

A Proportional Integral Controller-Enhanced Non-negative Latent Factor Analysis Model-Supplementary File

I. INTRODUCTION

This is the supplementary file for the paper entitled “*A Proportional Integral Controller-Enhanced Non-negative Latent Factor Analysis Model*”. It mainly contains the tables and figures of experimental results.

II. SUPPLEMENTARY TABLES

TABLE S(I). The comparison results on total time cost (Secs), where \circ points out that PI-NLF is outperformed by its peer.

No.	Time	D1	D2	D3	D4	D5	D6	D7	D8	Loss/Win
PI-NLF	Time(RMSE)	794.6 \pm 8.2	484.4 \pm 4.3	26.7 \pm 0.4	72.1 \pm 2.3	39.8 \pm 0.3	13.3 \pm 0.3	29.5 \pm 0.2	59.3 \pm 1.2	—
	Time(MAE)	712.1 \pm 6.7	442.3 \pm 11.7	24.2 \pm 0.8	64.7 \pm 3.17	54.4 \pm 1.1	14.5 \pm 0.5	22.2 \pm 0.2	53.6 \pm 1.8	—
NLF	Time(RMSE)	1481.8 \pm 75.3	813.3 \pm 37.4	41.8 \pm 1.1	127.6 \pm 5.6	83.4 \pm 1.7	34.3 \pm 1.1	32.1 \pm 0.3	116.5 \pm 2.1	0/16
	Time(MAE)	1401.1 \pm 88.7	804.9 \pm 66.8	48.1 \pm 1.5	115.9 \pm 3.7	82.8 \pm 0.9	26.9 \pm 0.4	27.3 \pm 0.2	106.4 \pm 0.9	0/16
PIDLF	Time(RMSE)	2531.7 \pm 98.3	1032.5 \pm 107.6	137.4 \pm 2.5	193.6 \pm 4.2	146.6 \pm 2.3	147.6 \pm 1.7	165.1 \pm 5.6	406.4 \pm 5.5	0/16
	Time(MAE)	2337.6 \pm 65.2	1066.8 \pm 97.8	142.3 \pm 3.1	176.8 \pm 5.6	147.8 \pm 1.4	120.9 \pm 2.1	146.5 \pm 3.2	378.2 \pm 6.2	0/16
VAE	Time(RMSE)	5722.2 \pm 89.3	632.0 \pm 12.8	27.9 \pm 0.9	632.2 \pm 32.4	61.4 \pm 0.4	28.2 \pm 0.6	33.2 \pm 0.7	127.3 \pm 1.1	0/16
	Time(MAE)	5831.7 \pm 106.8	597.1 \pm 21.5	26.9 \pm 0.5	597.1 \pm 28.6	64.2 \pm 0.8	29.8 \pm 1.1	34.6 \pm 0.3	126.7 \pm 1.6	0/16
SIF	Time(RMSE)	8858.7 \pm 99.4	56766.3 \pm 325.1	7582.3 \pm 110.7	4594.2 \pm 99.6	802.4 \pm 12.1	765.3 \pm 11.2	1961.3 \pm 33.9	1487.5 \pm 45.9	0/16
	Time(MAE)	8966.1 \pm 125.7	55128.1 \pm 227.9	7471.8 \pm 99.5	4722.5 \pm 57.9	794.2 \pm 9.9	778.2 \pm 15.1	1922.7 \pm 48.9	1422.8 \pm 85.2	0/16
MetaMF	Time(RMSE)	8121.4 \pm 229.2	6511.5 \pm 144.6	236.5 \pm 2.3	529.4 \pm 6.2	375.1 \pm 5.5	224.9 \pm 2.8	446.4 \pm 7.7	785.8 \pm 26.5	0/16
	Time(MAE)	8004.2 \pm 167.3	6633.7 \pm 132.8	234.2 \pm 2.9	522.1 \pm 8.8	370.8 \pm 6.1	227.5 \pm 3.6	455.2 \pm 4.4	771.2 \pm 38.2	0/16
LightGCN	Time(RMSE)	5264.1 \pm 96.1	2940.2 \pm 69.2	173.4 \pm 5.7	118.9 \pm 4.1	409.8 \pm 3.8	149.1 \pm 2.2	173.2 \pm 4.5	636.1 \pm 12.3	0/16
	Time(MAE)	5100.7 \pm 88.7	2998.8 \pm 77.1	171.5 \pm 4.9	120.5 \pm 4.2	416.6 \pm 6.3	142.4 \pm 3.6	175.6 \pm 6.2	622.7 \pm 9.9	0/16
DGCN-HN	Time(RMSE)	197924.1 \pm 511.4	67741.6 \pm 385.2	150.9 \pm 5.2	1677.9 \pm 131.8	2773.4 \pm 111.9	5400.8 \pm 309.2	645.5 \pm 35.1	327.3 \pm 12.1	0/16
	Time(MAE)	192205.4 \pm 496.5	86776.4 \pm 578.2	151.1 \pm 4.3	1814.6 \pm 142.9	2612.7 \pm 142.5	2427.1 \pm 279.5	302.6 \pm 8.9	363.8 \pm 15.5	0/16
HMLET	Time(RMSE)	146128.8 \pm 211.9	53277.9 \pm 510.9	15935.2 \pm 366.2	5923.5 \pm 205.3	4150.4 \pm 156.7	2296.2 \pm 172.3	2982.6 \pm 177.2	6939.9 \pm 366.7	0/16
	Time(MAE)	138659.2 \pm 389.2	55165.3 \pm 677.5	16262.5 \pm 412.8	5183.1 \pm 99.6	4205.7 \pm 205.2	1649.2 \pm 134.6	2544.8 \pm 98.5	8238.1 \pm 415.6	0/16
SGL	Time(RMSE)	96874.1 \pm 488.7	13357.8 \pm 177.5	3765.8 \pm 125.6	3621.8 \pm 144.5	966.4 \pm 14.2	856.6 \pm 37.4	1080.9 \pm 77.5	1978.5 \pm 85.3	0/16
	Time(MAE)	95005.2 \pm 439.5	13728.3 \pm 210.9	3960.7 \pm 77.3	3477.9 \pm 132.2	1041.9 \pm 22.9	229.4 \pm 9.5	996.5 \pm 62.3	2223.1 \pm 99.7	0/16
MGDCF	Time(RMSE)	48336.2 \pm 2.4	21712.1 \pm 4.3	35.1 \pm 0.6	179.1 \pm 1.1	66.0 \pm 0.8	167.5 \pm 3.2	42.1 \pm 0.2	2725.4 \pm 5.4	0/16
	Time(MAE)	48336.2 \pm 8.6	22355.5 \pm 4.2	49.3 \pm 0.4	213.0 \pm 2.1	62.7 \pm 1.2	144.8 \pm 4.1	21.2 \pm 0.6	2831.0 \pm 6.4	0/16
PopGo	Time(RMSE)	1026.4 \pm 4.6	1522.1 \pm 6.2	63.4 \pm 0.8	328.5 \pm 3.2	76.2 \pm 2.8	70.4 \pm 1.6	116.2 \pm 2.1	682.6 \pm 7.6	0/16
	Time(MAE)	1320.3 \pm 5.3	1836.1 \pm 7.7	82.8 \pm 1.6	153.1 \pm 4.3	98.5 \pm 2.3	114.4 \pm 1.9	119.8 \pm 3.2	742.2 \pm 5.4	0/16

