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LAMPIRAN

Lampiran 1. Data harga setiap aset

Date	BBRI	KALBE	AUD_IDR	GBP_USD	PLATINUM_F	COPPER_F
01/01/2013	1.551	1.090	10.106	15.854	31380	37.395
01/02/2013	1.844	1.290	9.868	15.160	28432	35.475
01/03/2013	1.707	1.240	10.120	15.201	28353	34.125
01/04/2013	1.834	1.390	10.079	15.531	24185	31.875
01/05/2013	1.737	1.450	9.369	15.198	22265	33.000
01/06/2013	1.512	1.440	9.063	15.210	19470	30.575
01/07/2013	1.610	1.430	9.222	15.206	19643	31.250
01/08/2013	1.288	1.350	9.706	15.508	23495	32.305
01/09/2013	1.415	1.180	10.774	16.184	21708	33.230
01/10/2013	1.541	1.300	10.654	16.040	21882	33.045
01/11/2013	1.454	1.220	10.891	16.365	20016	32.155
01/12/2013	1.415	1.250	10.838	16.556	19370	33.965
01/01/2014	1.624	1.405	10.683	16.432	19138	32.000
01/02/2014	1.810	1.450	10.358	16.743	21241	31.875
01/03/2014	1.868	1.465	10.517	16.662	19765	30.245
01/04/2014	1.932	1.545	10.729	16.870	19174	30.275
01/05/2014	1.990	1.540	10.864	16.750	18700	31.205
01/06/2014	2.015	1.660	11.170	17.103	21056	32.035
01/07/2014	2.185	1.730	10.759	16.884	20432	32.360
01/08/2014	2.156	1.660	10.906	16.597	19454	31.530
01/09/2014	2.034	1.700	10.651	16.212	17057	30.075
01/10/2014	2.161	1.705	10.623	15.995	16126	30.470
01/11/2014	2.249	1.750	10.380	15.646	15547	28.560
01/12/2014	2.273	1.830	10.112	15.573	15599	28.255
01/01/2015	2.278	1.865	9.836	15.066	17228	24.955
01/02/2015	2.512	1.805	10.089	15.432	16558	26.915
01/03/2015	2.590	1.865	9.940	14.816	16619	27.410
01/04/2015	2.268	1.795	10.242	15.349	16153	28.865
01/05/2015	2.298	1.840	10.097	15.288	16721	27.330
01/06/2015	2.020	1.675	10.269	15.705	15581	26.150
01/07/2015	1.951	1.745	9.876	15.622	14765	23.690
01/08/2015	2.073	1.675	9.986	15.342	14581	23.385
01/09/2015	1.688	1.375	10.276	15.127	14518	23.410
01/10/2015	2.054	1.430	9.760	15.428	15584	23.235

01/11/2015	2.102	1.335	9.994	15.054	14072	20.460
01/12/2015	2.229	1.320	10.029	14.738	13803	21.350
01/01/2016	2.190	1.335	9.752	14.245	14255	20.705
01/02/2016	2.161	1.300	9.541	13.915	14918	21.325
01/03/2016	2.229	1.445	10.145	14.358	15483	21.880
01/04/2016	2.020	1.375	10.019	14.611	17819	22.835
01/05/2016	2.020	1.430	9.871	14.477	16018	21.000
01/06/2016	2.107	1.530	9.837	13.306	18623	21.955
01/07/2016	2.249	1.675	9.947	13.226	20393	22.250
01/08/2016	2.273	1.795	9.967	13.137	18675	20.750
01/09/2016	2.381	1.715	9.986	12.975	19214	22.105
01/10/2016	2.381	1.740	9.927	12.242	17835	22.080
01/11/2016	2.127	1.500	10.003	12.504	16454	26.295
01/12/2016	2.278	1.515	9.719	12.336	15989	25.055
01/01/2017	2.288	1.450	10.121	12.577	17577	27.335
01/02/2017	2.332	1.530	10.208	12.380	18469	27.140
01/03/2017	2.532	1.540	10.163	12.545	18294	26.600
01/04/2017	2.517	1.585	9.974	12.946	17262	26.075
01/05/2017	2.824	1.540	9.896	12.888	17443	25.865
01/06/2017	2.976	1.625	10.242	13.025	16627	27.110
01/07/2017	2.883	1.735	10.662	13.212	16835	29.000
01/08/2017	2.951	1.710	10.602	12.929	17541	30.940
01/09/2017	2.981	1.665	10.551	13.396	16676	29.550
01/10/2017	3.044	1.600	10.380	13.282	16726	31.080
01/11/2017	3.132	1.600	10.232	13.525	16445	30.555
01/12/2017	3.551	1.690	10.582	13.512	17145	33.005
01/01/2018	3.610	1.665	10.782	14.190	17284	32.065
01/02/2018	3.688	1.600	10.664	13.760	16407	31.325
01/03/2018	3.512	1.500	10.565	14.015	16312	30.370
01/04/2018	3.141	1.505	10.476	13.769	16401	30.740
01/05/2018	3.005	1.370	10.511	13.298	16503	30.750
01/06/2018	2.771	1.220	10.603	13.207	16198	29.660
01/07/2018	2.995	1.295	10.705	13.124	15597	28.405
01/08/2018	3.102	1.345	10.587	12.961	14517	26.645
01/09/2018	3.073	1.380	10.770	13.028	14712	28.050
01/10/2018	3.073	1.370	10.751	12.765	14324	26.670
01/11/2018	3.532	1.525	10.460	12.751	14180	27.865
01/12/2018	3.571	1.520	10.133	12.757	17699	26.310

