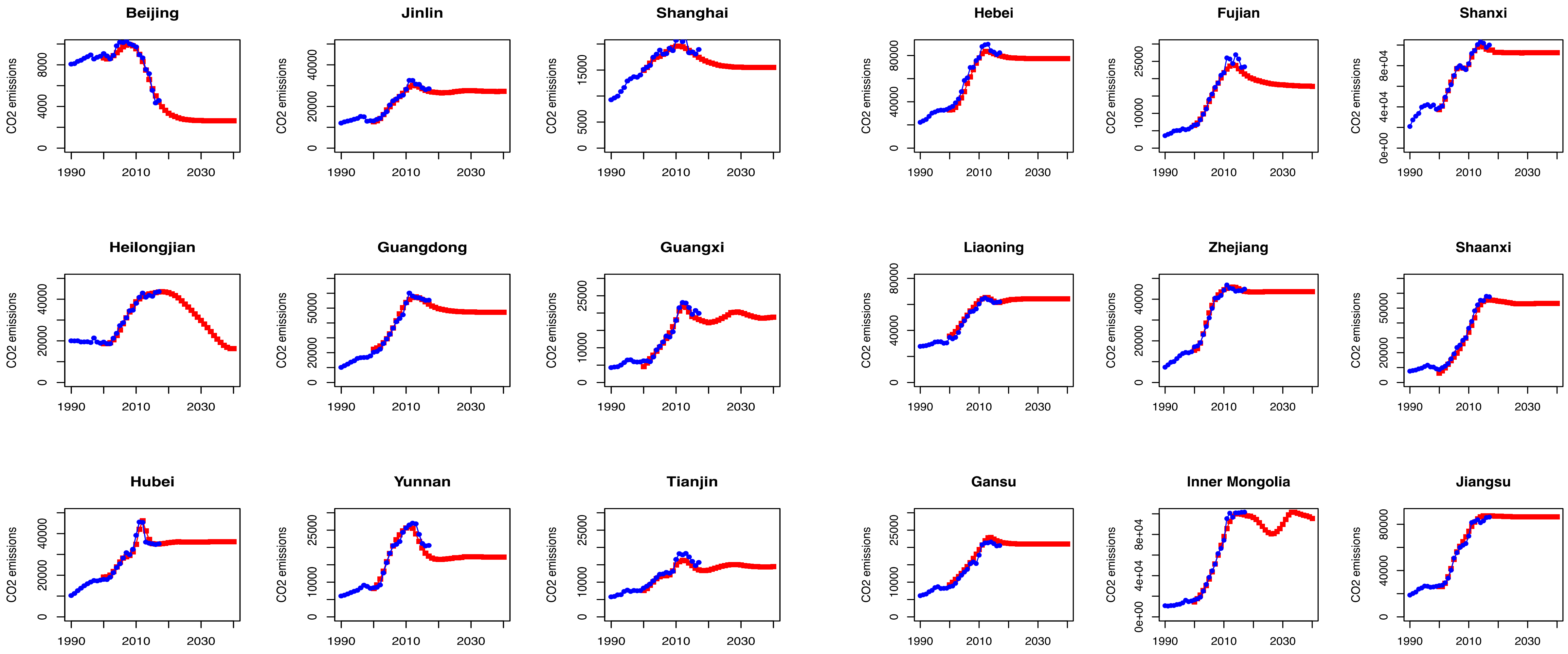
$$\ln C_{it} = \beta_1 \ln CE_{it-1} + \beta_2 \ln UR_{i,t} + \beta_3 \ln GDP_{i,t} + \beta_4 \ln SEC_{i,t} + \beta_5 \ln EC_{i,t} + \beta_6 \ln EI_{i.t} + \beta_7 \ln PD_{i,t} + u_i$$

