Supplement of

Tracking County-level Cooking Emissions and Their Drivers in China from 1990 to 2021 by Ensemble Machine Learning

Zeqi Li et al.

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Table S1. The initial resolution and source of predictor variables

indicator type	statistical indicator	initial resolution	data source
population-related	population	county-level	Chinese County Statistical Yearbook
	number of employees in enterprises	county-level	Chinese County Statistical Yearbook
	number of students in middle schools	county-level	Chinese County Statistical Yearbook
	number of students in primary schools	county-level	Chinese County Statistical Yearbook
economy-related	urbanization rate	county-level	Chinese County Statistical Yearbook
	total GDP	county-level	Chinese County Statistical Yearbook
	GDP of primary industries	county-level	Chinese County Statistical Yearbook
	GDP of secondary industries	county-level	Chinese County Statistical Yearbook
	GDP of tertiary industries	county-level	Chinese County Statistical Yearbook
	per capita disposable income	county-level	Chinese County Statistical Yearbook
catering-related	number of employees in the catering and accommodation industry	city-level	China Urban Statistical Yearbook
	household per capita oil consumption	province-level	China Market Statistics Yearbook
	household per capita meat consumption	province-level	China Market Statistics Yearbook
	number of chain restaurants	province-level	China Market Statistics Yearbook

Table S2. PAH species considered in this study and their TEFs

Type	Name	Molecular formula	Benzene ring numbers	TEF	Reference for TEFs
priority PAHs	Naphthalene	C10H8	2	0.001	(Nisbet et al., 1992)
	Acenaphthylene	C12H8	3	0.001	(Nisbet et al., 1992)
	Acenaphthene	C12H10	3	0.001	(Nisbet et al., 1992)
	Fluorene	C13H10	3	0.001	(Nisbet et al., 1992)
	Phenanthrene	C14H10	3	0.001	(Nisbet et al., 1992)
	Anthracene	C14H10	3	0.001	(Nisbet et al., 1992)
	Fluoranthene	C16H10	4	0.05	(Larsen et al., 1998)
	Pyrene	C16H10	4	0.001	(Nisbet et al., 1992)
	Benz(a)anthracene	C18H12	4	0.1	(Nisbet et al., 1992)
	Chrysene	C18H12	4	0.01	(Nisbet et al., 1992)
	Benzo(b)fluoranthene	C20H12	4	0.1	(Nisbet et al., 1992)
	Benzo(k)fluoranthene	C20H12	4	0.1	(Nisbet et al., 1992)
	Benzo(a)pyrene	C20H12	5	1	(Nisbet et al., 1992)
	Indeno(1,2,3-cd)pyrene	C22H12	5	0.1	(Nisbet et al., 1992)
	Dibenz(a,h)anthracene	C22H14	5	1	(Malcolm et al., 1994)
	Benzo(g,h,i)perylene	C22H12	6	0.01	(Nisbet et al., 1992)
non-priority PAHs	Cyclopenta(c,d)pyrene	C18H10	4	0.1	(Malcolm et al., 1994)
	Benzo(e)pyrene	C20H12	5	0.01	(Malcolm et al., 1994)
	Perylene	C20H12	5	0.001	(Malcolm et al., 1994)
	Coronene	C24H12	7	0.001	(Malcolm et al., 1994)
	Benzo(b)chrycene	C22H14	5	-	No TEF has been suggested.

Table S3. Values and sources of EFs for various pollutants emitted from cooking activities

Organics in the full volatility range

		VOC EF	IVOC EF	SVOC EF	xLVOC EF	Sources
Commercial cooking ($\mu g/m^3$)	uncontrolled	4077	2113	1570	98.89	(Li et al., 2023) The EF for commercial cooking varies across counties. Here, we list the national average EFs for commercial cooking.
	controlled	1631	845.1	627.8	39.56	
Residential cooking (g/kg oil)[b]	uncontrolled[a]	13.51	3.948	2.446	0.3939	
Canteen cooking (g/meal)[b]	uncontrolled	0.8328	0.3414	0.3037	0.01496	
	controlled	0.3590	0.1498	0.1329	0.006552	

