

Results of \tilde{T} -test on the Eight Models' Contribution Performance

The results of \tilde{T} -test[1] on contribution performance of the eight models are shown below, i.e., tables on the left. Note that $p\text{-value} < 0.05$ means the two models are different significantly on a specific dimension. The \tilde{T} -graphs[2] are on the right, where an edge from node A to node B if A tends to have higher values for a given metric than B (i.e., for the comparison A–B, \tilde{T} -test reports $p < 0.05$). \tilde{T} -graph omits direct edges between A and B if there is a path from A to B passing through at least one other node. Consider the example \tilde{T} -graph from Figure 1, summarizing the results of the \tilde{T} -test applied to four groups of values A, B, C and D: D tends to have higher values than both B and C, but lower than A; A tends to have higher values than all other groups (D directly, B and C transitively).

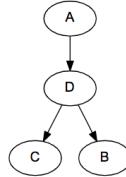


Fig. 1: Example \tilde{T} -graph

1. Contribution intensity

a) Contribution intensity at OpenStack level (CI^0)

i. Commit aspect:

-----Analysis-----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.230	-0.019	0.452	2.997	8.484739e-02
FSO - CO	0.454	0.292	0.590	8.405	1.018844e-06
RO - CO	-0.034	-0.206	0.141	-0.621	9.977390e-01
SBO - CO	0.232	0.062	0.389	4.412	3.387745e-03
SSO - CO	0.235	0.051	0.403	4.132	6.582521e-03
SsSo - CO	0.313	0.140	0.468	5.743	1.769058e-04
UO - CO	0.301	0.134	0.450	5.747	1.479984e-04
FSO - DIV	0.224	0.029	0.402	3.717	1.752240e-02
RO - DIV	-0.263	-0.448	-0.058	-4.133	6.555102e-03
SBO - DIV	0.003	-0.194	0.199	0.042	1.000000e+00
SSO - DIV	0.005	-0.204	0.214	0.075	1.000000e+00
SsSo - DIV	0.083	-0.122	0.282	1.319	8.654471e-01
UO - DIV	0.071	-0.127	0.263	1.155	9.261673e-01
RO - FSO	-0.487	-0.560	-0.407	-17.163	0.000000e+00
SBO - FSO	-0.221	-0.295	-0.144	-9.184	5.472254e-09
SSO - FSO	-0.219	-0.318	-0.115	-6.739	1.223501e-05
SsSo - FSO	-0.140	-0.226	-0.053	-5.180	4.450793e-04
UO - FSO	-0.153	-0.226	-0.078	-6.605	8.340795e-06
SBO - RO	0.266	0.181	0.347	9.883	1.805653e-09
SSO - RO	0.268	0.153	0.376	7.411	3.456538e-06
SsSo - RO	0.347	0.250	0.437	10.981	2.139404e-10
UO - RO	0.334	0.249	0.414	12.075	5.051515e-13
SSO - SBO	0.002	-0.108	0.112	0.069	1.000000e+00
SsSo - SBO	0.081	-0.014	0.174	2.782	1.305287e-01
UO - SBO	0.068	-0.013	0.149	2.716	1.474544e-01
SsSo - SSO	0.079	-0.041	0.196	2.129	3.940542e-01
UO - SSO	0.066	-0.043	0.173	1.955	4.967745e-01
UO - SsSo	-0.013	-0.105	0.080	-0.448	9.997243e-01

-----Overall-----	
Quantile	p.Value
1	3.2461 0

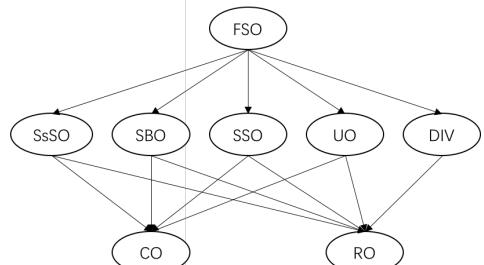


Fig. 2: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CI^0 in commit term

ii. Developer aspect:

-----Analysis-----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.175	-0.042	0.376	2.636	1.742653e-01
FSO - CO	0.460	0.299	0.596	8.575	1.197460e-07
RO - CO	0.007	-0.168	0.182	0.137	9.999999e-01
SBO - CO	0.208	0.042	0.363	4.059	8.057988e-03
SSO - CO	0.188	0.003	0.361	3.305	4.507325e-02
SsSo - CO	0.304	0.130	0.460	5.583	2.347029e-04
UO - CO	0.324	0.159	0.472	6.233	4.363421e-05
FSO - DIV	0.286	0.134	0.425	6.006	8.945291e-05
RO - DIV	-0.167	-0.334	0.010	-3.083	7.234086e-02
SBO - DIV	0.033	-0.126	0.191	0.679	9.961712e-01
SSO - DIV	0.013	-0.165	0.191	0.241	9.999960e-01
SsSo - DIV	0.129	-0.037	0.289	2.531	2.100093e-01
UO - DIV	0.150	-0.008	0.300	3.100	6.973620e-02
RO - FSO	-0.453	-0.545	-0.351	-13.041	1.186273e-12
SBO - FSO	-0.252	-0.330	-0.172	-9.931	3.238057e-09
SSO - FSO	-0.272	-0.378	-0.160	-7.720	2.706059e-07
SsSo - FSO	-0.156	-0.242	-0.068	-5.723	1.597807e-04
UO - FSO	-0.136	-0.207	-0.063	-6.080	6.462504e-05
SBO - RO	0.201	0.089	0.308	5.789	1.424257e-04
SSO - RO	0.181	0.042	0.312	4.242	5.112074e-03
SsSo - RO	0.297	0.177	0.408	7.828	3.550347e-06
UO - RO	0.317	0.210	0.417	9.256	3.088685e-08
SSO - SBO	-0.020	-0.140	0.100	-0.544	9.990551e-01
SsSo - SBO	0.096	-0.004	0.194	3.118	6.730765e-02
UO - SBO	0.116	0.030	0.200	4.395	3.506872e-03
SsSo - SSO	0.116	-0.013	0.241	2.939	9.750354e-02
UO - SSO	0.136	0.019	0.250	3.784	1.517241e-02
UO - SsSo	0.020	-0.074	0.114	0.697	9.955247e-01

#-----Overall-----	
Quantile	p.Value
1	3.258218 1.186273e-12

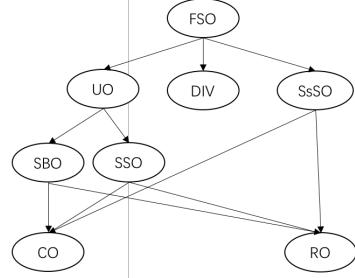


Fig. 3: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CI^0 in developer term

As shown in Figure 2 and 3, companies in FSO model contribute commits and developers to the overall OpenStack, more than any of the other models. On the contrary, research or community oriented companies make fewer contributions (commits and developers) to OpenStack than any of the other models. And other models' contributions are in the middle. These findings are consistent with the results shown in Table 5 in our paper.

b) Contribution intensity at project type level (CI^T)

i. Commit aspect:

-----Analysis-----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.176	-0.086	0.416	2.198	3.582714e-01
FSO - CO	0.398	0.212	0.556	6.675	7.807685e-06
RO - CO	-0.016	-0.206	0.176	-0.266	9.999918e-01
SBO - CO	0.232	0.042	0.405	3.965	1.029249e-02
SSO - CO	0.192	-0.011	0.380	3.086	7.183871e-02
SsSo - CO	0.370	0.175	0.537	5.981	5.870169e-05
UO - CO	0.246	0.058	0.417	4.230	5.353807e-03
FSO - DIV	0.221	0.022	0.404	3.606	2.316311e-02
RO - DIV	-0.192	-0.387	0.019	-2.971	9.103499e-02
SBO - DIV	0.055	-0.145	0.252	0.894	9.805461e-01
SSO - DIV	0.016	-0.197	0.227	0.237	9.999963e-01
SsSo - DIV	0.194	-0.015	0.386	3.021	8.243191e-02
UO - DIV	0.070	-0.132	0.265	1.123	9.356639e-01
RO - FSO	-0.413	-0.495	-0.324	-13.887	1.432188e-14
SBO - FSO	-0.166	-0.241	-0.089	-7.004	1.082903e-05
SSO - FSO	-0.206	-0.307	-0.099	-6.236	4.069317e-05
SsSo - FSO	-0.028	-0.116	0.061	-1.015	9.613867e-01
UO - FSO	-0.152	-0.227	-0.075	-6.386	2.502474e-05
SBO - RO	0.247	0.156	0.335	8.618	6.105484e-08
SSO - RO	0.208	0.086	0.323	5.527	2.3606484e-04
SsSo - RO	0.386	0.282	0.481	11.336	2.007892e-10
UO - RO	0.262	0.169	0.350	8.954	1.705630e-08
SSO - SBO	-0.040	-0.149	0.071	-1.171	9.215552e-01
SsSo - SBO	0.138	0.044	0.230	4.789	1.406912e-03
UO - SBO	0.014	-0.066	0.094	0.579	9.985561e-01
SsSo - SSO	0.178	0.057	0.293	4.788	1.366929e-03
UO - SSO	0.054	-0.056	0.163	1.590	7.248233e-01
UO - SsSo	-0.124	-0.216	-0.030	-4.278	5.015371e-03