01/01/2019	3.756	1.600	10.163	13.100	18231	27.890
01/02/2019	3.756	1.495	9.974	13.261	17710	29.480
01/03/2019	4.020	1.520	10.098	13.031	17031	29.395
01/04/2019	4.263	1.545	10.040	13.031	16857	29.040
01/05/2019	4.000	1.405	9.901	12.631	16187	26.405
01/06/2019	4.254	1.460	9.916	12.693	16741	27.135
01/07/2019	4.371	1.470	9.590	12.157	17852	26.715
01/08/2019	4.166	1.690	9.552	12.156	19567	25.470
01/09/2019	4.020	1.675	9.573	12.287	18395	25.785
01/10/2019	4.107	1.595	9.672	12.940	19451	26.425
01/11/2019	3.990	1.525	9.537	12.933	18378	26.560
01/12/2019	4.293	1.620	9.745	13.259	19156	27.970
01/01/2020	4.351	1.430	9.133	13.199	19224	25.200
01/02/2020	4.088	1.220	9.334	12.820	17570	25.400
01/03/2020	2.946	1.200	10.000	12.418	15016	22.320
01/04/2020	2.663	1.440	9.651	12.592	15953	23.440
01/05/2020	2.878	1.415	9.716	12.344	19473	24.345
01/06/2020	2.956	1.460	9.787	12.399	19753	27.285
01/07/2020	3.083	1.565	10.377	13.088	25770	28.770
01/08/2020	3.424	1.580	10.738	13.369	29744	30.555
01/09/2020	2.966	1.550	10.628	12.916	24595	30.325
01/10/2020	3.278	1.525	10.272	12.941	24761	30.515
01/11/2020	3.990	1.505	10.349	13.321	23464	34.335
01/12/2020	4.068	1.480	10.802	13.673	27228	35.190
01/01/2021	4.078	1.465	10.714	13.702	27688	35.580
01/02/2021	4.595	1.470	10.972	13.932	27862	40.925
01/03/2021	4.293	1.570	11.029	13.779	25965	40.000
01/04/2021	3.951	1.440	11.142	13.814	27225	44.680
01/05/2021	4.156	1.450	11.037	14.209	29326	46.810
01/06/2021	3.844	1.400	10.868	13.827	27356	42.890
01/07/2021	3.620	1.260	10.619	13.901	26137	44.655
01/08/2021	3.834	1.345	10.435	13.754	24523	43.700
01/09/2021	3.850	1.430	10.340	13.472	22484	40.890
01/10/2021	4.250	1.600	10.654	13.691	24373	43.590
01/11/2021	4.090	1.600	10.200	13.295	23324	42.805
01/12/2021	4.110	1.615	10.346	13.529	23890	44.635
01/01/2022	4.070	1.640	10.158	13.445	22992	43.265
01/02/2022	4.550	1.645	10.432	13.419	25087	44.545

01/03/2022	4.660	1.610	10.747	13.133	26112	47.520
01/04/2022	4.870	1.640	10.238	12.571	24063	44.085
01/05/2022	4.630	1.675	10.460	12.600	22785	42.990
01/06/2022	4.150	1.660	10.279	12.175	21303	37.100
01/07/2022	4.360	1.620	10.359	12.166	21064	35.750
01/08/2022	4.340	1.680	10.149	11.622	18657	35.190
01/09/2022	4.490	1.830	9.747	11.160	19704	34.125
01/10/2022	4.650	2.050	9.976	11.469	19970	33.750
01/11/2022	4.980	2.070	10.674	12.056	22603	37.380
01/12/2022	4.940	2.090	10.604	12.097	24881	38.105
01/01/2023	4.580	2.060	10.570	12.320	24742	42.260
01/02/2023	4.670	2.110	10.257	12.020	21720	40.740
01/03/2023	4.730	2.100	10.021	12.333	24851	40.945
01/04/2023	5.100	2.120	9.698	12.572	25773	38.812
01/05/2023	5.575	2.030	9.740	12.437	24135	36.370
01/06/2023	5.425	2.050	9.992	12.704	23337	37.595
01/07/2023	5.650	1.915	10.123	12.837	25335	40.080
01/08/2023	5.550	1.815	9.870	12.673	24812	38.220
01/09/2023	5.225	1.755	9.941	12.197	22450	37.375
01/10/2023	4.960	1.690	10.062	12.152	22952	36.490