TABLE S(II). The comparison results on RMSE/MAE, where \circ points out that PI-NLF is outperformed by its peer.

No.	Case	D1	D2	D3	D4	D5	D6	D7	D8	Loss/Win
PI-NLF	RMSE	0.7988 \pm 1.3E-4	0.8124 \pm 2.4E-4	1.0096 \pm 1.4E-3	0.7695 \pm 5.6E-4	0.8589 \pm 1.3E-4	0.1126 \pm 2.4E-4	0.1220 \pm 4.3E-4	0.2352 \pm 2.3E-4	—
	MAE	0.6115 \pm 2.1E-4	0.6237 \pm 3.3E-4	0.7794 \pm 2.2E-3	0.5776 \pm 4.2E-4	0.6723 \pm 2.5E-4	0.0739 \pm 3.1E-4	0.0807 \pm 2.3E-4	0.1795 \pm 1.3E-4	—
NLF	RMSE	0.8037 \pm 2.1E-4	0.8146 \pm 2.2E-4	1.0114 \pm 1.2E-3	0.7716 \pm 4.1E-4	0.8612 \pm 3.3E-4	0.1127 \pm 2.9E-4	0.1221 \pm 3.7E-4	0.2376 \pm 5.3E-4	2/14
	MAE	0.6246 \pm 2.1E-4	0.6380 \pm 5.6E-4	0.7960 \pm 8.5E-4	0.5980 \pm 3.6E-4	0.6827 \pm 2.9E-4	\circ 0.0738 \pm 2.6E-4	\circ 0.0801 \pm 2.6E-4	0.1859 \pm 3.3E-4	2/14
PIDLF	RMSE	0.8039 \pm 4.5E-4	0.8155 \pm 3.2E-4	\circ 1.0067 \pm 2.4E-3	0.7742 \pm 4.2E-4	0.8595 \pm 2.3E-4	0.1193 \pm 3.3E-4	0.1296 \pm 3.9E-4	0.2699 \pm 1.4E-4	1/15
	MAE	0.6253 \pm 1.3E-3	0.6400 \pm 5.1E-4	0.7907 \pm 6.3E-4	0.5907 \pm 2.9E-4	0.6817 \pm 4.5E-4	0.0742 \pm 3.9E-4	0.0824 \pm 5.2E-4	0.2204 \pm 2.4E-4	1/15
VAE	RMSE	0.8755 \pm 2.6E-3	0.9386 \pm 4.5E-3	1.2419 \pm 3.4E-4	0.8223 \pm 7.6E-4	0.9352 \pm 1.7E-4	\circ 0.1121 \pm 2.1E-4	0.1256 \pm 1.5E-4	0.2357 \pm 2.6E-4	1/15
	MAE	0.6821 \pm 1.4E-3	0.7671 \pm 5.7E-4	1.0299 \pm 3.4E-4	0.6261 \pm 3.9E-4	0.7388 \pm 1.4E-4	0.0741 \pm 4.3E-4	0.0858 \pm 1.9E-4	0.1899 \pm 1.9E-4	1/15
SIF	RMSE	0.8852 \pm 1.4E-4	0.8758 \pm 4.4E-4	1.1415 \pm 1.2E-3	0.8124 \pm 5.1E-4	0.9295 \pm 6.2E-4	0.1424 \pm 6.6E-4	0.1590 \pm 1.1E-4	0.2776 \pm 1.3E-3	0/16
	MAE	0.6871 \pm 2.6E-4	0.6985 \pm 5.1E-4	0.9265 \pm 4.8E-4	0.6177 \pm 4.6E-4	0.7361 \pm 4.5E-4	0.0941 \pm 4.3E-4	0.1098 \pm 1.2E-4	0.2210 \pm 1.1E-3	0/16
MetaMF	RMSE	0.8373 \pm 2.1E-4	0.8513 \pm 3.3E-4	1.0336 \pm 4.1E-4	0.7988 \pm 2.9E-4	0.8964 \pm 3.3E-4	0.1461 \pm 2.9E-4	0.1678 \pm 3.1E-4	0.2372 \pm 1.4E-4	0/16
	MAE	0.6595 \pm 1.9E-4	0.6618 \pm 3.7E-4	0.8026 \pm 2.7E-4	0.6029 \pm 4.2E-4	0.7041 \pm 1.1E-4	0.0950 \pm 2.2E-4	0.1137 \pm 1.9E-4	0.1845 \pm 2.1E-4	0/16
