附表 1　　考虑 0 日向前情况下天气温度的单一 MIDAS 模型的结构选择

	天气温度的滞后阶数分布						
	5	10	20	30	40	50	60
天然气的滞后阶数: 0							
Beta	0.6178	0.5771	**0.4651**	0.6163	0.5726	0.5904	0.6037
BetaNN	0.6199	0.5929	0.4663	0.6269	0.6389	0.5705	0.7437
ExpAlmon	0.5851	0.5977	0.5123	0.6380	0.5956	0.6119	0.5727
Almon	0.5939	0.6061	0.4763	0.6758	0.5564	0.6140	0.5051
Step	0.5852	0.5745	0.5117	0.7056	0.6944	0.7175	0.8471
UMIDAS	0.6092	1.4013	1.0934	1.3213	1.5491	3.1411	4.0477
天然气的滞后阶数: 1							
Beta	0.6284	0.5763	**0.4452**	0.6456	0.5711	0.5755	0.5910
BetaNN	0.6052	0.5946	0.4506	0.5240	0.5127	0.5388	0.6945
ExpAlmon	0.6358	0.6112	0.6256	0.6554	0.6273	0.6245	0.5885
Almon	0.6057	0.6089	0.4701	0.7031	0.5615	0.5867	0.4781
Step	0.5930	0.5750	0.5010	0.6955	0.7502	0.7430	0.9122
UMIDAS	0.6210	1.4593	1.1709	1.2993	1.4053	2.5763	3.1875
天然气的滞后阶数: 2							
Beta	0.6167	0.5567	0.4335	0.6459	0.5410	0.5747	0.5529
BetaNN	0.5833	0.5768	0.4432	0.5136	0.5635	0.6035	0.4221
ExpAlmon	0.5713	0.6015	0.5089	0.6462	0.6148	0.6117	0.5564
Almon	0.5879	0.5937	0.4622	0.7030	0.5402	0.5831	**0.4220**
Step	0.5778	0.5527	0.4684	0.6613	0.7084	0.7127	0.8074
UMIDAS	0.5847	1.4116	1.2330	1.2356	1.1328	1.8845	2.5391
天然气的滞后阶数: 3							
Beta	0.5966	0.5395	0.4237	0.6123	0.5281	0.5582	0.5234
BetaNN	0.5635	0.5577	0.4377	0.4847	0.4376	0.4970	0.4049
ExpAlmon	0.5966	0.5966	0.5966	0.5966	0.5966	0.5966	0.5966
Almon	0.5688	0.5800	0.4532	0.6856	0.5227	0.5682	**0.3995**
Step	0.5590	0.5397	0.4594	0.6387	0.7101	0.7206	0.9187
UMIDAS	0.5641	1.3854	1.2351	1.2337	1.2586	1.8856	2.2015
天然气的滞后阶数: 4							
Beta	0.6092	0.5539	0.4447	0.6136	0.5274	0.5345	0.5253
BetaNN	0.5478	0.5642	0.4502	0.4861	0.4485	0.4990	0.4254
ExpAlmon	0.6092	0.6092	0.6092	0.6092	0.6092	0.6092	0.6092
Almon	0.5736	0.5862	0.4741	0.6851	0.5473	0.5714	**0.4036**
Step	0.5708	0.5429	0.4782	0.6484	0.7406	0.7171	0.9292
UMIDAS	0.5745	1.3967	1.3347	1.3637	1.3054	1.9784	2.2006
天然气的滞后阶数: 5							
Beta	0.6033	0.5662	0.4523	0.6079	0.5343	0.5319	0.5230
BetaNN	0.5505	0.5570	0.4786	0.4740	0.4529	0.4955	0.4723
ExpAlmon	0.6033	0.6033	0.6033	0.6033	0.6033	0.6033	0.6033
Almon	0.5724	0.5807	0.4872	0.6956	0.5599	0.5698	**0.3900**
Step	0.5776	0.5367	0.4956	0.6852	0.8308	0.7702	1.0176
UMIDAS	0.5694	1.3962	1.4312	1.4301	1.2590	1.9541	2.8241

