Supplementary Material

Double Robust, Flexible Adjustment Methods for Causal Inference: An Overview and an Evaluation

Contents

S1 Main Simulations

Table 1: Main datasets: Results of Monte Carlo simulations using the first 20 DGPs from Dorie et al. (2019), 10 replications each. Percent bias is calculated as the estimator's bias as a percentage of its standard error, rmse is root mean squared error, mae is median absolute error, and comp_time is median computation time measured in seconds for each dataset.

method	estimator	bias	percent_bias	rmse	mae	comp_time	fail_count
ols	NA	0.250	0.157	0.74	0.41	0.061	0
psm	NA	0.203	0.131	0.86	0.53	0.668	6
ipw	logit	-6.690	-1.590	8.14	6.37	0.560	0
ipw	grf	0.433	0.266	0.81	0.46	32.227	0
ipw	superlearner	0.389	0.234	0.73	0.43	130.013	0
g-comp	grf	-0.115	-0.073	0.50	0.26	32.222	0
g-comp	superlearner	0.074	0.048	0.35	0.10	130.006	0
lin	NA	0.209	0.117	0.59	0.28	0.152	0
aipw	ols_logit	-8.240	-1.547	10.06	7.63	0.555	0
aipw	grf	0.060	0.039	0.45	0.22	32.223	0
aipw	grf (pack.)	0.238	0.157	0.46	0.25	8.314	2
aipw	superlearner	0.072	0.047	0.34	0.11	130.007	0
tmle	ols_logit	-1.583	-0.676	2.27	1.47	0.575	0
tmle	grf	0.349	0.230	0.58	0.33	32.241	0
tmle	superlearner	0.073	0.047	0.34	0.10	130.027	0
dml	ols_logit	0.311	0.192	0.79	0.42	0.665	0
dml	grf	0.380	0.247	0.86	0.51	31.574	0
dml	superlearner	0.152	0.068	1.64	0.46	129.160	0
dml	superlearner (pack.)	0.284	0.167	1.12	0.52	6.991	0

S2 Linear Simulations

Table 2: Linear DGPs: Results of Monte Carlo simulations using the two datasets from Dorie et al. (2019), with linear data generating processes, 100 replications each. Percent bias is calculated as the estimator's bias as a percentage of its standard error, rmse is root mean squared error, mae is median absolute error, and comp_time is median computation time measured in seconds for each dataset.

method	estimator	bias	percent_bias	rmse	mae	comp_time	fail_count
ols	NA	-0.024	-0.017	0.39	0.123	0.058	0
psm	NA	-0.053	-0.039	0.52	0.125	0.570	12
ipw	logit	-2.383	-0.897	3.42	2.256	0.596	0
ipw	grf	0.680	0.428	0.98	0.763	30.264	0
ipw	superlearner	0.480	0.309	0.72	0.517	126.091	0
g-comp	grf	-0.343	-0.219	0.61	0.390	30.259	0
g-comp	superlearner	-0.042	-0.029	0.25	0.077	126.085	0
lin	NA	0.027	0.017	0.28	0.072	0.155	0
aipw	ols_logit	-3.435	-1.012	4.75	2.062	0.592	0
aipw	grf	-0.035	-0.024	0.40	0.228	30.261	0
aipw	grf (pack.)	0.183	0.126	0.36	0.204	8.638	0
aipw	superlearner	-0.034	-0.023	0.25	0.076	126.086	0
tmle	ols_logit	-0.536	-0.339	0.91	0.329	0.609	0
tmle	grf	0.305	0.220	0.48	0.331	30.276	0
tmle	superlearner	-0.023	-0.016	0.25	0.077	126.102	0
dml	ols_logit	0.029	0.020	0.39	0.140	0.679	0
dml	grf	0.496	0.336	0.76	0.576	28.689	0
dml	superlearner	0.098	0.069	0.44	0.228	129.669	0
dml	superlearner (pack.)	-0.008	-0.006	0.41	0.155	6.502	0

S3 Data Generating Processes

Table 3: Data generating process: Within each DGP value, estimates are sorted from lowest to highest RMSE, based on Monte Carlo simulations using the first 20 DGPs from Dorie et al. (2019), 10 replications each. Percent bias is calculated as the estimator's bias as a percentage of its standard error, rmse is root mean squared error, mae is median absolute error, and datasets shows the number of distinct datasets in the simulations with each particular DGP parameter.