LightGCN	RMSE	0.7999 \pm 1.9E-4	0.8141 \pm 3.4E-4	1.0136 \pm 2.7E-4	0.7714 \pm 3.7E-4	0.8661 \pm 1.8E-4	\circ 0.1101 \pm 2.6E-4	0.1232 \pm 2.1E-4	0.2362 \pm 1.4E-4	3/13
	MAE	0.6137 \pm 2.1E-4	0.6266 \pm 1.8E-4	0.7859 \pm 3.4E-4	0.5803 \pm 2.6E-4	0.6798 \pm 1.5E-4	\circ 0.0676 \pm 2.8E-4	\circ 0.0791 \pm 3.3E-4	0.1813 \pm 3.6E-4	3/13
DGCN-HN	RMSE	0.8195 \pm 1.2E-4	0.8180 \pm 1.5E-4	1.0379 \pm 3.1E-4	0.8090 \pm 2.2E-4	0.8592 \pm 1.3E-4	\circ 0.1124 \pm 1.5E-4	0.1229 \pm 3.3E-4	0.2416 \pm 1.3E-4	2/14
	MAE	0.6291 \pm 1.3E-4	0.6341 \pm 2.3E-4	0.8118 \pm 3.1E-4	0.6041 \pm 2.9E-4	0.6726 \pm 1.5E-4	\circ 0.0735 \pm 1.1E-4	0.0809 \pm 3.2E-4	0.1870 \pm 1.2E-4	2/14
HMLET	RMSE	0.8357 \pm 0.7E-4	0.8395 \pm 1.5E-4	1.0137 \pm 1.6E-4	0.8271 \pm 2.6E-4	0.8818 \pm 2.7E-4	0.1141 \pm 1.9E-4	0.1245 \pm 2.9E-4	0.2484 \pm 2.3E-4	0/16
	MAE	0.6399 \pm 1.5E-4	0.6466 \pm 1.8E-4	0.7895 \pm 1.8E-4	0.6211 \pm 2.2E-4	0.6912 \pm 2.2E-4	0.0741 \pm 1.6E-4	0.0844 \pm 3.5E-4	0.1905 \pm 5.5E-4	0/16
SGL	RMSE	0.8177 \pm 1.7E-4	0.8141 \pm 2.5E-4	1.0223 \pm 3.2E-4	0.7832 \pm 1.4E-4	0.8607 \pm 1.2E-4	0.1351 \pm 2.9E-4	0.1442 \pm 0.6E-4	0.2505 \pm 3.3E-4	0/16
	MAE	0.6274 \pm 1.4E-4	0.6259 \pm 1.3E-4	0.7958 \pm 2.9E-4	0.5891 \pm 2.2E-4	0.6744 \pm 1.1E-4	0.0974 \pm 4.1E-4	0.1042 \pm 0.7E-4	0.1942 \pm 2.1E-4	0/16
MGDCF	RMSE	0.8538 \pm 3.2E-4	0.8248 \pm 5.1E-4	1.0646 \pm 4.1E-4	0.7973 \pm 6.2E-4	0.8664 \pm 5.1E-4	0.1149 \pm 6.2E-4	0.1338 \pm 4.9E-4	0.2392 \pm 5.7E-4	0/16
	MAE	0.6548 \pm 7.2E-4	0.6370 \pm 1.2E-4	0.8161 \pm 4.2E-4	0.5951 \pm 5.2E-4	0.6785 \pm 5.2E-4	0.0778 \pm 2.1E-4	0.0921 \pm 4.5E-4	0.1831 \pm 6.2E-4	0/16
PopGo	RMSE	0.8462 \pm 7.6E-4	0.8469 \pm 6.2E-4	1.0941 \pm 3.7E-4	0.8390 \pm 2.9E-4	0.8647 \pm 4.8E-4	0.1198 \pm 2.2E-4	0.1350 \pm 1.1E-4	0.2454 \pm 3.6E-4	0/16
	MAE	0.6497 \pm 4.4E-4	0.6629 \pm 5.7E-4	0.8811 \pm 2.2E-4	0.6484 \pm 4.8E-4	0.7215 \pm 3.5E-4	0.0830 \pm 2.9E-4	0.0901 \pm 3.5E-4	0.1864 \pm 4.8E-4	0/16