注：表格中的加粗项代表不同滞后项和权重联合下的最小 RMSE 值，其所对应的模型结构为单一最优 MIDAS 模型。

附表 2 不同驱动因子下的最优 MIDAS 模型选择

向前 H	模型选择	RMSE	模型选择	RMSE
	Temperature		*Wind speed*	
H=0	AR(5)-Almon-MIDAS(60,4,0)	0.3900	AR(3)-ExpAlmon-MIDAS(33,3,0)	0.5095
H=1	AR(5)-Almon-MIDAS(60,4,1)	0.3932	AR(3)-Almon-MIDAS(17,4,1)	0.4941
H=2	AR(5)-Almon-MIDAS(59,4,2)	0.3932	AR(5)-Almon-MIDAS(16,4,2)	0.5130
H=3	**AR(5)-Almon-MIDAS(58,4,3)**	**0.3881**	AR(3)-Almon-MIDAS(15,4,3)	0.4849
H=4	AR(5)-Almon-MIDAS(57,4,4)	0.3884	AR(3)-Almon-MIDAS(14,4,4)	0.5016
H=5	AR(5)-Almon-MIDAS(56,4,5)	0.3944	AR(3)-Almon-MIDAS(13,4,5)	0.5073
H=6	AR(5)-Almon-MIDAS(55,4,6)	0.3969	AR(3)-BetaNN-MIDAS(27,2,6)	0.5163
H=7	AR(5)-Almon-MIDAS(53,4,7)	0.4267	AR(3)-BetaNN-MIDAS(26,2,7)	0.5091
H=8	AR(5)-Almon-MIDAS(52,4,8)	0.4201	AR(3)-ExpAlmon-MIDAS(10,3,8)	0.4937
H=9	AR(5)-Almon-MIDAS(51,4,9)	0.4204	**AR(3)-BetaNN-MIDAS(24,2,9)**	**0.4574**
H=10	AR(3)-BetaNN-MIDAS(18,2,10)	0.4056	AR(3)-BetaNN-MIDAS(25,2,10)	0.5072
	Air humidity		*Rainfall capacity*	
H=0	AR(3)-BetaNN-MIDAS(21,2,0)	0.5513	AR(5)-BetaNN-MIDAS(36,2,0)	0.4998
H=1	AR(5)-Almon-MIDAS(36,4,1)	0.5716	AR(5)-Almon-MIDAS(36,4,1)	0.4941
H=2	AR(5)-BetaNN-MIDAS(34,2,2)	0.4816	AR(5)-Stepfun-MIDAS(35,5,2)	0.4148
H=3	**AR(5)-BetaNN-MIDAS(33,2,3)**	**0.4750**	AR(5)-BetaNN-MIDAS(33,2,3)	0.4958
H=4	AR(5)-BetaNN-MIDAS(32,2,4)	0.4913	AR(4)-Beta-MIDAS(48,1,4)	0.4426
H=5	AR(5)-Almon-MIDAS(32,4,5)	0.5320	AR(5)-Setpfun-MIDAS(32,5,5)	0.4254
H=6	AR(5)-ExpAlmon-MIDAS(30,3,6)	0.5049	AR(3)-Almon-MIDAS(30,4,6)	0.4955
H=7	AR(0)-BetaNN-MIDAS(29,2,7)	0.5258	AR(5)-BetaNN-MIDAS(31,2,7)	0.4519
H=8	AR(0)-ExpAlmon-MIDAS(60,3,8)	0.5164	AR(5)-Stepfun-MIDAS(29,5,8)	0.4211
H=9	AR(5)-Almon-MIDAS(28,4,9)	0.5108	**AR(3)-ExpAlmon-MIDAS(28,3,9)**	**0.4039**
H=10	AR(5)-ExpAlmon-MIDAS(26,3,10)	0.5049	AR(2)-ExpAlmon-MIDAS(27,3,10)	0.4126