DGP parameter	dgp_value	method_estimator	bias	percent_bias	rmse	mae	datasets
Alignment	0	g-comp, superl.	0.013	0.012	0.10	0.050	20
Alignment	0	aipw, superl.	0.016	0.014	0.11	0.049	20
Alignment	0	tmle, superl.	0.023	0.021	0.11	0.063	20
Alignment	0	ipw, superl.	-0.040	-0.036	0.19	0.123	20
Alignment	0	aipw, grf (pack.)	0.137	0.122	0.20	0.127	20
Alignment	0	ols	-0.085	-0.079	0.23	0.089	20
Alignment	0	lin	-0.092	-0.079	0.23	0.077	20
Alignment	0	ipw, grf	-0.029	-0.026	0.23	0.148	20
Alignment	0	dml, ols_logit	-0.038	-0.035	0.27	0.086	20
Alignment	0	dml, grf	-0.097	-0.087	0.28	0.120	20
Alignment	0	aipw, grf	-0.151	-0.146	0.29	0.077	20
Alignment	0	tmle, grf	0.065	0.063	0.30	0.139	20
Alignment	0	psm	-0.105	-0.096	0.36	0.201	20
Alignment	0	g-comp, grf	-0.295	-0.281	0.41	0.210	20
Alignment	0	dml, superl. (pack.)	-0.323	-0.228	0.73	0.195	20
Alignment	0	dml, superl.	0.322	0.213	1.34	0.156	20
Alignment	0	tmle, ols_logit	-2.140	-1.072	2.46	1.758	20
Alignment	0	ipw, logit	-8.215	-1.596	9.90	6.739	20
Alignment	0	aipw, ols_logit	-10.727	-1.707	12.63	8.951	20
Alignment	0.25	aipw, superl.	0.112	0.076	0.49	0.101	60
Alignment	0.25	tmle, superl.	0.114	0.078	0.49	0.102	60
Alignment	0.25	g-comp, superl.	0.119	0.081	0.49	0.095	60
Alignment	0.25	lin	0.020	0.011	0.51	0.270	60
Alignment	0.25	aipw, grf	0.079	0.054	0.57	0.226	60
Alignment	0.25	aipw, grf (pack.)	0.235	0.169	0.57	0.237	60
Alignment	0.25	g-comp, grf	-0.078	-0.052	0.59	0.295	60
Alignment	0.25	ipw, superl.	0.207	0.124	0.63	0.408	60
Alignment	0.25	tmle, grf	0.350	0.252	0.69	0.308	60
Alignment	0.25	ipw, grf	0.286	0.175	0.73	0.375	60
Alignment	0.25	dml, ols_logit	0.330	0.224	0.88	0.509	60
Alignment	0.25	ols	0.282	0.192	0.89	0.463	60
Alignment	0.25	dml, grf	0.335	0.243	1.00	0.500	60
Alignment	0.25	psm	0.285	0.213	1.09	0.604	60
Alignment	0.25	dml, superl. (pack.)	0.447	0.272	1.15	0.556	60
Alignment	0.25	dml, superl.	0.006	0.003	1.56	0.406	60
Alignment	0.25	tmle, ols_logit	-1.668	-0.739	2.43	1.523	60
Alignment	0.25	ipw, logit	-7.110	-1.916	8.27	6.530	60
Alignment	0.25	aipw, ols_logit	-8.714	-1.810	10.30	7.800	60
Alignment	0.75	aipw, superl.	0.061	0.037	0.27	0.113	120
Alignment	0.75	tmle, superl.	0.060	0.037	0.27	0.112	120
Alignment	0.75	g-comp, superl.	0.061	0.037	0.27	0.113	120
Alignment	0.75	aipw, grf	0.086	0.052	0.40	0.232	120
Alignment	0.75	aipw, grf (pack.)	0.256	0.157	0.44	0.283	120
Alignment	0.75	g-comp, grf	-0.103	-0.062	0.47	0.250	120

Alignment	0.75	tmle, grf	0.396	0.242	0.56	0.377	120
Alignment	0.75	lin	0.353	0.190	0.67	0.347	120
Alignment	0.75	ols	0.290	0.169	0.72	0.437	120
Alignment	0.75	psm	0.214	0.124	0.78	0.548	120
Alignment	0.75	dml, ols_logit	0.361	0.205	0.79	0.503	120
Alignment	0.75	ipw, superl.	0.552	0.324	0.83	0.550	120
Alignment	0.75	dml, grf	0.482	0.292	0.85	0.622	120
Alignment	0.75	ipw, grf	0.583	0.350	0.91	0.612	120
Alignment	0.75	dml, superl. (pack.)	0.303	0.171	1.16	0.617	120
Alignment	0.75	dml, superl.	0.196	0.080	1.73	0.518	120
Alignment	0.75	tmle, ols_logit	-1.447	-0.596	2.15	1.224	120
Alignment	0.75	ipw, logit	-6.226	-1.477	7.74	5.982	120
Alignment	0.75	aipw, ols_logit	-7.588	-1.435	9.44	7.085	120
Overlap	full	g-comp, superl.	0.047	0.024	0.12	0.047	10
Overlap	full	aipw, superl.	0.050	0.025	0.13	0.050	10
Overlap	full	tmle, superl.	0.051	0.026	0.13	0.062	10
Overlap	full	g-comp, grf	0.060	0.032	0.24	0.219	10
Overlap	full	aipw, grf (pack.)	0.197	0.104	0.27	0.237	10
Overlap	full	aipw, grf	0.191	0.101	0.27	0.258	10
Overlap	full	ols	0.237	0.120	0.51	0.411	10
Overlap	full	lin	0.359	0.182	0.52	0.410	10
Overlap	full	dml, ols_logit	0.295	0.149	0.53	0.423	10
Overlap	full	psm	0.060	0.031	0.55	0.431	10
Overlap	full	ipw, grf	0.451	0.235	0.56	0.455	10
Overlap	full	dml, grf	0.434	0.227	0.56	0.343	10
Overlap	full	dml, superl. (pack.)	0.091	0.047	0.60	0.436	10
Overlap	full	ipw, superl.	0.442	0.224	0.61	0.497	10
Overlap	full	dml, superl.	0.379	0.191	0.61	0.494	10
Overlap	full	tmle, grf	0.532	0.273	0.62	0.455	10
Overlap	full	tmle, ols_logit	-2.565	-1.467	3.10	2.578	10
Overlap	full	ipw, logit	-6.525	-1.046	9.84	8.059	10
Overlap	full	aipw, ols_logit	-7.598	-0.968	11.75	9.175	10
Overlap	one-term	aipw, superl.	0.073	0.048	0.35	0.111	190
Overlap	one-term	tmle, superl.	0.074	0.049	0.35	0.107	190
Overlap	one-term	g-comp, superl.	0.075	0.049	0.35	0.108	190
Overlap	one-term	aipw, grf	0.053	0.035	0.45	0.213	190
Overlap	one-term	aipw, grf (pack.)	0.240	0.161	0.47	0.251	190
Overlap	one-term	g-comp, grf	-0.124	-0.079	0.51	0.267	190
Overlap	one-term	tmle, grf	0.339	0.226	0.58	0.329	190
Overlap	one-term	lin	0.201	0.113	0.60	0.280	190
Overlap	one-term	ipw, superl.	0.386	0.234	0.74	0.428	190
Overlap	one-term	ols	0.251	0.160	0.75	0.413	190
Overlap	one-term	dml, ols_logit	0.312	0.194	0.80	0.423	190
Overlap	one-term	ipw, grf	0.432	0.268	0.82	0.455	190
Overlap	one-term	psm	0.210	0.137	0.87	0.531	190
Overlap	one-term	dml, grf	0.377	0.248	0.88	0.513	190
Overlap	one-term	dml, superl. (pack.)	0.294	0.174	1.14	0.532	190
Overlap	one-term	dml, superl.	0.140	0.062	1.68	0.461	190
Overlap	one-term	tmle, ols_logit	-1.531	-0.651	2.22	1.382	190
Overlap	one-term	ipw, logit	-6.699	-1.635	8.04	6.254	190
Overlap	one-term	aipw, ols_logit	-8.274	-1.595	9.96	7.607	190
Prob. of treat.	0.35	tmle, superl.	0.043	0.027	0.28	0.112	120
Prob. of treat.	0.35	aipw, superl.	0.041	0.026	0.28	0.113	120
Prob. of treat.	0.35	g-comp, superl.	0.043	0.027	0.29	0.113	120