III. SUPPLEMENTARY FIGURES

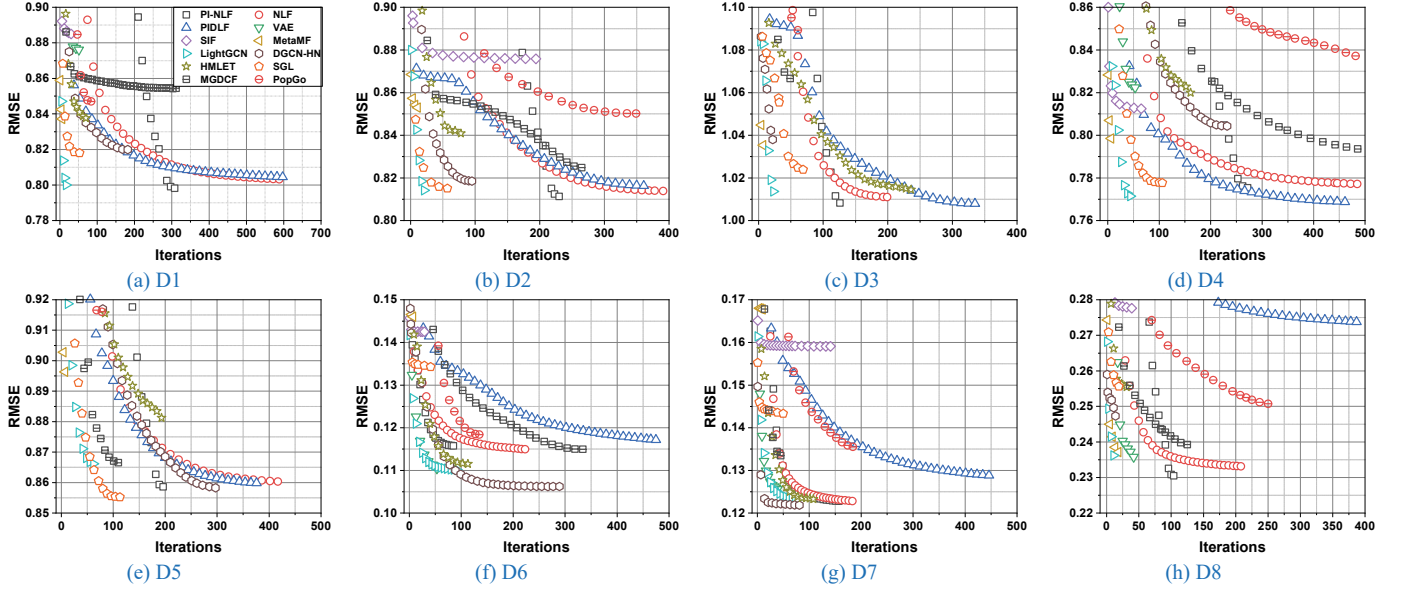


Fig. S1. Convergence curves in RMSE; all panels' legends are the same with panel (a)'s.