Lampiran 2. Return Harga saham setiap aset

Date	BBRI	KALBE	AUD_IDR	GBP_USD	PLATINUM_F	COPPER_F
01/01/2013						
01/02/2013	0,18891	0,183486	-0,0235521	-0,04377	-0,0939452	-0,05134
01/03/2013	-0,0743	-0,03876	0,02558147	0,002704	-0,0027786	-0,03805
01/04/2013	0,0744	0,120968	-0,0040958	0,021709	-0,1470038	-0,06593
01/05/2013	-0,05289	0,043165	-0,0704101	-0,02144	-0,0793881	0,035294
01/06/2013	-0,12953	-0,0069	-0,0326736	0,00079	-0,1255333	-0,07348
01/07/2013	0,064815	-0,00694	0,01760472	-0,00026	0,0088855	0,022077
01/08/2013	-0,2	-0,05594	0,05238082	0,019861	0,1961004	0,03376
01/09/2013	0,098602	-0,12593	0,11008558	0,04359	-0,0760587	0,028633
01/10/2013	0,089046	0,101695	-0,0110952	-0,0089	0,0080155	-0,00557
01/11/2013	-0,05646	-0,06154	0,02220389	0,020262	-0,0852756	-0,02693
01/12/2013	-0,02682	0,02459	-0,004848	0,011671	-0,0322742	0,05629
01/01/2014	0,147703	0,124	-0,0143169	-0,00749	-0,0119773	-0,05785
01/02/2014	0,114532	0,032028	-0,0304511	0,018926	0,1098861	-0,00391

01/03/2014	0,032044	0,010345	0,01537692	-0,00484	-0,0694883	-0,05114
01/04/2014	0,034261	0,054608	0,02018541	0,012483	-0,0299013	0,000992
01/05/2014	0,030021	-0,00324	0,01251807	-0,00711	-0,024721	0,030718
01/06/2014	0,012563	0,077922	0,02818955	0,021075	0,1259893	0,026598
01/07/2014	0,084367	0,042169	-0,0367848	-0,0128	-0,0296353	0,010145
01/08/2014	-0,01327	-0,04046	0,0136305	-0,017	-0,0478661	-0,02565
01/09/2014	-0,05659	0,024096	-0,0233091	-0,0232	-0,1232137	-0,04615
01/10/2014	0,062439	0,002941	-0,0026532	-0,01339	-0,0545817	0,013134
01/11/2014	0,040722	0,026393	-0,0228765	-0,02182	-0,0359048	-0,06268
01/12/2014	0,010671	0,045714	-0,025833	-0,00467	0,0033447	-0,01068
01/01/2015	0,0022	0,019126	-0,027328	-0,03256	0,1044298	-0,11679
01/02/2015	0,102722	-0,03217	0,02578277	0,024293	-0,0388902	0,078541
01/03/2015	0,031051	0,033241	-0,0148168	-0,03992	0,003684	0,018391
01/04/2015	-0,12432	-0,03753	0,03043842	0,035975	-0,0280402	0,053083
01/05/2015	0,013228	0,02507	-0,0141775	-0,00397	0,0351637	-0,05318
01/06/2015	-0,12097	-0,08967	0,01706929	0,027276	-0,0681777	-0,04318
01/07/2015	-0,03416	0,041791	-0,0383147	-0,00528	-0,0523715	-0,09407
01/08/2015	0,062532	-0,04011	0,01114221	-0,01792	-0,0124619	-0,01287
01/09/2015	-0,18572	-0,1791	0,02908071	-0,01401	-0,0043207	0,001069
01/10/2015	0,216825	0,04	-0,0502657	0,019898	0,0734261	-0,00748
01/11/2015	0,023369	-0,06643	0,02394606	-0,02424	-0,0970226	-0,11943
01/12/2015	0,060419	-0,01124	0,00350526	-0,02099	-0,019116	0,0435
01/01/2016	-0,0175	0,011364	-0,0275891	-0,03345	0,0327465	-0,03021
01/02/2016	-0,01324	-0,02622	-0,0215906	-0,02317	0,04651	0,029944
01/03/2016	0,031467	0,111538	0,06330544	0,031836	0,0378737	0,026026
01/04/2016	-0,09376	-0,04844	-0,0124135	0,017621	0,1508752	0,043647
01/05/2016	0	0,04	-0,0147952	-0,00917	-0,1010719	-0,08036
01/06/2016	0,043069	0,06993	-0,003415	-0,08089	0,1626295	0,045476
01/07/2016	0,067394	0,094771	0,01114919	-0,00601	0,0950438	0,013437
01/08/2016	0,010671	0,071642	0,0020257	-0,00673	-0,0842446	-0,06742
01/09/2016	0,047514	-0,04457	0,00189118	-0,01233	0,0288621	0,065301
01/10/2016	0	0,014577	-0,0058791	-0,05649	-0,0717706	-0,00113
01/11/2016	-0,10668	-0,13793	0,00756991	0,021402	-0,077432	0,190897
01/12/2016	0,070992	0,01	-0,0283926	-0,01344	-0,0282606	-0,04716
01/01/2017	0,00439	-0,0429	0,04140716	0,019536	0,0993183	0,091
01/02/2017	0,019231	0,055172	0,00854854	-0,01566	0,0507481	-0,00713
01/03/2017	0,085763	0,006536	-0,004386	0,013328	-0,0094753	-0,0199
01/04/2017	-0,00592	0,029221	-0,0185825	0,031965	-0,0564119	-0,01974