Prob. of treat.	0.35	aipw, grf	0.016	0.010	0.42	0.235	120
Prob. of treat.	0.35	aipw, grf (pack.)	0.221	0.139	0.45	0.241	120
Prob. of treat.	0.35	g-comp, grf	-0.187	-0.114	0.51	0.298	120
Prob. of treat.	0.35	tmle, grf	0.342	0.216	0.56	0.333	120
Prob. of treat.	0.35	lin	0.164	0.089	0.61	0.275	120
Prob. of treat.	0.35	ipw, superl.	0.329	0.189	0.70	0.434	120
Prob. of treat.	0.35	ols	0.187	0.114	0.77	0.405	120
Prob. of treat.	0.35	ipw, grf	0.387	0.226	0.80	0.481	120
Prob. of treat.	0.35	dml, ols_logit	0.258	0.155	0.83	0.420	120
Prob. of treat.	0.35	dml, grf	0.368	0.222	0.83	0.549	120
Prob. of treat.	0.35	psm	0.180	0.109	0.89	0.526	120
Prob. of treat.	0.35	dml, superl. (pack.)	0.194	0.106	1.33	0.585	120
Prob. of treat.	0.35	dml, superl.	0.053	0.020	2.01	0.580	120
Prob. of treat.	0.35	tmle, ols_logit	-1.652	-0.687	2.42	1.495	120
Prob. of treat.	0.35	ipw, logit	-6.471	-1.492	8.00	5.926	120
Prob. of treat.	0.35	aipw, ols_logit	-7.958	-1.458	9.81	7.025	120
Prob. of treat.	0.65	g-comp, superl.	0.120	0.080	0.41	0.094	80
Prob. of treat.	0.65	aipw, superl.	0.118	0.079	0.41	0.097	80
Prob. of treat.	0.65	tmle, superl.	0.117	0.078	0.42	0.091	80
Prob. of treat.	0.65	aipw, grf	0.127	0.088	0.48	0.187	80
Prob. of treat.	0.65	aipw, grf (pack.)	0.262	0.186	0.49	0.266	80
Prob. of treat.	0.65	g-comp, grf	-0.007	-0.005	0.50	0.227	80
Prob. of treat.	0.65	lin	0.275	0.159	0.57	0.306	80
Prob. of treat.	0.65	tmle, grf	0.360	0.254	0.63	0.327	80
Prob. of treat.	0.65	ols	0.344	0.227	0.70	0.432	80
Prob. of treat.	0.65	dml, superl. (pack.)	0.418	0.278	0.71	0.446	80
Prob. of treat.	0.65	dml, ols_logit	0.391	0.250	0.72	0.458	80
Prob. of treat.	0.65	ipw, superl.	0.478	0.309	0.78	0.428	80
Prob. of treat.	0.65	psm	0.235	0.166	0.81	0.540	80
Prob. of treat.	0.65	dml, superl.	0.299	0.209	0.82	0.391	80
Prob. of treat.	0.65	ipw, grf	0.503	0.337	0.84	0.404	80
Prob. of treat.	0.65	dml, grf	0.398	0.297	0.91	0.446	80
Prob. of treat.	0.65	tmle, ols_logit	-1.479	-0.656	2.03	1.417	80
Prob. of treat.	0.65	ipw, logit	-7.019	-1.759	8.35	6.853	80
Prob. of treat.	0.65	aipw, ols_logit	-8.662	-1.697	10.43	8.015	80
Response surface	exponential	aipw, superl.	0.062	0.048	0.31	0.099	120
Response surface	exponential	tmle, superl.	0.062	0.048	0.31	0.097	120
Response surface	exponential	g-comp, superl.	0.066	0.051	0.32	0.095	120
Response surface	exponential	aipw, grf	0.006	0.005	0.42	0.207	120
Response surface	exponential	aipw, grf (pack.)	0.199	0.157	0.45	0.216	120
Response surface	exponential	g-comp, grf	-0.143	-0.110	0.49	0.263	120
Response surface	exponential	tmle, grf	0.277	0.221	0.53	0.256	120
Response surface	exponential	lin	0.101	0.067	0.56	0.280	120
Response surface	exponential	ipw, superl.	0.238	0.170	0.62	0.374	120
Response surface	exponential	ipw, grf	0.266	0.196	0.66	0.347	120
Response surface	exponential	ols	0.124	0.095	0.70	0.361	120
Response surface	exponential	dml, grf	0.198	0.154	0.73	0.397	120
Response surface	exponential	dml, ols_logit	0.192	0.142	0.77	0.399	120
Response surface	exponential	psm	0.118	0.095	0.81	0.504	120
Response surface	exponential	dml, superl. (pack.)	0.211	0.133	1.31	0.566	120
Response surface	exponential	dml, superl.	-0.033	-0.014	2.02	0.478	120
Response surface	exponential	tmle, ols_logit	-1.847	-0.873	2.50	1.706	120
Response surface	exponential	ipw, logit	-7.790	-1.880	9.08	7.012	120
Response surface	exponential	aipw, ols_logit	-9.305	-1.810	10.93	8.790	120