Particles

		$PM_{2.5}$ EF	Sources			UFP EF	Sources
Commercial cooking ($\mu g/m^3$)	uncontrolled	2874	Calculated by POA/81.5% (Li et al., 2023)	Commercial cooking (#/m^3)	uncontrolled[c]	1.715×10^{11}	(Kim et al., 2024; Zhang et al., 2010)
	controlled	1149			controlled	9.529×10^{11}	
Residential cooking (g/kg oil)[b]	uncontrolled[a]	3.016		Residential cooking (#/kg oil)[b]	uncontrolled[a]	9.705×10^{14}	(Chen et al., 2018, 2017; Géhin et al., 2008)
Canteen cooking (g/meal)[b]	uncontrolled	0.2227		Canteen cooking (#/meal)[b]	uncontrolled[c]	3.420×10^{13}	Taking EF for commercial cooking and converting units
	controlled	0.09659			controlled	6.156×10^{12}	

PAHs

		Gaseous PAH EF[e]	Particulate PAH EF[e]	BaP_{eq} EF[f]	Sources
Commercial cooking ($\mu g/m^3$)	uncontrolled[d]	139.0	38.44	26.73	(Li et al., 2003)
	controlled	58.78	17.14	11.58	
Residential cooking (g/kg oil)[b]	uncontrolled[a]	0.006730	0.002174	0.001295	(Feng et al., 2021; Lin et al., 2022; Ye et al., 2013)
Canteen cooking (g/meal)[b]	uncontrolled[d]	0.001102	2.225×10^{-5}	5.102×10^{-5}	(Chen et al., 2007)
	controlled	0.0004718	9.024×10^{-6}	2.230×10^{-5}	

[a] Only uncontrolled EFs are considered for residential cooking because residential chimneys generally do not have specialized purification facilities (Liang et al., 2022).

[b] Unit conversions of EFs for residential and canteen cooking refer to the Supplementary Materials of Li et al., 2023.

[c] The removal efficiency of UFP is taken as the average (82%) of the removal efficiencies of 2 commercially available pollution control facilities (in-house dual-stage filtration system and electrostatic precipitator) (Gysel et al., 2018)

[d] In the absence of removal efficiencies for PAHs, we assume that the removal efficiencies for gaseous and particulate PAH are equal to those for VOCs and $PM_{2.5}$, respectively (Li et al., 2023).

[e] The test EFs of gaseous and particulate PAHs for commercial cooking are available from non-Chinese restaurants, Chinese restaurants, and fast food restaurants. Therefore, the final commercial cooking PAH EFs were weighted according to the proportions of these three types of restaurants in China (3.2%: 68.5%: 28.3%, from Li et al., 2023).

[f] The BaP_{eq} EFs are calculated from the PAH EFs and TEFs for the PAH species in Table S2.

Table S4. Purification facility installation proportion for CMC in each province.

Province	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.77	0.88	1.00	1.00
Tianjin	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.77	0.88	1.00	1.00	1.00	1.00
Hebei	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.65	0.65	0.77	0.88	1.00	1.00	1.00
Shanxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Inner Mongolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Liaoning	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.77	0.88	1.00	1.00	1.00	1.00
Jilin	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.64	0.64	0.65	0.65	0.65
Heilongjiang	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.31	0.47	0.53	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.77	0.88	1.00	1.00	1.00	1.00	1.00	1.00
Jiangsu	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.77
Zhejiang	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Anhui	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Fujian	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Jiangxi	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65
Shandong	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65
Henan	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.65	0.65	0.77	0.88	1.00	1.00
Hubei	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65
Hunan	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65
Guangdong	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Guangxi	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65
Hainan	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.31	0.47	0.53	0.65	0.65	0.65	0.77	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chongqing	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.65	0.65	0.65	0.65	0.77	0.88	1.00	1.00
Sichuan	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Guizhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65	0.65	0.65
Yunnan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65
Xizang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65
Shaanxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65	0.65
Gansu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.64	0.64	0.65	0.65
Qinghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59	0.65
Ningxia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.53	0.59
Xinjiang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.24	0.35	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.64	0.64	0.65	0.65

Table S5. Purification facility installation proportion for CTC in each province.