Variables Selection

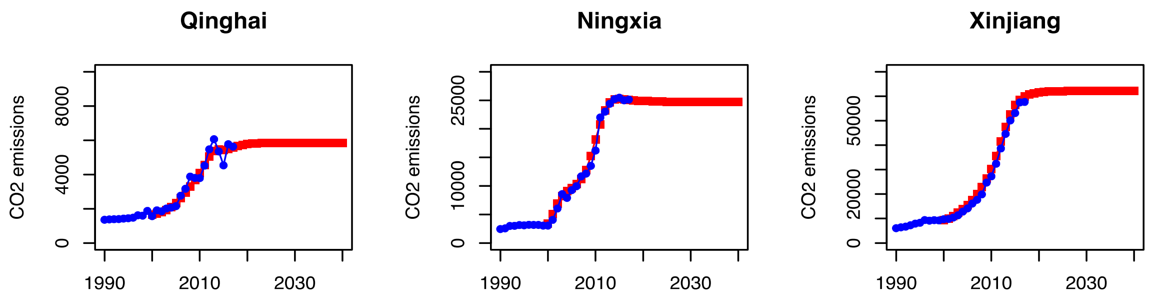


Research				
Behera et al. (2017)				n direct investment
You et al. (2015)				and industrialization level, economic globalization
Haseeb et al. (2017)				umption
Fan et al. (2006)				rbanization, population aged 15-64
Lin et al. (2009)				intensity
Shahbaz et al. (2016)				openness, GDP per capita
Shahbaz et al. (2017)				ry, services sectors value-added, transportation
Li et al. (2015)				tensity, FDI
Wang et al. (2017)				lation, urbanization level, technology level,
Yang et al. (2017)				urbanization, population, energy intensity
Zhang et al. (2017 a,b)				nology, energy structure, urban affordable revenue per capita, energy
Shuai et al. (2017)				intensity
Cansino et al. (2016)				ogy, structural demand, consumption patterns and scale
Su et al. (2017)				demand structure effect, total final demand effect
Geng et al. (2013)				intensity, production structure, consumption structure and per capita
Guan et al. (2009)				production structure, consumption pattern and per capita consumption
Zhang et al. (2009)				y and CO2 intensity
Zhang et al. (2016)				nissions intensity, energy structure, energy consumption, technology,
Wang et al. (2011)				ode
Chen et al. (2018)				re, energy intensity, per capita GDP, and population size
Xiao et al. (2017)	China	CGE	2010-2020	Energy efficiency, energy structure, industrial structure

➢When will China reach its peak CO2 emissions?



➢When will China reach its peak CO2 emissions?



PWP: Beijing, Jilin, Heilongjiang, Shanghai, Fujian, Hubei, Guangdong, Guangxi, Yunnan, Tianjin, Hebei, Shanxi, Zhejiang, Liaoning, Shaanxi, and Gansu (16)

PWTP: Inner Mongolia, Jiangsu, Anhui, Jiangxi, Shandong, Henan, Hunan, Hainan, Chongqing, Sichuan, Guizhou, Qinghai, Ningxia, and Xinjiang (14)

➢The accuracy of prediction result

Province	MAPE			Province	MAPE		
	LSTM	BPNN	GM(1,1)		LSTM	BPNN	GM(1,1)
Beijing	3.9%	4.8%	15.1 %	Hainan	4.6%	9.7%	19.9%
Tianjin	6.1%	16.4%	8.9%	Chongqing	2.1%	0.9%	6.5%
Hebei	5.2%	13.7%	11.9%	Sichuan	4.6%	22.3%	20.9%
Shanxi	2.2%	76.2%	9.3%	Guizhou	4.5%	19.5%	12.9%
Inner Mongolia	4.1%	32.3%	33.3%	Yunnan	5.5%	0.01%	23.9%
Liaoning	3.6%	75.0%	7.7%	Shaanxi	6.6%	58.6%	17.7%
Jilin	3.4%	72.9%	11.7%	Gansu	5.4%	0.07%	7.6%
Heilongjiang	2.6%	85.5%	10.5%	Qinghai	5.5%	4.2%	11.8%
Shanghai	3.6%	76.2%	8.8%	Ningxia	5.4%	0.36%	26.6%
Jiangsu	3.3%	32.3%	11.9%	Xinjiang	6.2%	72.2%	25.1%
Zhejiang	3.4%	85.6%	21.5%	Henan	3.2%	38.4%	21.4%
Anhui	3.8%	75.8%	7.1%	Hubei	4.4%	17.7%	11.3%
Fujian	4.7%	9.8%	24.0%	Hunan	5.5%	16.8%	20.2%
Jiangxi	5.0%	5.4%	11.7%	Guangdong	4.0%	90.2%	14.6%
Shandong	3.4%	21.1%	21.6%	Guangxi	6.0%	0.21%	14.7%