Response surface	linear	g-comp, superl.	0.083	0.040	0.41	0.107	60
Response surface	linear	aipw, superl.	0.085	0.041	0.41	0.109	60
Response surface	linear	tmle, superl.	0.088	0.043	0.41	0.109	60
Response surface	linear	aipw, grf	0.145	0.070	0.49	0.213	60
Response surface	linear	aipw, grf (pack.)	0.316	0.159	0.52	0.329	60
Response surface	linear	g-comp, grf	-0.097	-0.046	0.54	0.266	60
Response surface	linear	lin	0.290	0.124	0.59	0.226	60
Response surface	linear	tmle, grf	0.504	0.252	0.70	0.493	60
Response surface	linear	dml, superl. (pack.)	0.414	0.204	0.78	0.424	60
Response surface	linear	dml, ols_logit	0.481	0.225	0.81	0.416	60
Response surface	linear	ols	0.440	0.210	0.81	0.437	60
Response surface	linear	dml, superl.	0.438	0.215	0.83	0.396	60
Response surface	linear	ipw, superl.	0.604	0.277	0.84	0.573	60
Response surface	linear	psm	0.338	0.163	0.96	0.612	60
Response surface	linear	ipw, grf	0.739	0.349	1.00	0.679	60
Response surface	linear	dml, grf	0.740	0.376	1.09	0.780	60
Response surface	linear	tmle, ols_logit	-0.942	-0.356	1.62	0.801	60
Response surface	linear	ipw, logit	-4.581	-1.331	5.95	4.270	60
Response surface	linear	aipw, ols_logit	-6.334	-1.258	8.25	5.365	60
Response surface	step	tmle, superl.	0.088	0.080	0.32	0.107	20
Response surface	step	aipw, grf (pack.)	0.237	0.202	0.33	0.229	20
Response surface	step	aipw, superl.	0.092	0.084	0.33	0.125	20
Response surface	step	g-comp, superl.	0.094	0.086	0.33	0.124	20
Response surface	step	aipw, grf	0.129	0.107	0.45	0.255	20
Response surface	step	g-comp, grf	-0.001	-0.001	0.48	0.238	20
Response surface	step	tmle, grf	0.313	0.256	0.49	0.323	20
Response surface	step	dml, superl.	0.402	0.315	0.73	0.481	20
Response surface	step	dml, superl. (pack.)	0.333	0.283	0.74	0.640	20
Response surface	step	lin	0.611	0.456	0.79	0.717	20
Response surface	step	ols	0.435	0.350	0.79	0.748	20
Response surface	step	dml, ols_logit	0.520	0.420	0.79	0.819	20
Response surface	step	dml, grf	0.393	0.346	0.81	0.702	20
Response surface	step	psm	0.307	0.225	0.82	0.780	20
Response surface	step	ipw, superl.	0.649	0.582	0.98	0.889	20
Response surface	step	ipw, grf	0.519	0.449	1.00	0.719	20
Response surface	step	tmle, ols_logit	-1.916	-0.848	2.46	2.312	20
Response surface	step	ipw, logit	-6.420	-1.552	7.84	4.296	20
Response surface	step	aipw, ols_logit	-7.563	-1.349	9.54	5.553	20
Treat. assign.	linear	aipw, superl.	0.080	0.046	0.30	0.118	60
Treat. assign.	linear	tmle, superl.	0.085	0.049	0.30	0.123	60
Treat. assign.	linear	g-comp, superl.	0.082	0.048	0.31	0.118	60
Treat. assign.	linear	aipw, grf	0.077	0.044	0.46	0.245	60
Treat. assign.	linear	aipw, grf (pack.)	0.273	0.160	0.51	0.264	60
Treat. assign.	linear	g-comp, grf	-0.105	-0.058	0.53	0.376	60
Treat. assign.	linear	lin	-0.002	-0.001	0.53	0.133	60
Treat. assign.	linear	tmle, grf	0.327	0.192	0.55	0.333	60
Treat. assign.	linear	ols	0.064	0.036	0.66	0.298	60
Treat. assign.	linear	ipw, superl.	0.337	0.176	0.74	0.413	60
Treat. assign.	linear	dml, ols_logit	0.118	0.065	0.77	0.252	60
Treat. assign.	linear	psm	0.091	0.052	0.79	0.521	60
Treat. assign.	linear	dml, grf	0.367	0.209	0.85	0.531	60
Treat. assign.	linear	ipw, grf	0.459	0.246	0.89	0.509	60
Treat. assign.	linear	dml, superl. (pack.)	0.298	0.155	1.30	0.312	60
Treat. assign.	linear	dml, superl.	-0.340	-0.127	1.98	0.397	60