Province	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Beijing	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83	0.83	0.83	0.89	0.94	1.00	1.00
Tianjin	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.89	0.94	1.00	1.00	1.00	1.00
Hebei	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.89	0.94	1.00	1.00	1.00
Shanxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Inner Mongolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Liaoning	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.89	0.94	1.00	1.00	1.00	1.00
Jilin	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83
Heilongjiang	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0.43	0.64	0.70	0.77	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.89	0.94	1.00	1.00	1.00	1.00	1.00	1.00
Jiangsu	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.89
Zhejiang	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Anhui	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Fujian	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Jiangxi	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83
Shandong	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83
Henan	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.89	0.94	1.00	1.00
Hubei	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83
Hunan	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83
Guangdong	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Guangxi	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83
Hainan	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0.43	0.64	0.70	0.77	0.83	0.83	0.89	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chongqing	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.89	0.94	1.00	1.00
Sichuan	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Guizhou	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83	0.83	0.83
Yunnan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83
Xizang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83
Shaanxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83	0.83
Gansu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83
Qinghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83
Ningxia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77
Xinjiang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.32	0.48	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.70	0.77	0.83

Table S6: The values of validation metrics of all models for activity levels of three cooking sectors on the training data set.

Model	Commercial cooking			Residential cooking			Canteen cooking		
	R^2	RMSE (10^9 m^3)	MAE (10^9 m^3)	R^2	RMSE (kt)	MAE (kt)	R^2	RMSE (10^6 meals)	MAE (10^6 meals)
Multiple linear regression	0.737	21.464	14.301	0.949	0.803	0.416	0.966	4.825	2.272
Non-negative least squares regression	0.635	22.341	17.271	0.903	1.174	0.869	0.960	5.072	2.095
Generalized linear models with exponential link	0.689	25.860	13.019	0.401	3.014	2.518	0.541	17.351	13.258
Poisson regression	0.504	26.836	17.285	0.048	3.911	2.804	0.243	19.056	14.923
Power function Regression	0.779	18.184	9.664	0.985	0.312	0.163	0.978	2.894	1.692
RF	0.982	8.013	3.885	0.997	0.135	0.060	0.995	1.056	1.055
XGBoost	0.936	11.450	6.029	0.996	0.114	0.048	0.997	1.183	1.161
MLP	0.887	14.642	7.651	0.993	0.205	0.108	0.989	1.726	1.273
DNN	0.898	12.395	6.822	0.994	0.178	0.092	0.986	2.412	1.325
Ensemble machine learning model	0.985	7.852	3.915	0.997	0.095	0.059	0.995	1.054	1.116

Table S7: Comparison of cooking emissions in this study with those in previous studies. Bolded words represent this study.

region and year	inventory studies	VOC emissions (kt)	$PM_{2.5}$ emissions (kt)
China, 2012	**this study**	**416**	**334**
China, 2012	Wang et al., 2018a	66.0	
China, 2017	**this study**	**520**	**376**
China, 2017	Jin et al., 2021	34.0	
China, 2018	**this study**	**531**	**384**
China, 2018*	Cheng et al., 2022 ($PM_{2.5}$=POA/81.5%=1.8OC/81.5%) (Huang, 2023)	-	5.57
China, 2019	**this study**	**539**	**389**
China, 2019	Liang et al., 2022	234	
China, 2020	**this study**	**524**	**379**
China, 2020	Zhang et al., 2024	557	82.1

* Cheng et al provided multi-year organic carbon (OC) emissions for China, and we use their most recent year (2018) for comparison. We apply the conversion relationship mentioned in the main text to convert OC into $PM_{2.5}$ for comparison. The emission results from Cheng et al. were significantly lower than those of this study because their calculations were based solely on meat consumption, whereas cooking emissions involve not only meat but also vegetables, cooking oil, and other factors. This led to a substantial underestimation of their emissions.