#-----Overall-----	
Quantile	p.Value
1	3.258898 1.432188e-14

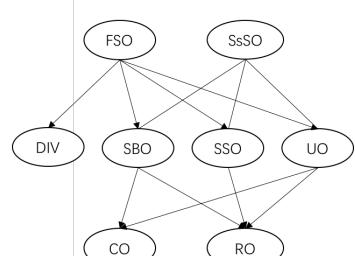


Fig. 4: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CI^T in commit term

ii. Developer aspect:

#----Analysis----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.095	-0.143	0.323	1.300	8.747855e-01
FSO - CO	0.380	0.200	0.535	6.632	2.349621e-05
RO - CO	-0.012	-0.201	0.177	-0.207	9.999986e-01
SBO - CO	0.228	0.045	0.396	4.049	8.559524e-03
SSO - CO	0.138	-0.061	0.327	2.269	3.239210e-01
SsSo - CO	0.359	0.170	0.522	6.014	7.118314e-05
UO - CO	0.239	0.057	0.406	4.271	5.095680e-03
FSO - DIV	0.285	0.111	0.442	5.279	4.40003e-04
RO - DIV	-0.107	-0.292	0.085	-1.822	5.831934e-01
SBO - DIV	0.133	-0.045	0.302	2.435	2.479344e-01
SSO - DIV	0.043	-0.152	0.236	0.717	9.945959e-01
SsSo - DIV	0.264	0.081	0.429	4.661	2.012080e-03
UO - DIV	0.144	-0.033	0.313	2.657	1.682862e-01
RO - FSO	-0.392	-0.486	-0.290	-11.649	2.541956e-11
SBO - FSO	-0.152	-0.229	-0.074	-6.333	3.567505e-05
SSO - FSO	-0.242	-0.350	-0.127	-6.755	1.291049e-05
SsSo - FSO	-0.021	-0.108	0.065	-0.808	9.891331e-01
UO - FSO	-0.141	-0.216	-0.064	-5.976	1.123784e-04
SBO - RO	0.240	0.132	0.342	7.169	1.273772e-05
SSO - RO	0.150	0.014	0.282	3.591	2.436364e-02
SsSo - RO	0.371	0.256	0.475	9.958	5.895308e-09
UO - RO	0.251	0.145	0.352	7.556	8.985192e-07
SSO - SBO	-0.089	-0.206	0.030	-2.442	2.451180e-01
SsSo - SBO	0.131	0.037	0.222	4.549	2.643060e-03
UO - SBO	0.012	-0.071	0.094	0.459	9.996837e-01
SSo - SSO	0.220	0.093	0.340	5.604	1.948341e-04
UO - SSO	0.101	-0.018	0.217	2.776	1.346586e-01
UO - SsSo	-0.119	-0.210	-0.027	-4.205	6.076442e-03

#----Overall----	
Quantile	p.Value
1	3.265349 2.541956e-11

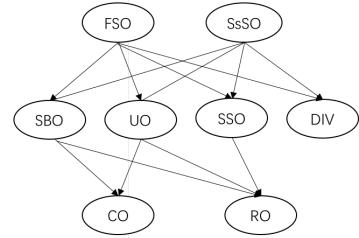


Fig. 5: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CI^T in developer term