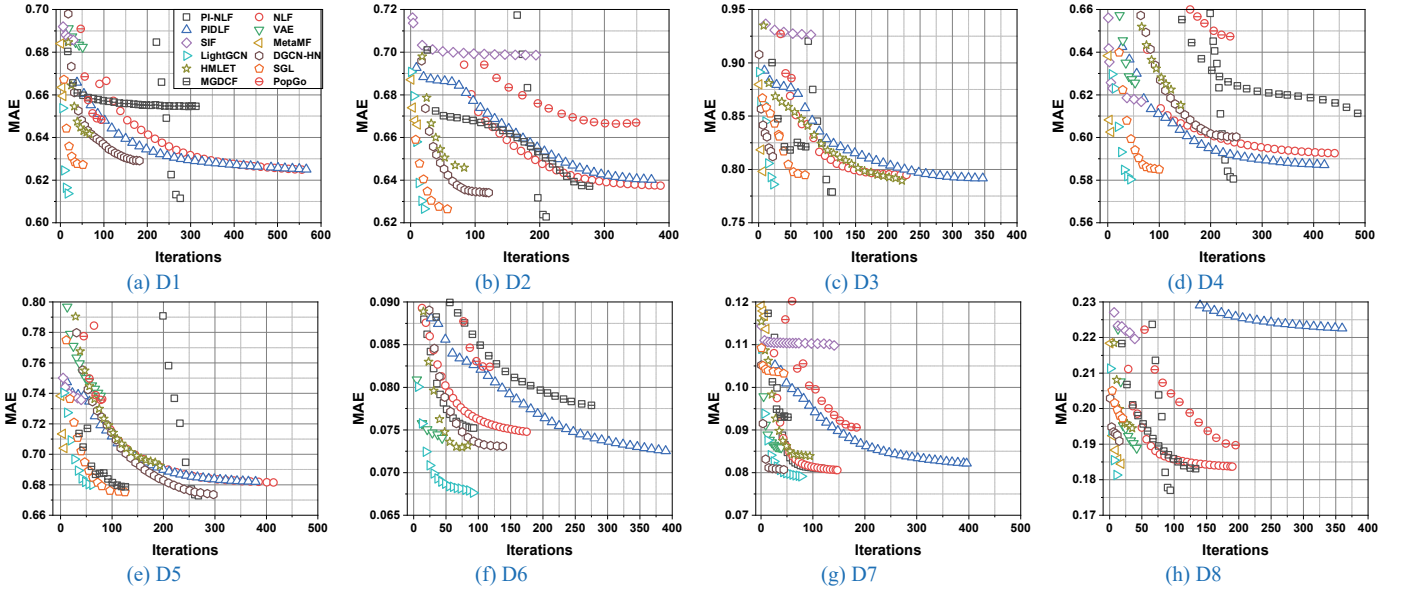
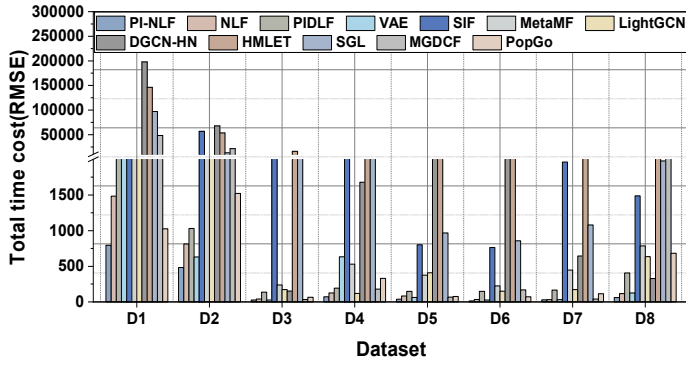
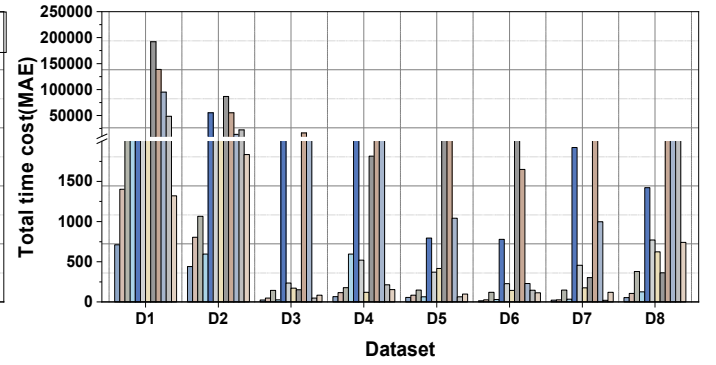