➢Estimated results for the PWP and PWTP

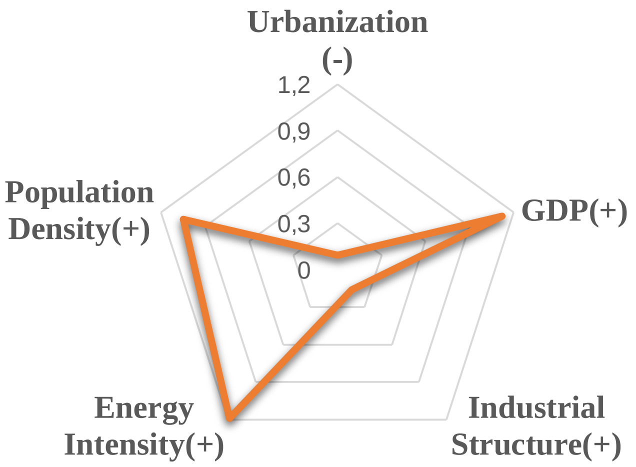
Explanatory Variables	OLS Model		Fixed Effect Model		Random Effect Model	
	PWTP	PWP	PWTP	PWP	PWTP	PWP
Interept	8.342*** (0.396)	-0.814*** (0.235)			1.395*** (0.493)	0.862** (0.387)
lnUR	0.037 (0.037)	0.0345* (0.014)	-0.088*** (0.023)	-0.093*** (0.024)	-0.081*** (0.022)	-0.021 (0.021)
lnGDP	48.371 (49.336)	-0.292*** (0.019)	-15.340 (18.114)	1.123*** (0.039)	-15.074 (18.468)	-0.112*** (0.020)
lnSEC	-1.595*** (0.137)	0.372*** (0.057)	0.295*** (0.080)	0.1594** (0.049)	0.268*** (0.078)	0.349*** (0.053)
lnEC	-47.494 (49.338)	1.382*** (0.032)	16.249 (18.112)	NA	15.966 (18.467)	1.105*** (0.049)
lnEI	48.210 (49.336)	NA	15.421 (18.115)	1.190*** (0.053)	15.163 (18.469)	NA
lnPD	0.005 (0.023)	0.103*** (0.013)	0.045* (0.246)	1.049*** (0.089)	0.003 (0.083)	0.190*** (0.034)
Obs.	504	335	504	335	504	335
R-Squared	0.782	0.940	0.931	0.95461	0.926	0.938
Adj. R-Squared	0.780	0.939	0.927	0.95233	0.925	0.937
F-statistic	297.725***(df = 6; 497)	1031.2***(df = 5; 329)	1,075.068***(df = 6; 480)	1337.55***(df = 5; 318)	6,219.978***	4,969.931***
F test	F 1= 203.57, df1 = 17, df2 = 480, p-value < 2.2e-16		F 2= 74.372, df1 = 11, df2 = 318, p-value< 2.2e-16			
Hausman test			Chisq1 = 80.309, df = 6, p-value = 3.085e-15		Chisq2 = 22.306, df = 4, p-value = 0.0001742	