01/05/2017	0,121971	-0,02839	-0,0077963	-0,00448	0,0104855	-0,00805
01/06/2017	0,053824	0,055195	0,03490542	0,01063	-0,0467809	0,048135
01/07/2017	-0,03125	0,067692	0,0410346	0,014357	0,0125098	0,069716
01/08/2017	0,023587	-0,01441	-0,0056566	-0,02142	0,0419364	0,066897
01/09/2017	0,010166	-0,02632	-0,0047635	0,03612	-0,049313	-0,04493
01/10/2017	0,021134	-0,03904	-0,0161946	-0,00851	0,0029983	0,051777
01/11/2017	0,028909	0	-0,0142502	0,018295	-0,0168002	-0,01689
01/12/2017	0,13378	0,05625	0,034186	-0,00096	0,0425661	0,080183
01/01/2018	0,016615	-0,01479	0,01888385	0,050178	0,0081073	-0,02848
01/02/2018	0,021607	-0,03904	-0,0109702	-0,0303	-0,0507406	-0,02308
01/03/2018	-0,04772	-0,0625	-0,0092539	0,018532	-0,0057902	-0,03049
01/04/2018	-0,10564	0,003333	-0,0084534	-0,01755	0,0054561	0,012183
01/05/2018	-0,0433	-0,0897	0,00333536	-0,03421	0,0062191	0,000325
01/06/2018	-0,07787	-0,10949	0,00883017	-0,00684	-0,0184815	-0,03545
01/07/2018	0,080837	0,061475	0,00954508	-0,00628	-0,0371033	-0,04231
01/08/2018	0,035726	0,03861	-0,0109579	-0,01242	-0,0692441	-0,06196
01/09/2018	-0,00935	0,026022	0,017232	0,005169	0,0134325	0,05273
01/10/2018	0	-0,00725	-0,0017419	-0,02019	-0,026373	-0,0492
01/11/2018	0,149365	0,113139	-0,0270218	-0,0011	-0,0100531	0,044807
01/12/2018	0,011042	-0,00328	-0,0313094	0,000471	0,2481664	-0,0558
01/01/2019	0,051806	0,052632	0,00298433	0,026887	0,0300582	0,060053
01/02/2019	0	-0,06563	-0,0185985	0,01229	-0,0285777	0,05701
01/03/2019	0,070288	0,016722	0,01244716	-0,01734	-0,0383399	-0,00288
01/04/2019	0,060448	0,016447	-0,0057861	0	-0,0102167	-0,01208
01/05/2019	-0,06169	-0,09061	-0,0138796	-0,0307	-0,0397461	-0,09074
01/06/2019	0,0635	0,039146	0,00153729	0,004909	0,034225	0,027646
01/07/2019	0,027504	0,006849	-0,0328709	-0,04223	0,066364	-0,01548
01/08/2019	-0,0469	0,14966	-0,0039792	-8,2E-05	0,0960677	-0,0466
01/09/2019	-0,03505	-0,00888	0,0021902	0,010777	-0,0598968	0,012367
01/10/2019	0,021642	-0,04776	0,01041413	0,053146	0,0574069	0,024821
01/11/2019	-0,02849	-0,04389	-0,0139595	-0,00054	-0,0551643	0,005109
01/12/2019	0,07594	0,062295	0,02179981	0,025207	0,0423332	0,053087
01/01/2020	0,01351	-0,11728	-0,0627933	-0,00453	0,0035498	-0,09903
01/02/2020	-0,06045	-0,14685	0,02197363	-0,02871	-0,0860383	0,007937
01/03/2020	-0,27935	-0,01639	0,07136773	-0,03136	-0,1453614	-0,12126
01/04/2020	-0,09606	0,2	-0,0348968	0,014012	0,0624001	0,050179
01/05/2020	0,080736	-0,01736	0,00669562	-0,0197	0,2206482	0,038609
01/06/2020	0,027102	0,031802	0,00734275	0,004456	0,0143789	0,120764