As shown in Figure 4 and 5, companies in FSO and SsSO models tend to contribute commits and developers to a specific types of projects in OpenStack, more than any of the other models. Although the FSO model's median value of CI^T is larger than SsSO model's, there is no significant difference between the two distributions. Similar to CI^0 aspect, research or community oriented companies make fewer contributions (commits and developers) to OpenStack's project types than any of the other models. And other models are in the middle. These findings add more details to the results shown in our paper.

c) Contribution intensity at project level (CI^P)

i. Commit aspect:

#----Analysis----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.322	0.071	0.535	4.135	6.492753e-03
FSO - CO	0.214	0.042	0.374	4.039	8.441647e-03
RO - CO	-0.043	-0.233	0.149	-0.729	9.942459e-01
SBO - CO	0.061	-0.116	0.234	1.116	9.394933e-01
SSO - CO	0.068	-0.122	0.253	1.159	9.273361e-01
SsSo - CO	0.189	-0.001	0.367	3.239	5.238110e-02
UO - CO	0.111	-0.064	0.280	2.068	4.344805e-01
FSO - DIV	-0.107	-0.290	0.083	-1.843	5.725789e-01
RO - DIV	-0.365	-0.547	-0.150	-5.391	2.697444e-04
SBO - DIV	-0.261	-0.439	-0.063	-4.261	4.927687e-03
SSO - DIV	-0.254	-0.442	-0.044	-3.929	1.089003e-02
SsSo - DIV	-0.132	-0.326	0.072	-2.108	4.113269e-01
UO - DIV	-0.211	-0.391	-0.015	-3.496	2.952374e-02
RO - FSO	-0.258	-0.363	-0.146	-7.360	1.141600e-06
SBO - FSO	-0.154	-0.234	-0.071	-6.027	9.187818e-05
SSO - FSO	-0.147	-0.247	-0.043	-4.581	2.167096e-03
SsSo - FSO	-0.025	-0.131	0.082	-0.759	9.926918e-01
UO - FSO	-0.103	-0.180	-0.025	-4.309	4.377596e-03
SBO - RO	0.104	-0.012	0.218	2.917	1.018717e-01
SSO - RO	0.111	-0.022	0.241	2.717	1.503514e-01
SsSo - RO	0.233	0.096	0.361	5.492	2.507704e-04
UO - RO	0.155	0.040	0.265	4.388	3.392860e-03
SSO - SBO	0.007	-0.102	0.116	0.213	9.999984e-01
SsSo - SBO	0.129	0.015	0.239	3.692	1.893936e-02
UO - SBO	0.050	-0.035	0.135	1.918	5.253077e-01
SsSo - SSO	0.122	-0.009	0.248	3.035	8.025284e-02
UO - SSO	0.043	-0.063	0.149	1.323	8.675035e-01
UO - SsSo	-0.078	-0.187	0.032	-2.303	3.081169e-01

#----Overall----	
Quantile	p.Value
1	3.257435 1.1416e-06

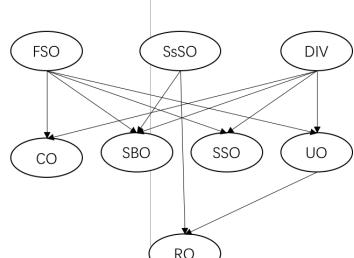


Fig. 6: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CI^P in commit term

ii. Developer aspect:

#----Analysis----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.191	-0.064	0.422	2.447	2.428820e-01
FSO - CO	0.081	-0.076	0.234	1.680	6.744361e-01
RO - CO	-0.106	-0.278	0.073	-1.924	5.218606e-01
SBO - CO	-0.067	-0.225	0.094	-1.360	8.510880e-01
SSO - CO	0.024	-0.159	0.205	0.424	9.998194e-01
SsSo - CO	0.061	-0.114	0.233	1.130	9.356796e-01
UO - CO	0.027	-0.133	0.184	0.540	9.991132e-01
FSO - DIV	-0.110	-0.312	0.102	-1.685	6.718491e-01
RO - DIV	-0.296	-0.500	-0.062	-4.085	7.233164e-03
SBO - DIV	-0.258	-0.454	-0.038	-3.807	1.448514e-02
SSO - DIV	-0.167	-0.382	0.066	-2.337	2.918958e-01
SsSo - DIV	-0.130	-0.342	0.095	-1.879	5.487759e-01
UO - DIV	-0.164	-0.366	0.052	-2.475	2.321219e-01
RO - FSO	-0.187	-0.293	-0.076	-5.444	2.416397e-04
SBO - FSO	-0.148	-0.229	-0.065	-5.801	8.635421e-05
SSO - FSO	-0.057	-0.175	0.063	-1.550	7.520488e-01
SsSo - FSO	-0.020	-0.127	0.087	-0.611	9.980632e-01
UO - FSO	-0.055	-0.132	0.023	-2.283	3.174350e-01
SBO - RO	0.039	-0.078	0.154	1.074	9.498759e-01
SSO - RO	0.130	-0.017	0.271	2.884	1.090832e-01
SsSo - RO	0.167	0.030	0.297	3.961	1.007581e-02
UO - RO	0.132	0.018	0.244	3.751	1.657998e-02
SSO - SBO	0.091	-0.035	0.214	2.361	2.808816e-01
SsSo - SBO	0.128	0.014	0.239	3.645	2.132071e-02
UO - SBO	0.094	0.006	0.180	3.476	3.095568e-02
SsSo - SSO	0.037	-0.106	0.178	0.842	9.866159e-01
UO - SSO	0.003	-0.120	0.125	0.067	1.000000e+00
UO - SsSo	-0.034	-0.145	0.077	-1.007	9.640757e-01

#----Overall----	
Quantile	p.Value
1	3.255274 8.635421e-05

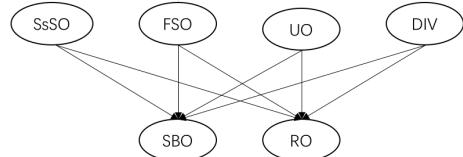


Fig. 7: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CI^P in developer term

As shown in Figure 6 and 7, companies in FSO, SsSO, DIV, and UO (only in developer term) models tend to make contributions to a specific project in OpenStack, more than SBO and RO models. However, there are less statistical differences among SBO, SSO, and CO models. The reason might be the existence of several other factors, e.g., a company's size and domain, which also affect its contribution performance in an OSS ecosystem.

2. Contribution extent

a) Contribution extent at project type level (CE^T)

#----Analysis----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	-0.005	-0.179	0.170	-0.090	1.000000e+00
FSO - CO	0.498	0.362	0.614	10.593	9.275458e-11
RO - CO	0.073	-0.094	0.237	1.424	8.190826e-01
SBO - CO	0.241	0.094	0.377	5.286	3.154141e-04
SSO - CO	0.197	0.035	0.349	3.946	1.042418e-02
SsSo - CO	0.326	0.176	0.461	6.871	4.331660e-06
UO - CO	0.302	0.157	0.434	6.605	7.493667e-06
FSO - DIV	0.503	0.388	0.603	12.491	2.426948e-13
RO - DIV	0.078	-0.072	0.225	1.694	6.649727e-01
SBO - DIV	0.245	0.120	0.363	6.277	2.256946e-05
SSO - DIV	0.202	0.059	0.337	4.575	2.151792e-03
SsSo - DIV	0.331	0.202	0.449	8.026	1.517383e-07
UO - DIV	0.306	0.182	0.421	7.785	8.286843e-07
RO - FSO	-0.425	-0.524	-0.315	-11.564	9.115819e-12
SBO - FSO	-0.258	-0.329	-0.183	-10.964	2.407619e-11
SSO - FSO	-0.301	-0.392	-0.204	-9.738	6.850996e-10
SsSo - FSO	-0.172	-0.250	-0.091	-6.896	8.401176e-06
UO - FSO	-0.197	-0.267	-0.124	-8.670	2.093170e-08
SBO - RO	0.167	0.047	0.282	4.523	2.614361e-03
SSO - RO	0.124	-0.013	0.256	2.949	9.422296e-02
SsSo - RO	0.253	0.128	0.370	6.460	2.508521e-05
UO - RO	0.228	0.109	0.341	6.158	4.437741e-05
SSO - SBO	-0.043	-0.149	0.064	-1.311	8.715245e-01
SsSo - SBO	0.086	-0.006	0.176	3.045	7.781608e-02
UO - SBO	0.061	-0.024	0.145	2.340	2.899664e-01
SsSo - SSO	0.129	0.015	0.239	3.686	1.888900e-02
UO - SSO	0.104	-0.003	0.209	3.175	5.895475e-02
UO - SsSo	-0.025	-0.115	0.066	-0.881	9.823851e-01