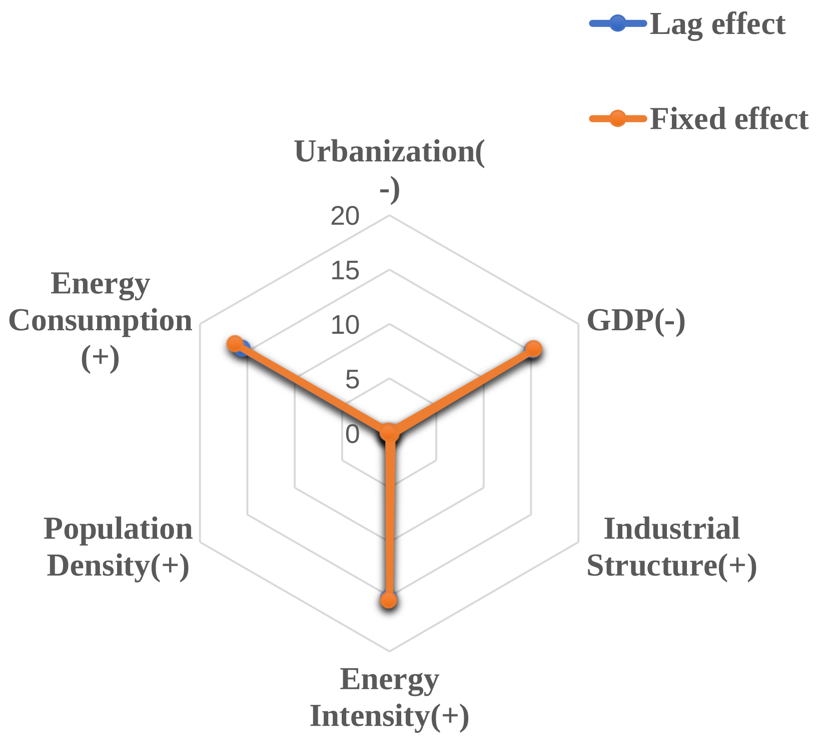
➢Empirical results for the provinces without a CO_2 emissions peak value (dynamic)

Explanatory Variables	OLS Model	Fixed Effect Model	Random Effect Model
lag(lnCE, 1)	0.995*** (0.009)	0.800*** (0.021)	0.986*** (0.011)
lnUR	0.022*** (0.007)	-0.016 (0.012)	-0.028*** (0.008)
lnGDP	-11.390 (9.530)	-15.262* (8.685)	-12.729 (9.503)
lnSEC	0.056* (0.031)	0.175*** (0.039))	0.057* (0.033)
lnEC	11.387 (9.530)	15.465* (8.684)	12.733 (9.502)
lnEI	11.364 (9.530)	15.205* (8.685)	-12.694 (9.502)
lnPD	-0.002 (0.004)	0.031 (0.121)	0.005 (0.006)
Constant	-0.159 (0.109)		-0.174 (0.120)
Obs.	486	486	486
R-Squared	0.992	0.984	0.989
Adj. R-Squared	0.992	0.983	0.989
F-statistic	8,295.984***(df = 7; 478)	3,961.978***(df = 7; 461)	44,102.180***
F test		F = 9.1255, df1 = 17, df2 = 461, p-value < 2.2e-16	
Hausman test			chisq = 144.57, df = 7, p-value < 2.2e-16

➢ What are the factors that affect CO2 emissions?

■ **CO2 emissions drivers rank**





GDP had a greater inhibitory effect on CO2 emissions in the PWTP, but a significantly positive impact on CO2 emissions in PWP

Urbanization had a negative effect on CO2 emissions

Population density, energy intensity, and industrial structure, energy consumption had a positive effect on CO2 emissions, but the PWTP energy intensity was much greater than the PWP

The PWP CO2 emissions were found to be more affected by current factors whereas the PWTP was found to be affected by **both current and past** factors.

➢ How to achieve the commitment of peaking before 2030?

Economic development -- Abandon traditional **economic development mode**, get rid of the traditional idea of GDP growth at the expense of the environment.

Energy consumption -- Optimized **energy supply structure** by increasing the share of new energy and renewable energy according to local advantages and resource characteristics. Develop new energy planning projects such as nuclear, hydropower, wind, solar, and biomass power generation, increase the proportion of renewable energy consumption, promote the diversification of energy supply and consumption, and actively optimize and adjust the energy consumption structure in China.

Energy intensity -- Establish **regional innovation system**, emphatically improve energy-intensive enterprise independent innovation ability, strictly implementing energy-saving projects, increase the theory related to energy efficiency technology research and development funding, to reduce emissions of China comprehensive preparation for establishing the mechanism of clean energy development.

Perfecting the laws and regulations

THANK YOU FOR ATTENTION!

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