01/07/2020	0,042963	0,071918	0,06031343	0,055569	0,304612	0,054426
01/08/2020	0,110607	0,009585	0,03475557	0,02147	0,1542103	0,062044
01/09/2020	-0,13376	-0,01899	-0,0102058	-0,03388	-0,1731105	-0,00753
01/10/2020	0,105192	-0,01613	-0,0335328	0,001936	0,0067493	0,006265
01/11/2020	0,217206	-0,01311	0,00750583	0,029364	-0,0523808	0,125184
01/12/2020	0,019549	-0,01661	0,04379797	0,026424	0,160416	0,024902
01/01/2021	0,002458	-0,01014	-0,0081741	0,002121	0,0168944	0,011083
01/02/2021	0,126778	0,003413	0,02406553	0,016786	0,0062843	0,150225
01/03/2021	-0,06572	0,068027	0,00523792	-0,01098	-0,0680856	-0,0226
01/04/2021	-0,07966	-0,0828	0,01020093	0,00254	0,0485269	0,117
01/05/2021	0,051886	0,006944	-0,0093763	0,028594	0,0771717	0,047672
01/06/2021	-0,07507	-0,03448	-0,0153188	-0,02688	-0,0671759	-0,08374
01/07/2021	-0,05827	-0,1	-0,0229041	0,005352	-0,0445606	0,041152
01/08/2021	0,059116	0,06746	-0,0173804	-0,01057	-0,0617515	-0,02139
01/09/2021	0,004173	0,063197	-0,0090504	-0,0205	-0,0831464	-0,0643
01/10/2021	0,103896	0,118881	0,0302783	0,016256	0,0840153	0,066031
01/11/2021	-0,03765	0	-0,042555	-0,02892	-0,0430394	-0,01801
01/12/2021	0,00489	0,009375	0,01425078	0,017601	0,0242668	0,042752
01/01/2022	-0,00973	0,01548	-0,0181209	-0,00621	-0,0375889	-0,03069
01/02/2022	0,117936	0,003049	0,026957	-0,00193	0,0911186	0,029585
01/03/2022	0,024176	-0,02128	0,0302343	-0,02131	0,0408578	0,066786
01/04/2022	0,045064	0,018634	-0,0474018	-0,04279	-0,0784697	-0,07229
01/05/2022	-0,04928	0,021341	0,02167161	0,002307	-0,0531106	-0,02484
01/06/2022	-0,10367	-0,00896	-0,0172711	-0,03373	-0,0650428	-0,13701
01/07/2022	0,050602	-0,0241	0,00775559	-0,00074	-0,0112191	-0,03639
01/08/2022	-0,00459	0,037037	-0,0202418	-0,04471	-0,1142708	-0,01566
01/09/2022	0,034562	0,089286	-0,0396125	-0,03975	0,0561183	-0,03026
01/10/2022	0,035635	0,120219	0,02350147	0,027688	0,0134998	-0,01099
01/11/2022	0,070968	0,009756	0,06999314	0,051181	0,1318478	0,107556
01/12/2022	-0,00803	0,009662	-0,0065531	0,003401	0,1007831	0,019395
01/01/2023	-0,07287	-0,01435	-0,0032072	0,018434	-0,0055866	0,109041
01/02/2023	0,019651	0,024272	-0,0296658	-0,02435	-0,1221405	-0,03597
01/03/2023	0,012848	-0,00474	-0,023011	0,02604	0,1441529	0,005032
01/04/2023	0,078224	0,009524	-0,0322189	0,019379	0,0371011	-0,05209
01/05/2023	0,093137	-0,04245	0,00436071	-0,01074	-0,0635549	-0,06292
01/06/2023	-0,02691	0,009852	0,02588024	0,021468	-0,033064	0,033682
01/07/2023	0,041475	-0,06585	0,01306302	0,010469	0,0856151	0,066099
01/08/2023	-0,0177	-0,05222	-0,0249426	-0,01278	-0,0206434	-0,04641