Treat. assign.	linear	tmle, ols_logit	-1.415	-0.542	2.26	0.947	60
Treat. assign.	linear	ipw, logit	-5.989	-1.306	7.40	5.890	60
Treat. assign.	linear	aipw, ols_logit	-7.375	-1.323	9.10	6.861	60
Treat. assign.	polynomial	aipw, superl.	0.064	0.042	0.36	0.099	120
Treat. assign.	polynomial	tmle, superl.	0.064	0.042	0.36	0.092	120
Treat. assign.	polynomial	g-comp, superl.	0.066	0.043	0.37	0.099	120
Treat. assign.	polynomial	aipw, grf	0.041	0.028	0.44	0.196	120
Treat. assign.	polynomial	aipw, grf (pack.)	0.220	0.150	0.46	0.251	120
Treat. assign.	polynomial	g-comp, grf	-0.139	-0.092	0.49	0.221	120
Treat. assign.	polynomial	lin	0.247	0.144	0.58	0.318	120
Treat. assign.	polynomial	tmle, grf	0.366	0.249	0.62	0.333	120
Treat. assign.	polynomial	ipw, superl.	0.372	0.232	0.68	0.418	120
Treat. assign.	polynomial	ipw, grf	0.406	0.258	0.73	0.393	120
Treat. assign.	polynomial	ols	0.312	0.200	0.78	0.412	120
Treat. assign.	polynomial	dml, ols_logit	0.374	0.235	0.79	0.503	120
Treat. assign.	polynomial	dml, grf	0.384	0.258	0.88	0.456	120
Treat. assign.	polynomial	psm	0.240	0.160	0.90	0.524	120
Treat. assign.	polynomial	dml, superl. (pack.)	0.268	0.160	1.08	0.593	120
Treat. assign.	polynomial	dml, superl.	0.355	0.168	1.56	0.526	120
Treat. assign.	polynomial	tmle, ols_logit	-1.611	-0.726	2.24	1.497	120
Treat. assign.	polynomial	ipw, logit	-7.086	-1.774	8.53	6.638	120
Treat. assign.	polynomial	aipw, ols_logit	-8.785	-1.719	10.59	8.235	120
Treat. assign.	step	tmle, superl.	0.088	0.080	0.32	0.107	20
Treat. assign.	step	aipw, grf (pack.)	0.237	0.202	0.33	0.229	20
Treat. assign.	step	aipw, superl.	0.092	0.084	0.33	0.125	20
Treat. assign.	step	g-comp, superl.	0.094	0.086	0.33	0.124	20
Treat. assign.	step	aipw, grf	0.129	0.107	0.45	0.255	20
Treat. assign.	step	g-comp, grf	-0.001	-0.001	0.48	0.238	20
Treat. assign.	step	tmle, grf	0.313	0.256	0.49	0.323	20
Treat. assign.	step	dml, superl.	0.402	0.315	0.73	0.481	20
Treat. assign.	step	dml, superl. (pack.)	0.333	0.283	0.74	0.640	20
Treat. assign.	step	lin	0.611	0.456	0.79	0.717	20
Treat. assign.	step	ols	0.435	0.350	0.79	0.748	20
Treat. assign.	step	dml, ols_logit	0.520	0.420	0.79	0.819	20
Treat. assign.	step	dml, grf	0.393	0.346	0.81	0.702	20
Treat. assign.	step	psm	0.307	0.225	0.82	0.780	20
Treat. assign.	step	ipw, superl.	0.649	0.582	0.98	0.889	20
Treat. assign.	step	ipw, grf	0.519	0.449	1.00	0.719	20
Treat. assign.	step	tmle, ols_logit	-1.916	-0.848	2.46	2.312	20
Treat. assign.	step	ipw, logit	-6.420	-1.552	7.84	4.296	20
Treat. assign.	step	aipw, ols_logit	-7.563	-1.349	9.54	5.553	20
Treat. heterogeneity	high	tmle, superl.	0.076	0.053	0.35	0.103	180
Treat. heterogeneity	high	aipw, superl.	0.076	0.053	0.36	0.106	180
Treat. heterogeneity	high	g-comp, superl.	0.080	0.056	0.36	0.106	180
Treat. heterogeneity	high	aipw, grf	0.070	0.049	0.46	0.227	180
Treat. heterogeneity	high	aipw, grf (pack.)	0.237	0.168	0.48	0.241	180
Treat. heterogeneity	high	g-comp, grf	-0.092	-0.063	0.51	0.234	180
Treat. heterogeneity	high	tmle, grf	0.337	0.241	0.58	0.330	180
Treat. heterogeneity	high	lin	0.210	0.125	0.59	0.296	180
Treat. heterogeneity	high	ipw, superl.	0.384	0.247	0.74	0.438	180
Treat. heterogeneity	high	ols	0.264	0.180	0.77	0.460	180
Treat. heterogeneity	high	dml, ols_logit	0.318	0.213	0.81	0.478	180
Treat. heterogeneity	high	ipw, grf	0.423	0.278	0.81	0.464	180
Treat. heterogeneity	high	dml, grf	0.375	0.264	0.88	0.519	180

Treat. heterogeneity	high	psm	0.210	0.148	0.90	0.587	180
Treat. heterogeneity	high	dml, superl. (pack.)	0.298	0.190	1.08	0.528	180
Treat. heterogeneity	high	dml, superl.	0.179	0.088	1.53	0.461	180
Treat. heterogeneity	high	tmle, ols_logit	-1.617	-0.730	2.27	1.497	180
Treat. heterogeneity	high	ipw, logit	-6.846	-1.692	8.23	6.526	180
Treat. heterogeneity	high	aipw, ols_logit	-8.538	-1.642	10.30	7.878	180
Treat. heterogeneity	none	g-comp, superl.	0.021	0.009	0.17	0.090	20
Treat. heterogeneity	none	aipw, superl.	0.030	0.013	0.18	0.099	20
Treat. heterogeneity	none	tmle, superl.	0.047	0.021	0.19	0.110	20
Treat. heterogeneity	none	aipw, grf	-0.024	-0.010	0.30	0.112	20
Treat. heterogeneity	none	aipw, grf (pack.)	0.239	0.107	0.31	0.264	20
Treat. heterogeneity	none	psm	0.133	0.054	0.36	0.108	20
Treat. heterogeneity	none	ols	0.127	0.052	0.38	0.142	20
Treat. heterogeneity	none	g-comp, grf	-0.321	-0.131	0.49	0.383	20
Treat. heterogeneity	none	dml, ols_logit	0.250	0.100	0.57	0.158	20
Treat. heterogeneity	none	tmle, grf	0.457	0.201	0.60	0.340	20
Treat. heterogeneity	none	lin	0.193	0.074	0.62	0.218	20
Treat. heterogeneity	none	dml, grf	0.424	0.184	0.65	0.474	20
Treat. heterogeneity	none	ipw, superl.	0.432	0.179	0.68	0.425	20
Treat. heterogeneity	none	ipw, grf	0.522	0.224	0.82	0.423	20
Treat. heterogeneity	none	dml, superl. (pack.)	0.154	0.058	1.46	0.368	20
Treat. heterogeneity	none	tmle, ols_logit	-1.270	-0.396	2.22	0.598	20
Treat. heterogeneity	none	dml, superl.	-0.096	-0.027	2.45	0.531	20
Treat. heterogeneity	none	ipw, logit	-5.289	-1.022	7.24	3.836	20
Treat. heterogeneity	none	aipw, ols_logit	-5.556	-1.012	7.49	4.052	20