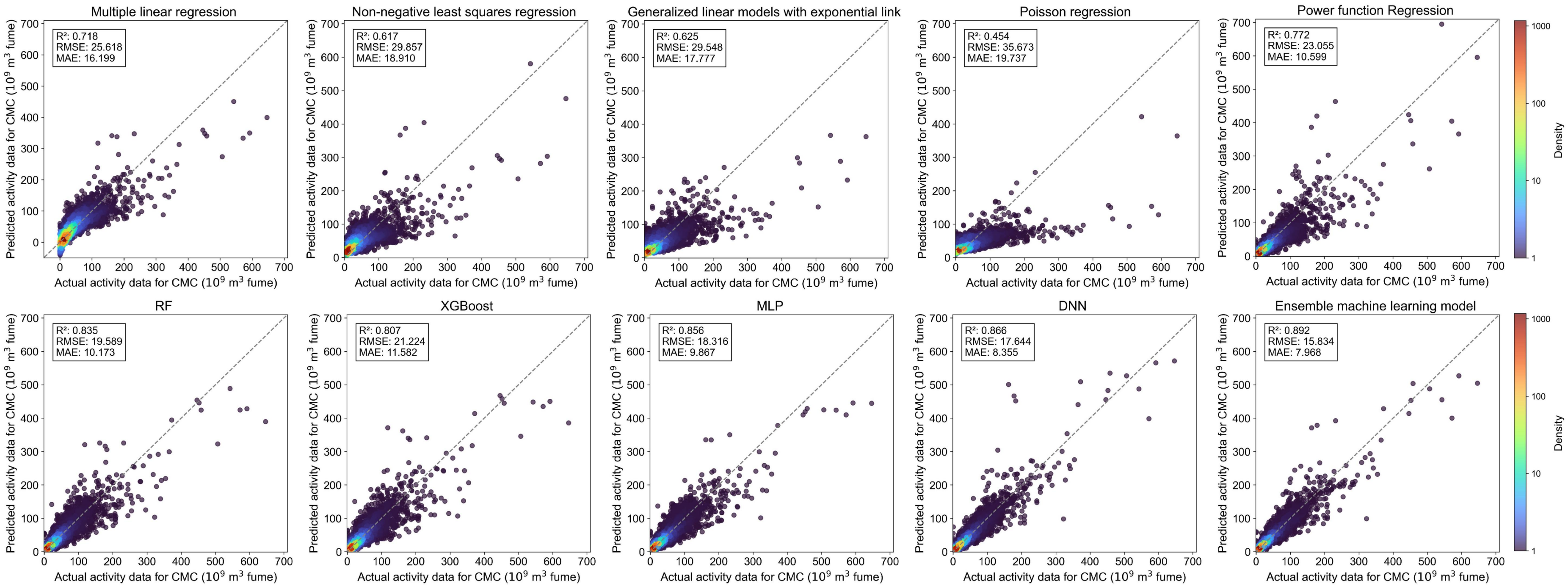

Figure S1. The predictive performance of all models on commercial cooking (CMC)