01/09/2023	-0,05856	-0,03306	0,00710814	-0,03756	-0,0951959	-0,02211
01/10/2023	-0,05072	-0,03704	0,01217641	-0,00369	0,0223608	-0,02368

Lampiran 3. Program software Phyton Risk Parity Portfolio (RPP)

```
import pandas as pd
import math as mt
import numpy as np
import sympy as sp
#load the data
from google.colab import files
files.upload()
data=pd.read_csv('APRILBARU0.csv', sep=';')
data
ds = data.describe()
tds = ds.transpose()
print(tds)
#hitung skewness dan kurtosis
skewness = skew(data, bias=False)
kurtosis = kurtosis(data, bias=False)

#cetak hasil
print("Skewness:", skewness)
print("Kurtosis:", kurtosis)

# Hitung return bulanan
returns = data.pct_change()
returns
ds = returns.describe()
tds = ds.transpose()
print(tds)
ratareturns=(returns.mean())
# Plot nilai portofolio
Stocks=['BBRI','KALBE','AUD_IDR','GBP_USD','PLATINUM_F','COPP
ER_F']
plt.figure(figsize=(10, 6))
plt.plot(returns, label=stocks)
plt.legend()
plt.title('Return')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()
EQUALLY WEIGHTED PORTFOLIO
```

```
stocks=['BBRI','KALBE','AUD_IDR','GBP_USD','PLATINUM_F','COPP
ER_F']
weights=np.array([0.16666667,0.16666667,0.16666667,0.16666667
,0.16666667])
noa = len(data.columns)
noa
phi = np.array(noa * [1 / noa])
phi
plt.pie(phi, labels=data.columns, autopct='%1.1f%%')
# Create and show the annualized covariance matrix
cov_matrix_annual = returns.cov()*12
cov_matrix_annual
# Calculate the portfolio variance
port_variance = np.dot(phi.T,np.dot(cov_matrix_annual,phi))
port_variance
# Calculate the portfolio volatility aka standard deviation
port_volatility = np.sqrt(port_variance)
port_volatility
port_volatility / noa  # "average" risk contribution\
#calculate the annual portfolio return
portfolio_simple_annual_return =
np.sum(returns.mean()*phi)*12
portfolio_simple_annual_return
#calculate the annual portfolio return
portfolio_simple_annual_return =
np.sum(returns.mean()*phi)*12
portfolio_simple_annual_return
np.dot(cov_matrix_annual, phi)
mvols = np.dot(cov_matrix_annual, phi) / port_volatility  #
marginal volatilities
mvols
rc = mvols * phi  # risk contributions (%-points)
rc
rc.sum()
rrc = rc / rc.sum()  # relative risk contributions (%)
rrc
rrc.sum()
import matplotlib.pyplot as plt
plt.pie(rrc, labels=data.columns, autopct='%1.1f%%')
plt.title('Relative Risk Contributions');
plt.bar(x=range(len(rrc)), height=rrc)
plt.title("Relative Risk Contributions'");
plt.show()
```

```
sum(rc / rc.sum())  # checking for sum of relative risk
contribution
```

RISK PARITY PORTFOLIO

```
from scipy.optimize import minimize
rrc = rel_risk_contributions(phi)
rrc
plt.pie(rrc, labels=data.columns, autopct='%1.1f%%')
plt.title('Risk Contributio Portfolio');
def mse_risk_contributions(phi, target, returns=returns):
    rc = rel_risk_contributions(phi, returns)
    mse = ((rc - target) ** 2).mean()
    return mse * 100
mse_risk_contributions(phi, phi)
bnds = noa * [(0, 2),]
cons = {'type': 'eq', 'fun': lambda weights: weights.sum() -
1}
target = noa * [1 / noa,]  # risk parity as target
target = [0.16666666666666666, 0.16666666666666666,
0.16666666666666666,
0.16666666666666666,0.16666666666666666,0.16666666666666666]
 # example risk budget as target
target
opt = minimize(lambda w: mse_risk_contributions(w,
target=target), phi, bounds=bnds, constraints=cons)
opt
phi_ = opt['x']
phi_
plt.pie(phi_, labels=data.columns, autopct='%1.1f%%')
plt.title('Optimal Portfolio Weights');
rrc=rel_risk_contributions(opt['x'])
rrc
plt.pie(rrc, labels=data.columns, autopct='%1.1f%%')
plt.title('Relative Risk Contributions');
```