S4 Sample Sizes

Table 4: Sample size: Results of Monte Carlo simulations using DGP 7 from Dorie et al. (2019) with varying sample sizes, 20 replications each. Percent bias is calculated as the estimator's bias as a percentage of its standard error, rmse is root mean squared error, mae is median absolute error, and comp_time is median computation time measured in seconds for each dataset.

method	estimator	size	bias	percent_bias	rmse	mae	comp_time	fail_count
ols	NA	150	NaN	NaN	NaN	NA	0.010	20
ols	NA	300	-0.125	-0.148	1.63	1.769	0.012	17
ols	NA	600	-0.042	-0.034	1.03	0.471	0.018	7
ols	NA	1200	0.215	0.171	0.95	0.590	0.025	0
ols	NA	2400	0.186	0.149	0.83	0.680	0.035	0
ols	NA	4802	0.186	0.150	0.79	0.692	0.061	0
ols	NA	9604	0.275	0.185	0.65	0.477	0.115	0
ols	NA	24010	0.253	0.136	0.62	0.440	0.273	0
ols	NA	48020	0.228	0.242	0.57	0.357	0.597	0
ols	NA	96040	0.183	0.121	0.52	0.314	1.090	0
psm	NA	150	NaN	NaN	NaN	NA	0.013	20
psm	NA	300	NaN	NaN	NaN	NA	0.015	20
psm	NA	600	NaN	NaN	NaN	NA	0.085	20
psm	NA	1200	0.441	0.230	0.55	0.514	0.151	17
psm	NA	2400	0.201	0.150	1.01	0.626	0.274	6
psm	NA	4802	0.174	0.137	0.93	0.761	0.579	1
psm	NA	9604	0.203	0.140	0.66	0.467	1.528	1
psm	NA	24010	0.190	0.105	0.55	0.318	7.664	1
psm	NA	48020	0.198	0.223	0.60	0.334	27.511	1
psm	NA	96040	0.128	0.093	0.37	0.165	113.044	1
ipw	logit	150	0.331	0.185	1.46	1.008	0.077	0
ipw	logit	300	-4.856	-1.395	5.99	3.923	0.098	0
ipw	logit	600	-5.981	-1.964	6.87	5.217	0.140	0
ipw	logit	1200	-7.081	-2.511	7.73	7.662	0.206	0
ipw	logit	2400	-7.201	-2.436	7.88	7.618	0.319	0
ipw	logit	4802	-7.888	-2.757	8.52	8.004	0.529	0
ipw	logit	9604	-9.370	-2.434	10.30	9.599	1.135	0
ipw	logit	24010	-6.516	-2.179	7.49	6.492	1.783	0
ipw	logit	48020	-8.914	-2.652	9.66	8.666	3.513	0
ipw	logit	96040	-8.635	-1.779	9.88	8.161	7.372	0
ipw	grf	150	0.351	0.206	1.24	0.787	1.613	0
ipw	grf	300	0.377	0.248	1.17	0.588	2.533	0
ipw	grf	600	0.351	0.248	0.99	0.421	4.428	0
ipw	grf	1200	0.425	0.303	0.99	0.552	7.752	0
ipw	grf	2400	0.334	0.241	0.79	0.576	15.160	0
ipw	grf	4802	0.320	0.240	0.69	0.492	36.832	0
ipw	grf	9604	0.244	0.148	0.60	0.268	77.877	0
ipw	grf	24010	0.299	0.162	0.59	0.294	217.183	0
ipw	grf	48020	0.172	0.143	0.56	0.390	589.802	0
ipw	grf	96040	0.128	0.077	0.34	0.182	1872.404	0
ipw	superlearner	150	0.294	0.180	1.18	0.869	10.070	0
ipw	superlearner	300	0.334	0.238	1.02	0.661	12.480	0
ipw	superlearner	600	0.367	0.264	0.98	0.451	21.676	0
ipw	superlearner	1200	0.392	0.285	0.94	0.583	37.717	0
ipw	superlearner	2400	0.342	0.255	0.76	0.519	67.716	0