Fig. S2. Convergence curves in MAE; all panels' legends are the same with panel (a)'s.

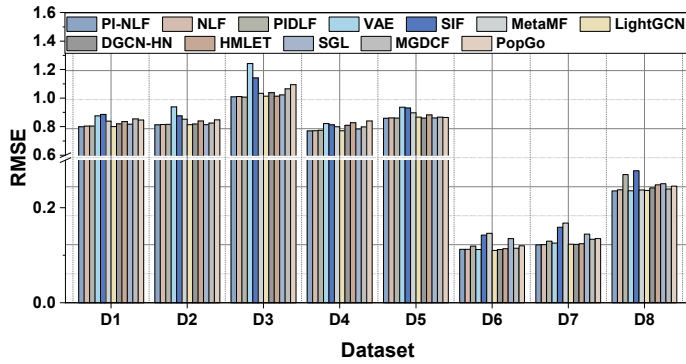


(a) Total time cost Time corresponding to RMSE

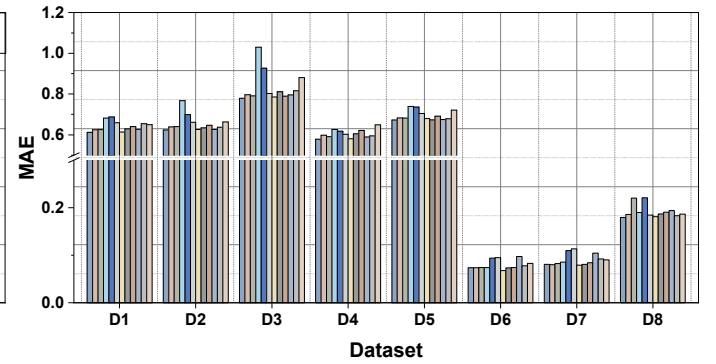


(b) Total time cost Time corresponding to MAE

Fig. S3. Total time cost of compared models; all panels' legends are the same with panel (a)'s.



(a) RMSE



(b) MAE

Fig. S4. Lowest RMSE/MAE of compared models; all panels' legends are the same with panel (a)'s.