Lampiran 4. Program software Compleks-Based Risk Parity Portfolio (RPP)

```
import pandas as pd
import math as mt
import numpy as np
import sympy as sp
#load the data
from google.colab import files
files.upload()
data=pd.read_csv('aprilreturn.csv')
data
```

```
x1=data["BBRI"]
x2=data["KALBE"]
x3=data["AUD_IDR"]
x4=data["GBP_USD"]
x5=data["PLATINUM_F"]
x6=data["COPPER_F"]
i=1j
data.head()
#untuk n dimulai dari 0 dan N=130
Rumus Euler
```

$$e^{ix} = \cos x + i \sin x$$

$$\cos 2\left(\pi \times \frac{n}{N}\right) + i \sin(2 \times \pi \times \frac{n}{N})$$

```
exp1=np.cos(2*np.pi*(0/129))+i*np.sin(2*np.pi*(0/129))
exp2=np.cos(2*np.pi*(1/129))+i*np.sin(2*np.pi*(1/129))
exp3=np.cos(2*np.pi*(2/129))+i*np.sin(2*np.pi*(2/129))
exp4=np.cos(2*np.pi*(3/129))+i*np.sin(2*np.pi*(3/129))
exp5=np.cos(2*np.pi*(4/129))+i*np.sin(2*np.pi*(4/129))
exp6=np.cos(2*np.pi*(5/129))+i*np.sin(2*np.pi*(5/129))
exp7=np.cos(2*np.pi*(6/129))+i*np.sin(2*np.pi*(6/129))
exp8=np.cos(2*np.pi*(7/129))+i*np.sin(2*np.pi*(7/129))
exp9=np.cos(2*np.pi*(8/129))+i*np.sin(2*np.pi*(8/129))
exp10=np.cos(2*np.pi*(9/129))+i*np.sin(2*np.pi*(9/129))
exp11=np.cos(2*np.pi*(10/129))+i*np.sin(2*np.pi*(10/129))
exp12=np.cos(2*np.pi*(11/129))+i*np.sin(2*np.pi*(11/129))
exp13=np.cos(2*np.pi*(12/129))+i*np.sin(2*np.pi*(12/129))
exp14=np.cos(2*np.pi*(13/129))+i*np.sin(2*np.pi*(13/129))
exp15=np.cos(2*np.pi*(14/129))+i*np.sin(2*np.pi*(14/129))
exp16=np.cos(2*np.pi*(15/129))+i*np.sin(2*np.pi*(15/129))
exp17=np.cos(2*np.pi*(16/129))+i*np.sin(2*np.pi*(16/129))
exp18=np.cos(2*np.pi*(17/129))+i*np.sin(2*np.pi*(17/129))
exp19=np.cos(2*np.pi*(18/129))+i*np.sin(2*np.pi*(18/129))
exp20=np.cos(2*np.pi*(19/129))+i*np.sin(2*np.pi*(19/129))
exp21=np.cos(2*np.pi*(20/129))+i*np.sin(2*np.pi*(20/129))
exp22=np.cos(2*np.pi*(21/129))+i*np.sin(2*np.pi*(21/129))
exp23=np.cos(2*np.pi*(22/129))+i*np.sin(2*np.pi*(22/129))
exp24=np.cos(2*np.pi*(23/129))+i*np.sin(2*np.pi*(23/129))
exp25=np.cos(2*np.pi*(24/129))+i*np.sin(2*np.pi*(24/129))
exp26=np.cos(2*np.pi*(25/129))+i*np.sin(2*np.pi*(25/129))
exp27=np.cos(2*np.pi*(26/129))+i*np.sin(2*np.pi*(26/129))
exp28=np.cos(2*np.pi*(27/129))+i*np.sin(2*np.pi*(27/129))
exp29=np.cos(2*np.pi*(28/129))+i*np.sin(2*np.pi*(28/129))
exp30=np.cos(2*np.pi*(29/129))+i*np.sin(2*np.pi*(29/129))
exp31=np.cos(2*np.pi*(30/129))+i*np.sin(2*np.pi*(30/129))
```

```
exp32=np.cos(2*np.pi*(31/129))+i*np.sin(2*np.pi*(31/129))
exp33=np.cos(2*np.pi*(32/129))+i*np.sin(2*np.pi*(32/129))
exp34=np.cos(2*np.pi*(33/129))+i*np.sin(2*np.pi*(33/129))
exp35=np.cos(2*np.pi*(34/129))+i*np.sin(2*np.pi*(34/129))
exp36=np.cos(2*np.pi*(35/129))+i*np.sin(2*np.pi*(35/129))
exp37=np.cos(2*np.pi*(36/129))+i*np.sin(2*np.pi*(36/129))
exp38=np.cos(2*np.pi*(37/129))+i*np.sin(2*np.pi*(37/129))