ipw	superlearner	4802	0.319	0.248	0.65	0.449	125.311	0
ipw	superlearner	9604	0.249	0.152	0.56	0.157	251.578	0
ipw	superlearner	24010	0.273	0.148	0.51	0.288	623.468	0
ipw	superlearner	48020	0.103	0.090	0.46	0.322	1175.452	0
ipw	superlearner	96040	0.021	0.013	0.31	0.131	2240.567	0
g-comp	grf	150	-2.439	-1.828	2.77	2.528	1.611	0
g-comp	grf	300	-1.758	-1.177	2.08	1.951	2.531	0
g-comp	grf	600	-1.089	-0.769	1.42	1.187	4.426	0
g-comp	grf	1200	-0.634	-0.498	0.99	0.655	7.751	0
g-comp	grf	2400	-0.386	-0.324	0.71	0.378	15.157	0
g-comp	grf	4802	-0.250	-0.219	0.56	0.192	36.828	0
g-comp	grf	9604	-0.127	-0.073	0.37	0.239	77.868	0
g-comp	grf	24010	-0.079	-0.045	0.27	0.156	217.163	0
g-comp	grf	48020	-0.117	-0.115	0.24	0.103	589.773	0
g-comp	grf	96040	-0.154	-0.098	0.26	0.123	1872.343	0
g-comp	superlearner	150	-0.567	-0.385	1.33	0.607	10.035	0
g-comp	superlearner	300	-0.359	-0.283	0.89	0.528	12.479	0
g-comp	superlearner	600	-0.197	-0.157	0.75	0.293	21.673	0
g-comp	superlearner	1200	0.048	0.041	0.60	0.301	37.716	0
g-comp	superlearner	2400	0.006	0.005	0.38	0.150	67.708	0
g-comp	superlearner	4802	-0.004	-0.003	0.28	0.089	125.308	0
g-comp	superlearner	9604	0.122	0.078	0.33	0.107	251.571	0
g-comp	superlearner	24010	0.019	0.011	0.14	0.050	623.449	0
g-comp	superlearner	48020	-0.010	-0.010	0.25	0.053	1175.419	0
g-comp	superlearner	96040	0.041	0.025	0.21	0.151	2240.497	0
lin	NA	150	NaN	NaN	NaN	NA	0.011	20
lin	NA	300	-1.027	-0.557	2.93	2.322	0.011	17
lin	NA	600	0.175	0.138	1.16	0.550	0.030	7
lin	NA	1200	0.310	0.225	0.94	0.493	0.048	0
lin	NA	2400	0.255	0.184	0.73	0.540	0.078	0
lin	NA	4802	0.230	0.170	0.72	0.517	0.157	0
lin	NA	9604	0.258	0.158	0.58	0.440	0.325	0
lin	NA	24010	0.402	0.206	0.69	0.489	0.824	0
lin	NA	48020	0.111	0.112	0.51	0.354	1.646	0
lin	NA	96040	0.007	0.004	0.89	0.464	3.359	0
aipw	ols_logit	150	-0.368	-0.140	1.86	0.681	0.075	0
aipw	ols_logit	300	-6.828	-0.814	10.31	4.078	0.097	0
aipw	ols_logit	600	-6.623	-1.890	7.53	5.425	0.139	0
aipw	ols_logit	1200	-8.480	-2.252	9.23	8.810	0.204	0
aipw	ols_logit	2400	-8.606	-2.188	9.48	8.856	0.318	0
aipw	ols_logit	4802	-9.584	-2.455	10.41	10.369	0.527	0
aipw	ols_logit	9604	-11.622	-2.343	12.81	11.258	1.127	0
aipw	ols_logit	24010	-7.479	-2.309	8.59	6.902	1.772	0
aipw	ols_logit	48020	-11.523	-2.400	12.66	11.548	3.481	0
aipw	ols_logit	96040	-10.762	-1.780	12.29	9.426	7.334	0
aipw	grf	150	-0.517	-0.349	1.32	0.927	1.612	0
aipw	grf	300	-0.383	-0.285	0.98	0.581	2.532	0
aipw	grf	600	-0.290	-0.222	0.81	0.330	4.426	0
aipw	grf	1200	-0.116	-0.092	0.66	0.183	7.751	0
aipw	grf	2400	-0.086	-0.071	0.50	0.213	15.158	0
aipw	grf	4802	-0.073	-0.063	0.42	0.189	36.829	0
aipw	grf	9604	-0.035	-0.021	0.29	0.227	77.869	0
aipw	grf	24010	-0.001	-0.001	0.24	0.087	217.166	0
aipw	grf	48020	-0.075	-0.074	0.20	0.055	589.777	0