	Oil spot price		*HS 300-index*	
H=0	AR(3)-Almon-MIDAS(18,4,0)	0.4673	AR(3)-BetaNN-MIDAS(30,2,0)	0.5380
H=1	AR(3)-Almon-MIDAS(17,4,1)	0.4834	AR(5)-Stepfun-MIDAS(14,5,1)	0.5350
H=2	AR(3)-Almon-MIDAS(16,4,2)	0.4686	AR(5)-Stepfun-MIDAS(28,5,2)	0.5339
H=3	AR(3)-Almon-MIDAS(15,4,3)	0.5052	AR(0)-BetaNN-MIDAS(27,2,3)	0.5357
H=4	AR(3)-Stepfun-MIDAS(14,5,4)	0.4959	AR(3)-BetaNN-MIDAS(46,2,4)	0.5390
H=5	AR(3)-BetaNN-MIDAS(16,2,5)	0.5046	AR(5)-Stepfun-MIDAS(25,5,5)	0.5281
H=6	AR(3)-BetaNN-MIDAS(15,2,6)	0.4943	AR(5)-Umidas-MIDAS(9,6,6)	0.5101
H=7	AR(3)-BetaNN-MIDAS(14,2,7)	0.4901	AR(4)-Umidas-MIDAS(7,6,7)	0.5040
H=8	AR(3)-Almon-MIDAS(10,4,8)	0.4877	**AR(4)-Umidas-MIDAS(6,6,8)**	**0.4940**
H=9	AR(3)-BetaNN-MIDAS(12,2,9)	0.4672	AR(5)-Umidas-MIDAS(5,6,9)	0.5081
H=10	**AR(3)-BetaNN-MIDAS(11,2,10)**	**0.4523**	AR(5)-Umidas-MIDAS(4,6,10)	0.5070
	SWS gas-index		*Baidu search-index*	
H=0	AR(3)-Almon-MIDAS(40,4,0)	0.5087	**AR(4)-Stepfun-MIDAS(33,5,0)**	**0.4256**
H=1	**AR(0)-Almon-MIDAS(39,4,1)**	**0.5055**	AR(4)-BetaNN-MIDAS(35,2,1)	0.4590
H=2	AR(0)-BetaNN-MIDAS(36,2,2)	0.5242	AR(4)-BetaNN-MIDAS(31,2,2)	0.4699
H=3	AR(0)-Almon-MIDAS(31,4,3)	0.5153	AR(4)-Setpfun-MIDAS(30,5,3)	0.4445
H=4	AR(0)-Almon-MIDAS(36,4,4)	0.5183	AR(3)-BetaNN-MIDAS(52,2,4)	0.4835
H=5	AR(3)-Almon-MIDAS(35,4,5)	0.5373	AR(3)-BetaNN-MIDAS(54,2,5)	0.4399
H=6	AR(3)-Almon-MIDAS(35,4,6)	0.5461	AR(5)-Almon-MIDAS(27,4,6)	0.4662
H=7	AR(3)-Almon-MIDAS(33,4,7)	0.5491	AR(5)-Almon-MIDAS(26,4,7)	0.4813
H=8	AR(3)-Almon-MIDAS(36,2,8)	0.5555	AR(0)-Beta-MIDAS(60,1,8)	0.4500
H=9	AR(3)-BetaNN-MIDAS(35,2,9)	0.5549	AR(3)-Beta-MIDAS(60,1,9)	0.4444
H=10	AR(4)-ExpAlmon-MIDAS(34,3,10)	0.5285	AR(4)-Stepfun-MIDAS(25,5,10)	0.4982
	Steam coal price			
H=0	**AR(4)-Stepfun-MIDAS(10,5,0)**	**0.5317**		
H=1	AR(3)-Almon-MIDAS(3,4,1)	0.5549		