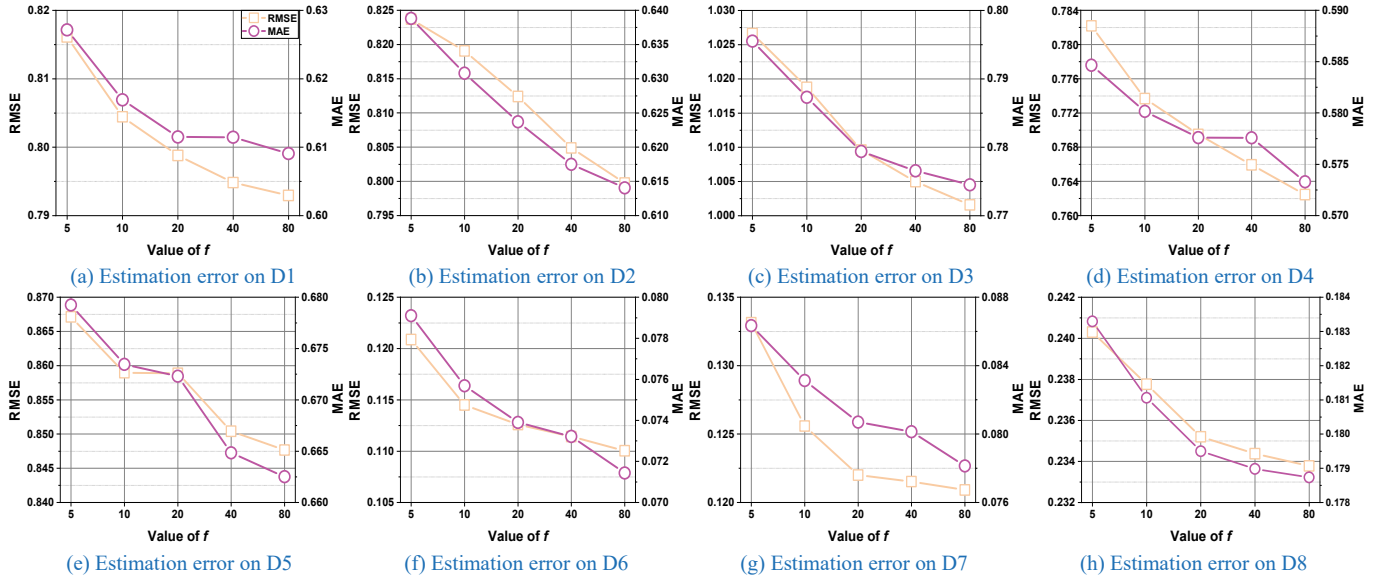


Fig. S5. PI-NLF's estimation error as f varies; all panels' legends are the same with panel (a)'s.

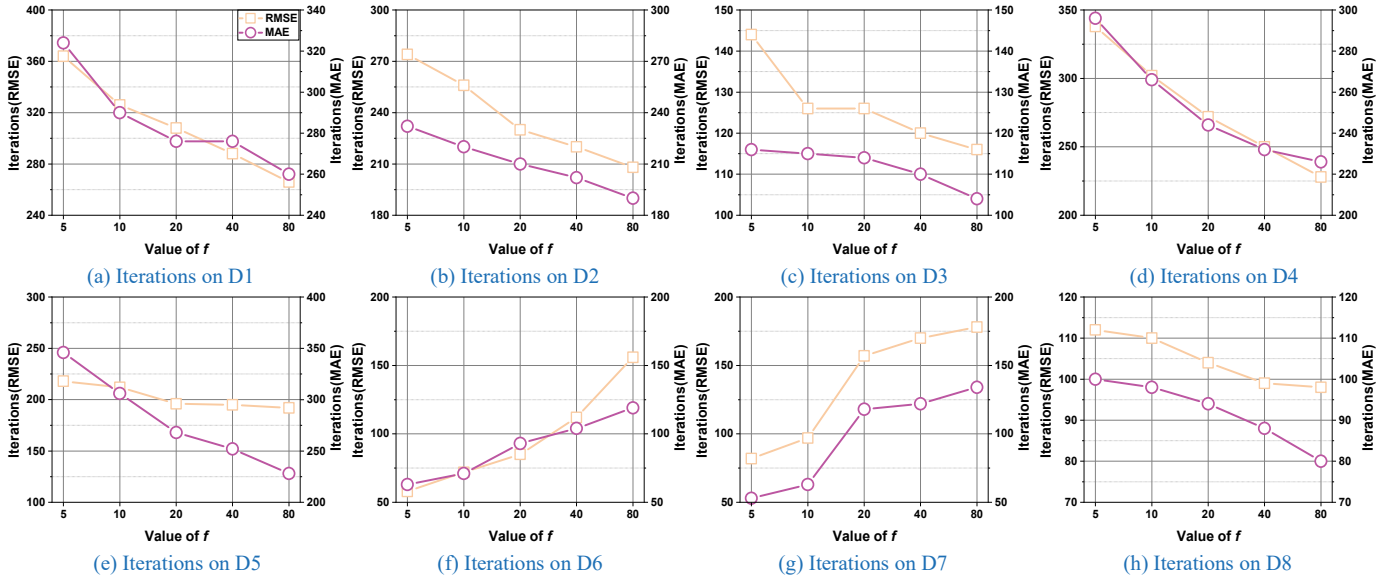


Fig. S6. PI-NLF's iterations as f varies; all panels' legends are the same with panel (a)'s.