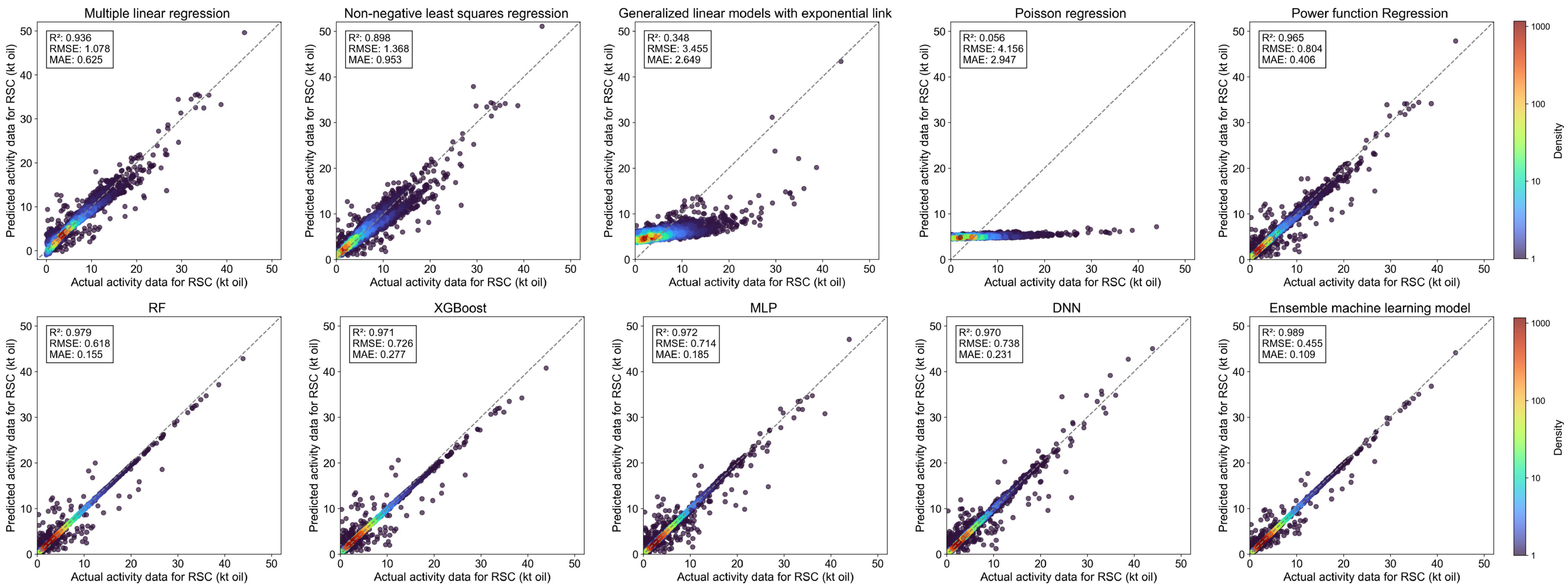

Figure S2. The predictive performance of all models on residential cooking (RSC)