H=2	AR(3)-BetaNN-MIDAS(8,2,2)	0.5719		
H=3	AR(3)-Stepfun-MIDAS(7,5,3)	0.5686		
H=4	AR(5)-BetaNN-MIDAS(6,2,4)	0.5709		
H=5	AR(3)-Beta-MIDAS(38,1,5)	0.5701		
H=6	AR(3)-Stepfun-MIDAS(5,5,6)	0.5681		
H=7	AR(4)-Umidas-MIDAS(4,6,7)	0.5552		
H=8	AR(3)-Stepfun-MIDAS(3,5,8)	0.5729		
H=9	AR(3)-Almon-MIDAS(3,4,9)	0.5682		
H=10	AR(0)-Stepfun-MIDAS(10,5,10)	0.5747		

注：加粗项代表不同向前步数下，各因子的最优 MIDAS 模型结构。

附表 3　　不同权重方案 MIDAS-QR 的联合概率预测区间效果

Panel A：全预测期内联合概率预测区间效果

联合预测权重	80% Interval		90% Interval	
	PICP	PINAW	PICP	PINAW
MSFE	81.8182	39.5231	90.9091	57.1798
DMSFE	81.8182	38.3384	90.9091	56.7260
MAE	84.8485	41.7957	90.9091	60.9310
AIC	81.8182	32.8540	93.9394	47.4137
BIC	93.9394	33.8456	96.9697	50.2316
EW	87.8788	45.2944	90.9091	66.6265

Panel B：结构性突变情况下联合概率预测区间效果

联合预测权重	非结构性突变期（2018.04-2019.12）				结构性突变期（2020.01-2020.12）			
	80% Interval		90% Interval		80% Interval		90% Interval	
	PICP	PINAW	PICP	PINAW	PICP	PINAW	PICP	PINAW
MSFE	80.9524	49.7495	95.2381	71.2372	83.3333	39.7736	83.3333	58.5639
DMSFE	85.7143	48.1477	95.2381	70.4571	75.0000	38.7345	83.3333	58.3968
MAE	85.7143	52.5409	95.2381	76.0013	83.3333	42.1567	83.3333	62.2803
AIC	85.7143	40.9817	100.000	59.6289	75.0000	33.5792	83.3333	47.7874
BIC	100.000	42.5979	100.000	63.2875	83.3333	34.0671	91.6667	50.4688
EW	90.4762	56.8845	95.2381	83.1941	83.3333	45.7610	83.3333	67.9791