aipw	grf	96040	-0.132	-0.084	0.24	0.107	1872.350	0
aipw	grf (pack.)	150	0.161	0.104	1.20	0.919	0.148	0
aipw	grf (pack.)	300	0.137	0.100	0.95	0.623	0.337	0
aipw	grf (pack.)	600	0.067	0.052	0.77	0.361	0.699	0
aipw	grf (pack.)	1200	0.173	0.137	0.64	0.260	1.559	0
aipw	grf (pack.)	2400	0.144	0.114	0.44	0.267	3.758	0
aipw	grf (pack.)	4802	0.142	0.117	0.34	0.242	9.009	0
aipw	grf (pack.)	9604	0.161	0.102	0.25	0.217	20.465	2
aipw	grf (pack.)	24010	0.132	0.071	0.21	0.116	58.905	3
aipw	grf (pack.)	48020	0.045	0.054	0.15	0.145	139.646	7
aipw	grf (pack.)	96040	0.099	0.179	0.19	0.033	331.110	17
aipw	superlearner	150	-0.347	-0.238	1.24	0.590	10.035	0
aipw	superlearner	300	-0.283	-0.225	0.85	0.391	12.479	0
aipw	superlearner	600	-0.169	-0.133	0.77	0.268	21.674	0
aipw	superlearner	1200	0.057	0.048	0.62	0.300	37.717	0
aipw	superlearner	2400	0.011	0.009	0.38	0.149	67.708	0
aipw	superlearner	4802	-0.003	-0.002	0.27	0.081	125.308	0
aipw	superlearner	9604	0.102	0.064	0.28	0.095	251.572	0
aipw	superlearner	24010	0.023	0.013	0.14	0.050	623.451	0
aipw	superlearner	48020	-0.016	-0.016	0.20	0.050	1175.424	0
aipw	superlearner	96040	-0.020	-0.012	0.16	0.100	2240.504	0
tmle	ols_logit	150	-0.138	-0.077	1.33	0.587	0.080	0
tmle	ols_logit	300	-1.275	-0.650	2.12	0.954	0.101	0
tmle	ols_logit	600	-1.648	-0.850	2.24	1.452	0.147	0
tmle	ols_logit	1200	-1.350	-0.732	2.07	1.317	0.212	0
tmle	ols_logit	2400	-1.359	-0.653	2.04	1.065	0.327	0
tmle	ols_logit	4802	-1.283	-0.625	2.06	0.948	0.544	0
tmle	ols_logit	9604	-0.680	-0.311	1.37	1.063	1.185	0
tmle	ols_logit	24010	-1.124	-0.498	1.64	0.797	1.875	0
tmle	ols_logit	48020	-1.248	-0.622	1.94	0.923	3.693	0
tmle	ols_logit	96040	-0.864	-0.543	1.46	0.643	7.596	0
tmle	grf	150	1.186	0.693	1.81	1.649	1.615	0
tmle	grf	300	1.413	0.638	2.43	1.178	2.537	0
tmle	grf	600	0.795	0.537	1.37	0.871	4.430	0
tmle	grf	1200	0.573	0.422	0.94	0.704	7.756	0
tmle	grf	2400	0.341	0.265	0.64	0.541	15.167	0
tmle	grf	4802	0.225	0.183	0.40	0.416	36.842	0
tmle	grf	9604	0.137	0.085	0.34	0.255	77.898	0
tmle	grf	24010	0.113	0.064	0.28	0.143	217.227	0
tmle	grf	48020	-0.003	-0.003	0.16	0.071	589.889	0
tmle	grf	96040	-0.106	-0.067	0.23	0.113	1872.553	0
tmle	superlearner	150	-0.031	-0.022	1.23	0.757	10.039	0
tmle	superlearner	300	-0.110	-0.088	0.90	0.557	12.484	0
tmle	superlearner	600	-0.088	-0.070	0.81	0.303	21.679	0
tmle	superlearner	1200	0.089	0.075	0.66	0.298	37.722	0
tmle	superlearner	2400	0.030	0.023	0.40	0.150	67.717	0
tmle	superlearner	4802	0.005	0.004	0.29	0.098	125.321	0
tmle	superlearner	9604	0.086	0.054	0.26	0.091	251.605	0
tmle	superlearner	24010	0.014	0.008	0.14	0.048	623.518	0
tmle	superlearner	48020	0.002	0.002	0.14	0.058	1175.546	0
tmle	superlearner	96040	-0.140	-0.092	0.31	0.105	2240.722	0
dml	ols_logit	150	-56.640	-0.281	204.19	3.448	0.093	0
dml	ols_logit	300	-2.596	-0.162	15.70	2.425	0.140	0
dml	ols_logit	600	-0.263	-0.050	5.01	0.902	0.196	0

dml	ols_logit	1200	0.654	0.362	1.90	0.770	0.265	0
dml	ols_logit	2400	-0.291	-0.105	2.47	0.656	0.450	0
dml	ols_logit	4802	-0.098	-0.054	1.42	0.695	0.660	0
dml	ols_logit	9604	0.263	0.174	0.64	0.432	1.173	0
dml	ols_logit	24010	0.294	0.156	0.66	0.475	2.197	0
dml	ols_logit	48020	0.218	0.227	0.58	0.327	3.121	0
dml	ols_logit	96040	0.122	0.079	0.57	0.335	6.145	0
dml	grf	150	-0.444	-0.260	1.09	0.996	1.756	14
dml	grf	300	-0.270	-0.100	2.50	1.062	3.010	0
dml	grf	600	0.379	0.238	1.38	1.014	4.722	0
dml	grf	1200	0.593	0.356	1.48	0.619	8.475	0
dml	grf	2400	0.409	0.301	0.98	0.744	16.105	0
dml	grf	4802	0.423	0.306	0.96	0.626	31.840	0
dml	grf	9604	0.283	0.186	0.61	0.399	65.090	0
dml	grf	24010	0.179	0.097	0.49	0.377	174.612	0
dml	grf	48020	0.227	0.223	0.54	0.368	391.386	0
dml	grf	96040	0.188	0.119	0.32	0.210	855.111	0
dml	superlearner	150	-1.382	-0.229	5.75	1.051	9.933	0
dml	superlearner	300	0.366	0.206	1.76	1.072	18.926	0
dml	superlearner	600	1.394	0.356	3.98	0.898	23.790	0
dml	superlearner	1200	1.884	0.427	4.73	0.884	40.678	0
dml	superlearner	2400	1.729	0.423	4.38	1.166	75.058	0
dml	superlearner	4802	1.672	0.456	3.96	1.027	129.318	0
dml	superlearner	9604	0.110	0.062	1.15	0.586	242.361	0
dml	superlearner	24010	-0.081	-0.037	1.31	0.630	574.176	0
dml	superlearner	48020	-0.107	-0.028	3.49	0.573	1105.293	0
dml	superlearner	96040	-0.092	-0.041	1.33	0.340	2218.412	0
dml	superlearner (pack.)	150	-1.112	-0.270	3.91	1.089	4.937	0
dml	superlearner (pack.)	300	-0.896	-0.300	2.93	1.103	5.333	0
dml	superlearner (pack.)	600	-0.941	-0.270	3.41	0.921	6.215	0
dml	superlearner (pack.)	1200	-0.864	-0.262	3.15	0.812	5.721	0
dml	superlearner (pack.)	2400	-0.932	-0.281	3.17	0.848	5.805	0
dml	superlearner (pack.)	4802	-0.997	-0.288	3.33	0.875	6.940	0
dml	superlearner (pack.)	9604	0.240	0.147	0.87	0.505	9.498	0
dml	superlearner (pack.)	24010	0.276	0.137	1.01	0.522	19.652	0
dml	superlearner (pack.)	48020	0.365	0.146	2.59	0.489	36.202	0
dml	superlearner (pack.)	96040	0.344	0.197	1.65	0.476	69.661	0