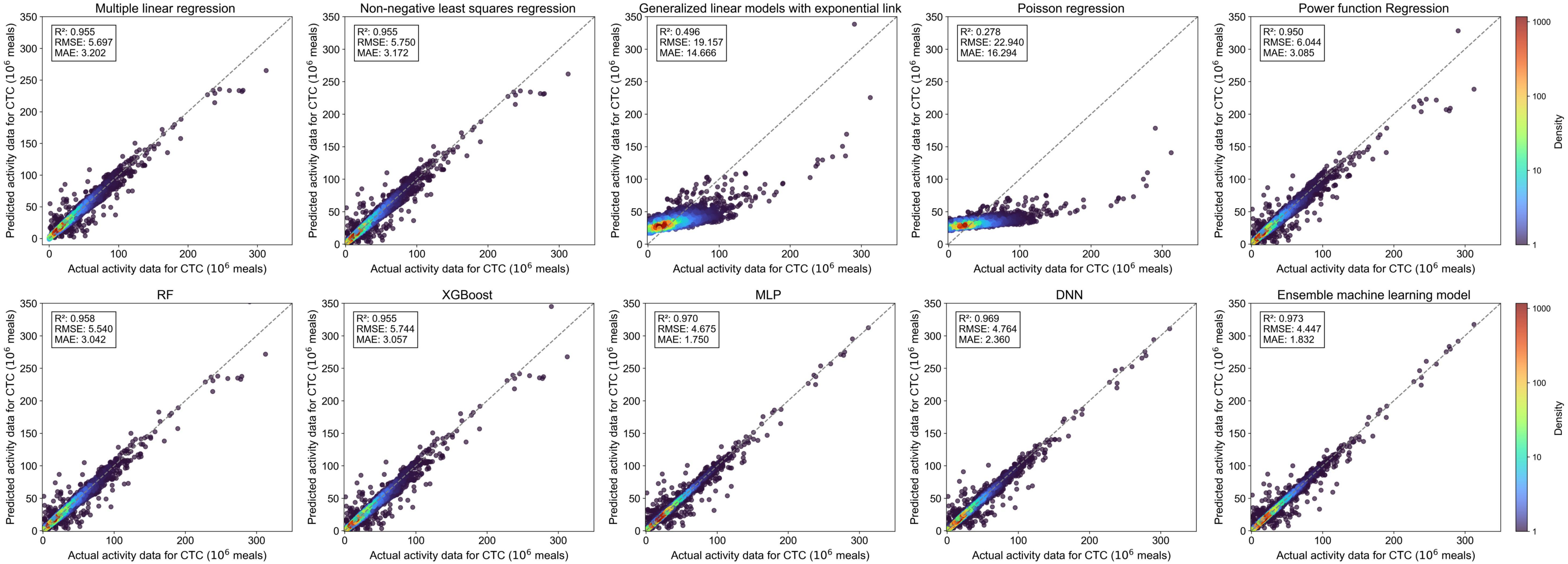

Figure S3. The predictive performance of all models on canteen cooking (CTC)

Figure. S4. Map of Chinese provinces.

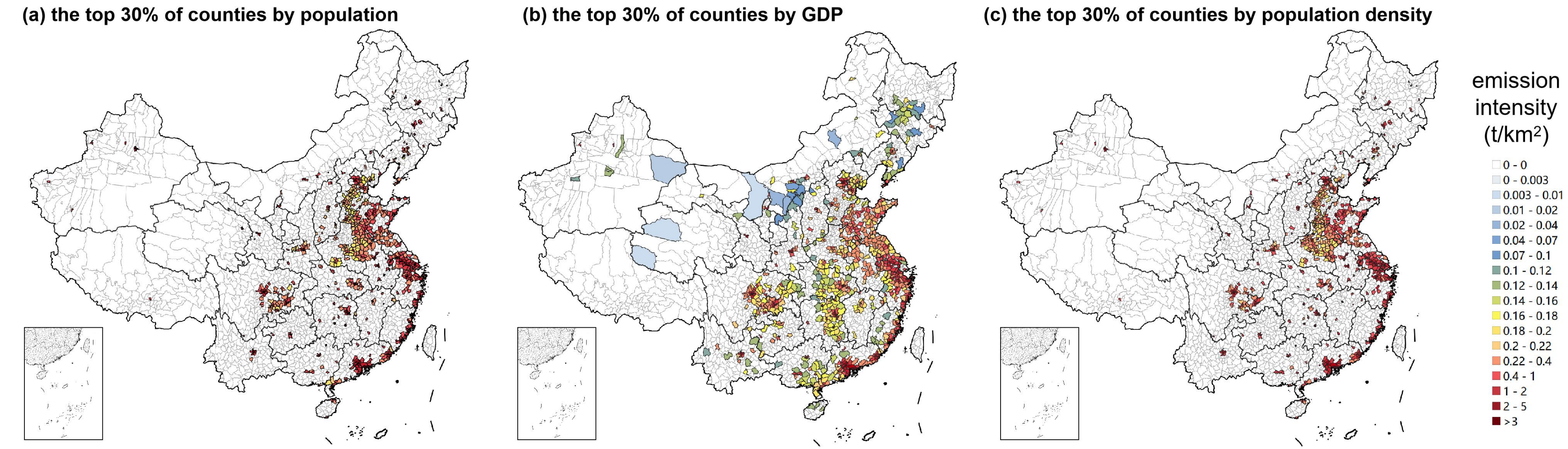

Figure. S5. The top 30% of counties by population, GDP, and population density.