注：PPICP 越大代表模型能够覆盖更宽的区间，PINAW 越小代表模型能够反映更多的预测信息。

附表 4　　基于 MAE 评估准则的 MIDAS-QR-KDE 联合概率预测效果

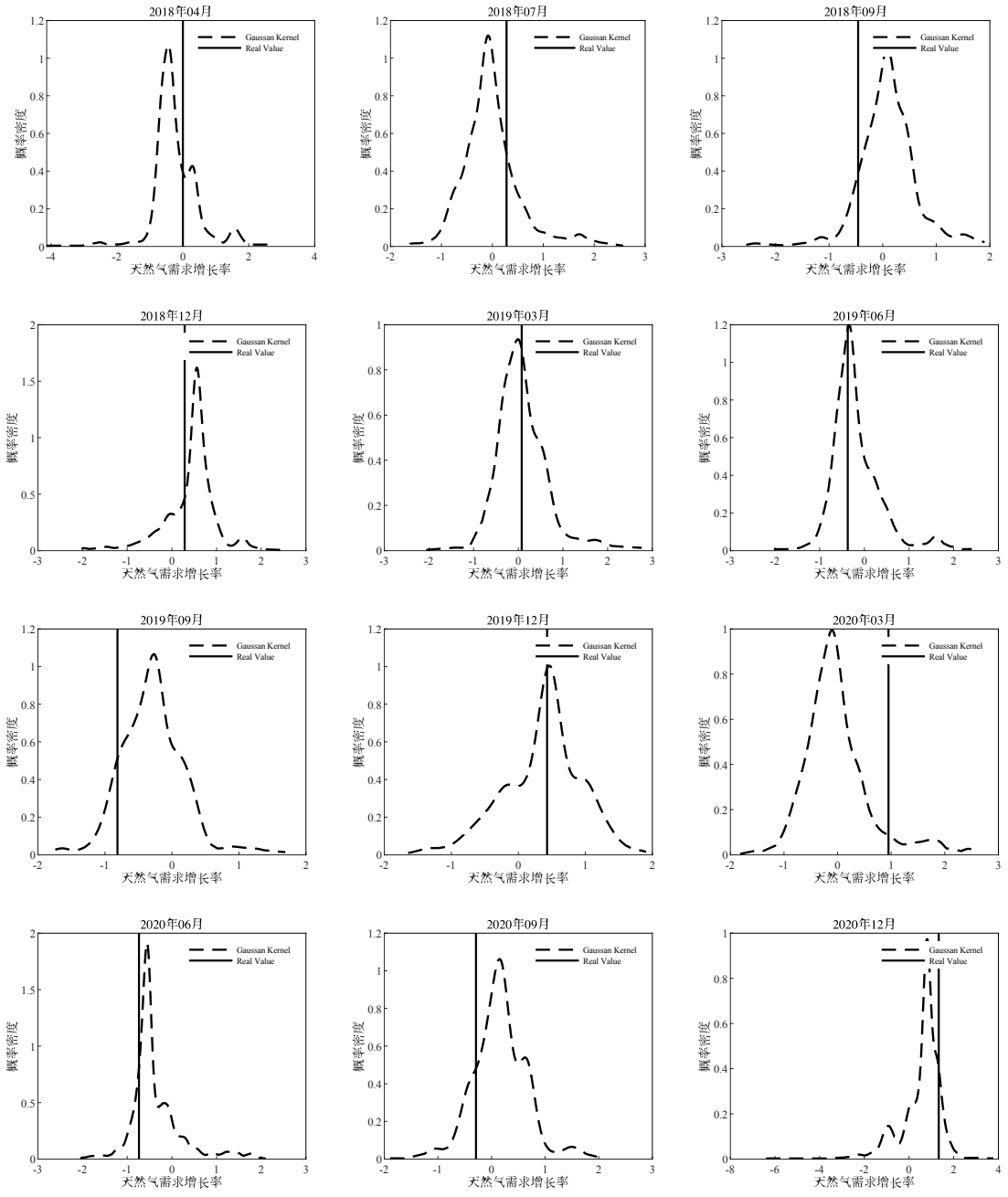
Panel A：不同驱动因子下的最优 MIDAS 模型

变量名称	最优模型	MAE
Temperature	AR(5)-Almon-MIDAS(55,4,6)	0.2998
Wind speed	AR(3)-ExpAlmon-MIDAS(10,23,8)	0.3547
Air humidity	AR(5)-BetaNN-MIDAS(33,2,3)	0.3357
Rainfall capacity	AR(3)-ExpAlmon -MIDAS(28,3,9)	0.3026
Oil spot price	AR(3)-BetaNN-MIDAS(7,2,10)	0.3350
HS 300-index	AR(3)-Umidas-MIDAS(6,6,5)	0.3752
SWS gas-index	AR(3)-ExpAlmon -MIDAS(40,3,4)	0.3753
Baidu search-index	AR(4)-Stepfun-MIDAS(33,5,0)	0.3157
Steam coal price	AR(0)-Stepfun-MIDAS(4,5,0)	0.3706