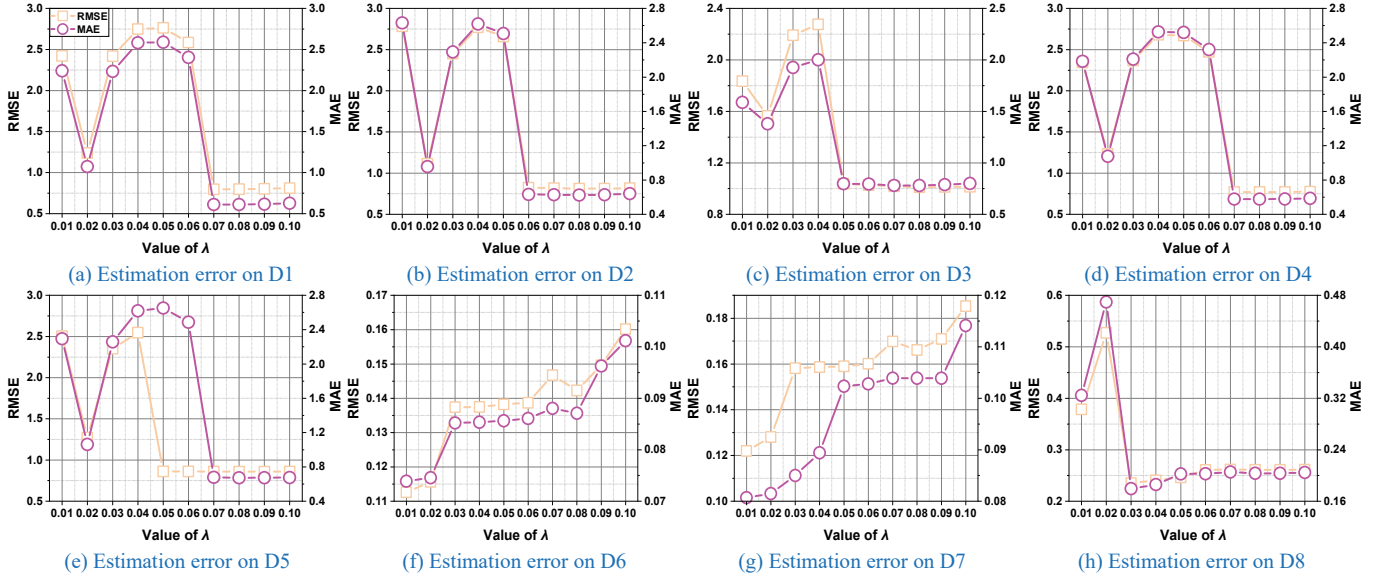


Fig. S7. PI-NLF's estimation error as λ varies; all panels' legends are the same with panel (a)'s.

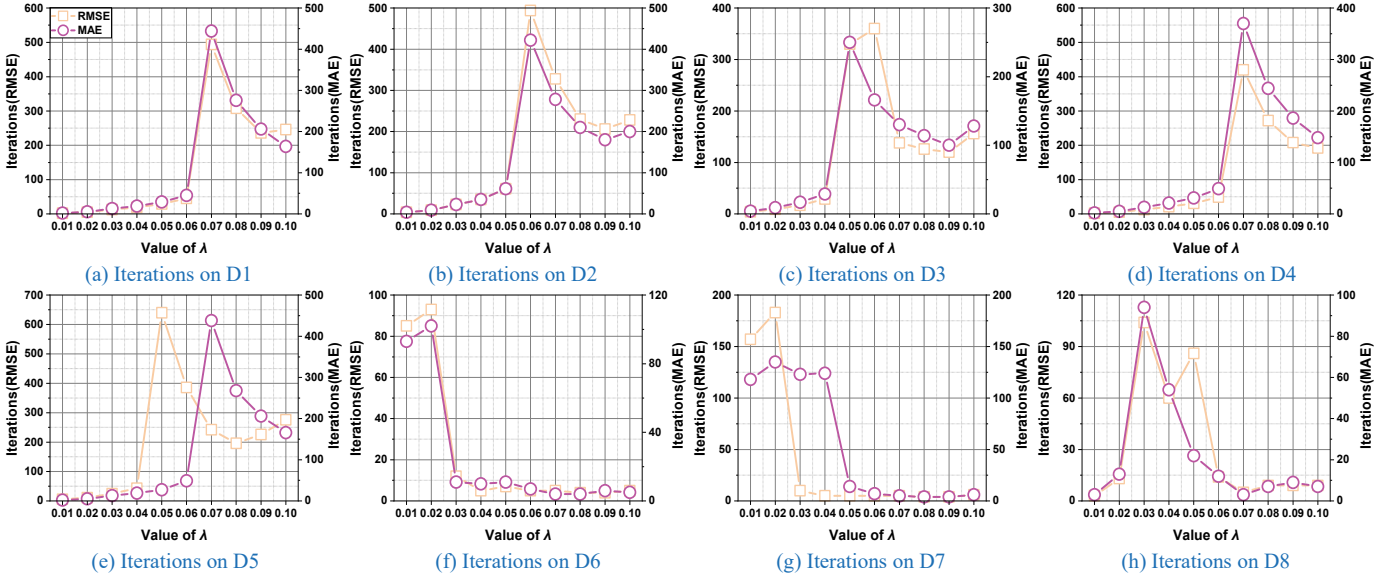


Fig. S8. PI-NLF's iterations as λ varies; all panels' legends are the same with panel (a)'s.