#----Overall----	
Quantile	p.Value
1	3.254197 2.426948e-13

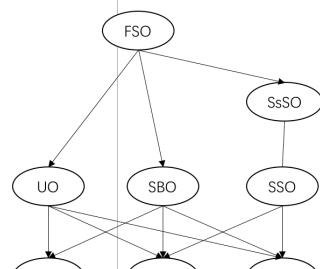


Fig. 8: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CE^T

b) Contribution extent at project level (CE^P)

----Analysis----					
	Estimator	Lower	Upper	Statistic	p.Value
DIV - CO	0.037	-0.209	0.279	0.486	9.994846e-01
FSO - CO	0.484	0.296	0.637	7.698	1.396227e-06
RO - CO	-0.002	-0.199	0.196	-0.027	1.000000e+00
SBO - CO	0.228	0.033	0.406	3.804	1.527455e-02
SSO - CO	0.238	0.029	0.427	3.699	1.942612e-02
SsSo - CO	0.249	0.048	0.431	4.026	9.227403e-03
UO - CO	0.284	0.090	0.457	4.721	1.849067e-03
FSO - DIV	0.447	0.265	0.598	7.503	2.316456e-06
RO - DIV	-0.039	-0.228	0.153	-0.658	9.965083e-01
SBO - DIV	0.191	0.003	0.366	3.313	4.505927e-02
SSO - DIV	0.200	-0.002	0.387	3.229	5.384840e-02
SsSo - DIV	0.212	0.018	0.391	3.563	2.626978e-02
UO - DIV	0.246	0.059	0.417	4.272	5.411233e-03
RO - FSO	-0.486	-0.565	-0.399	-15.893	0.000000e+00
SBO - FSO	-0.256	-0.327	-0.182	-11.000	1.467628e-09
SSO - FSO	-0.247	-0.345	-0.143	-7.629	8.846900e-07
SsSo - FSO	-0.235	-0.314	-0.153	-9.135	1.675017e-07
UO - FSO	-0.201	-0.269	-0.131	-9.237	1.217802e-08
SBO - RO	0.230	0.134	0.322	7.684	2.805860e-06
SSO - RO	0.239	0.116	0.356	6.237	3.848384e-05
SsSo - RO	0.251	0.149	0.348	7.867	7.792883e-07
UO - RO	0.285	0.192	0.374	9.634	5.081398e-09
SSO - SBO	0.010	-0.102	0.121	0.277	9.999881e-01
SsSo - SBO	0.021	-0.068	0.111	0.774	9.907648e-01
UO - SBO	0.055	-0.025	0.135	2.250	3.278549e-01
SsSo - SSO	0.012	-0.107	0.130	0.323	9.999662e-01
UO - SSO	0.046	-0.065	0.155	1.355	8.443695e-01
UO - SsSo	0.034	-0.054	0.121	1.265	8.832458e-01

----Overall----		
Quantile	p.Value	0
1	3.261981	0

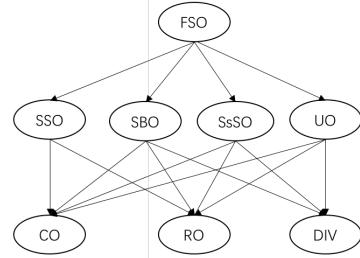


Fig. 9: Results of \tilde{T} -test and \tilde{T} -graph on the eight models' CE^T

As shown in Figure 8 and 9, the companies in FSO tend to have the most extensive contributing scope. Companies in the UO, SSO, SsSo, and SBO have the middle scope to contribute. And DIV, RO, and CO models cover a smaller range of projects than any others. We also found the same rules when comparing the median CE^P and CE^T of the eight models.

In summary, the FSO model had the best performance, while CO and RO had the worst, with the remaining models being in the middle. Most of findings concluded by means of \tilde{T} -test consist with the results obtained by using median values in the paper. Moreover, the results of \tilde{T} -tests can illustrate in greater detail which of the differences in contribution performance are statistically significant.

Reference

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