Panel B： 基于最优模型的联合概率密度预测效果

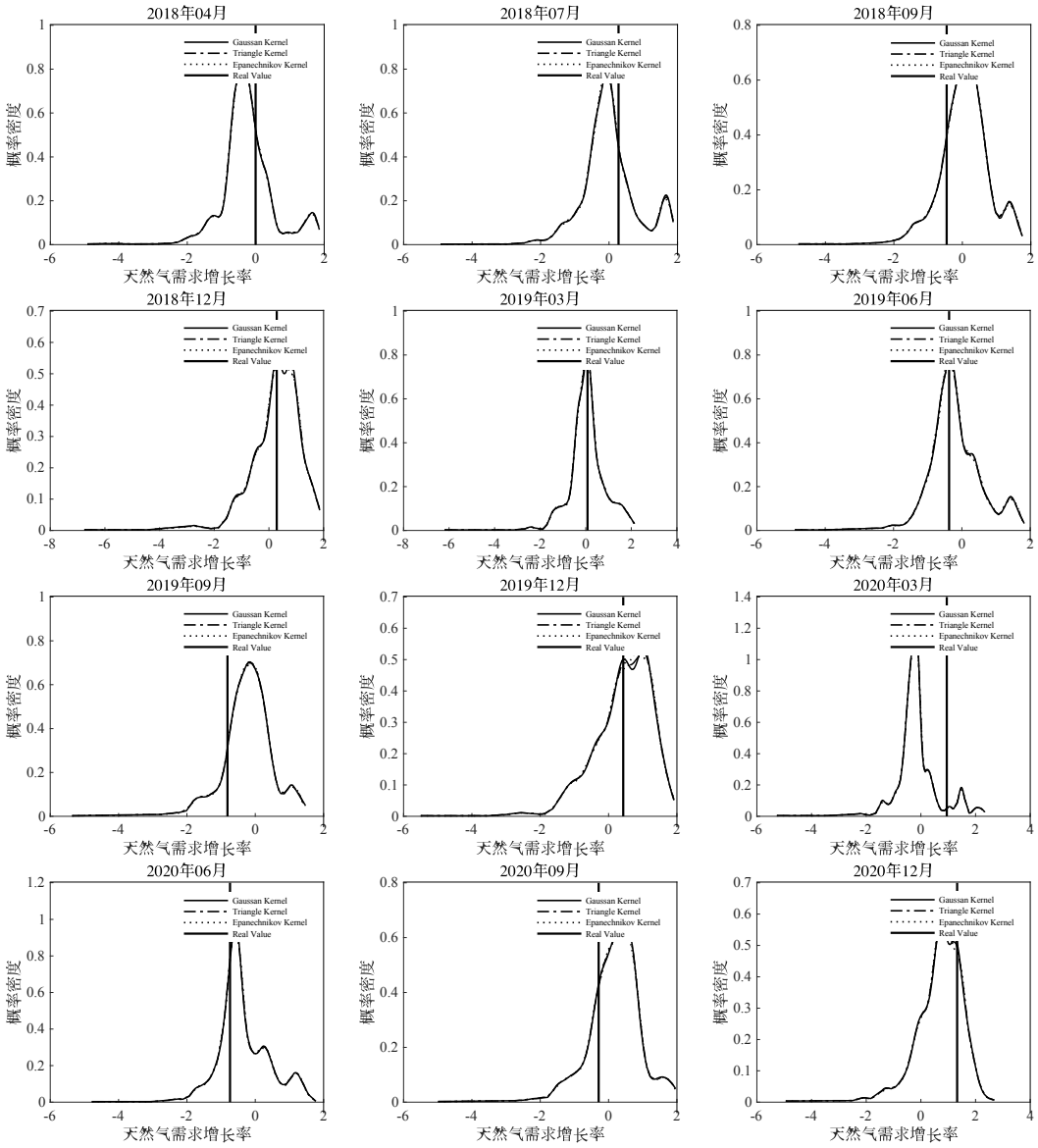
联合预测权重	MAE		
	Mode	Median	Mean
MSFE	0.4013	0.4056	0.3987
DMSFE	0.3995	0.4048	0.3957
MAE	0.4081	0.4156	0.4062
AIC	0.3663	0.3615	0.3690
BIC	**0.3580**	**0.3567**	**0.3650**
EW	0.4130	0.4226	0.4124

注：加粗体代表在不同的联合权重方案下，不同概率密度预测中所反映的最小化 MAE。



附图 1 基于 MIDAS-QR-KDE 模型的联合概率密度预测曲线

注：虚线为高斯核（Gaussan Kernel）概率密度曲线，实线所对应横坐标的值为中国实际月度天然气需求（Real Value）。



附图 2 基于 MAE 评估准则的联合概率密度预测曲线