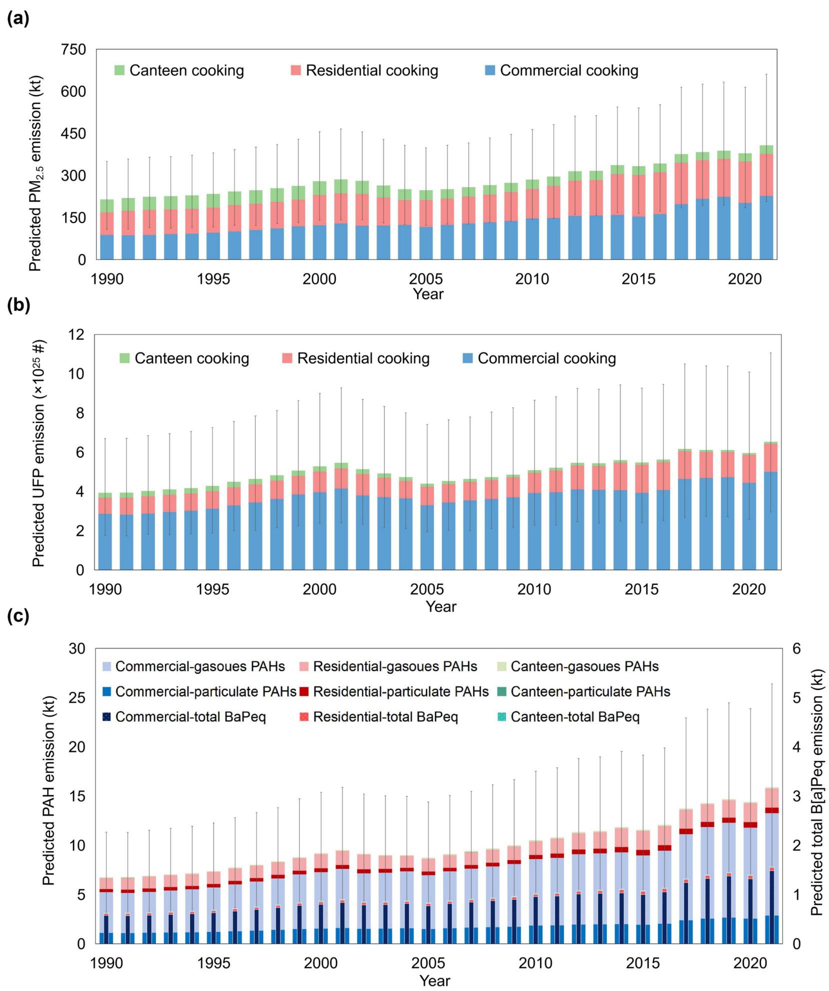

Figure S6. $PM_{2.5}$, UFP, and PAH emissions in the four volatility ranges from the three cooking sectors from 1990 to 2021 in China.

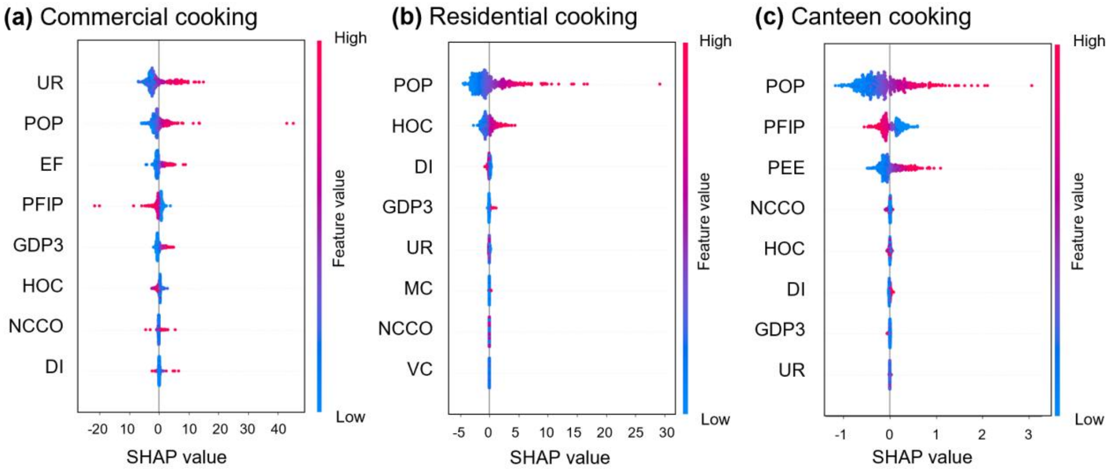

Figure. S7. SHAP summary plots of the main influencing factors for the emissions of the three cooking sectors. Each point represents a sample of (district, year), with its color indicating its factor value - blue representing lower variable values, and red representing higher feature values. We only select the top 8 most important factors to display in the figures.

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