exp39=np.cos(2*np.pi*(38/129))+i*np.sin(2*np.pi*(38/129))
exp40=np.cos(2*np.pi*(39/129))+i*np.sin(2*np.pi*(39/129))
exp41=np.cos(2*np.pi*(40/129))+i*np.sin(2*np.pi*(40/129))
exp42=np.cos(2*np.pi*(41/129))+i*np.sin(2*np.pi*(41/129))
exp43=np.cos(2*np.pi*(42/129))+i*np.sin(2*np.pi*(42/129))
exp44=np.cos(2*np.pi*(43/129))+i*np.sin(2*np.pi*(43/129))
exp45=np.cos(2*np.pi*(44/129))+i*np.sin(2*np.pi*(44/129))
exp46=np.cos(2*np.pi*(45/129))+i*np.sin(2*np.pi*(45/129))
exp47=np.cos(2*np.pi*(46/129))+i*np.sin(2*np.pi*(46/129))
exp48=np.cos(2*np.pi*(47/129))+i*np.sin(2*np.pi*(47/129))
exp49=np.cos(2*np.pi*(48/129))+i*np.sin(2*np.pi*(48/129))
exp50=np.cos(2*np.pi*(49/129))+i*np.sin(2*np.pi*(49/129))
exp51=np.cos(2*np.pi*(50/129))+i*np.sin(2*np.pi*(50/129))
exp52=np.cos(2*np.pi*(51/129))+i*np.sin(2*np.pi*(51/129))
exp53=np.cos(2*np.pi*(52/129))+i*np.sin(2*np.pi*(52/129))
exp54=np.cos(2*np.pi*(53/129))+i*np.sin(2*np.pi*(53/129))
exp55=np.cos(2*np.pi*(54/129))+i*np.sin(2*np.pi*(54/129))
exp56=np.cos(2*np.pi*(55/129))+i*np.sin(2*np.pi*(55/129))
exp57=np.cos(2*np.pi*(56/129))+i*np.sin(2*np.pi*(56/129))
exp58=np.cos(2*np.pi*(57/129))+i*np.sin(2*np.pi*(57/129))
exp59=np.cos(2*np.pi*(58/129))+i*np.sin(2*np.pi*(58/129))
exp60=np.cos(2*np.pi*(59/129))+i*np.sin(2*np.pi*(59/129))
exp61=np.cos(2*np.pi*(60/129))+i*np.sin(2*np.pi*(60/129))
exp62=np.cos(2*np.pi*(61/129))+i*np.sin(2*np.pi*(61/129))
exp63=np.cos(2*np.pi*(62/129))+i*np.sin(2*np.pi*(62/129))
exp64=np.cos(2*np.pi*(63/129))+i*np.sin(2*np.pi*(63/129))
exp65=np.cos(2*np.pi*(64/129))+i*np.sin(2*np.pi*(64/129))
exp66=np.cos(2*np.pi*(65/129))+i*np.sin(2*np.pi*(65/129))
exp67=np.cos(2*np.pi*(66/129))+i*np.sin(2*np.pi*(66/129))
exp68=np.cos(2*np.pi*(67/129))+i*np.sin(2*np.pi*(67/129))
exp69=np.cos(2*np.pi*(68/129))+i*np.sin(2*np.pi*(68/129))
exp70=np.cos(2*np.pi*(69/129))+i*np.sin(2*np.pi*(69/129))
exp71=np.cos(2*np.pi*(70/129))+i*np.sin(2*np.pi*(70/129))
exp72=np.cos(2*np.pi*(71/129))+i*np.sin(2*np.pi*(71/129))
exp73=np.cos(2*np.pi*(72/129))+i*np.sin(2*np.pi*(72/129))
exp74=np.cos(2*np.pi*(73/129))+i*np.sin(2*np.pi*(73/129))
exp75=np.cos(2*np.pi*(74/129))+i*np.sin(2*np.pi*(74/129))
```

```
exp76=np.cos(2*np.pi*(75/129))+i*np.sin(2*np.pi*(75/129))
exp77=np.cos(2*np.pi*(76/129))+i*np.sin(2*np.pi*(76/129))
exp78=np.cos(2*np.pi*(77/129))+i*np.sin(2*np.pi*(77/129))
exp79=np.cos(2*np.pi*(78/129))+i*np.sin(2*np.pi*(78/129))
exp80=np.cos(2*np.pi*(79/129))+i*np.sin(2*np.pi*(79/129))
exp81=np.cos(2*np.pi*(80/129))+i*np.sin(2*np.pi*(80/129))
exp82=np.cos(2*np.pi*(81/129))+i*np.sin(2*np.pi*(81/129))
exp83=np.cos(2*np.pi*(82/129))+i*np.sin(2*np.pi*(82/129))
exp84=np.cos(2*np.pi*(83/129))+i*np.sin(2*np.pi*(83/129))
exp85=np.cos(2*np.pi*(84/129))+i*np.sin(2*np.pi*(84/129))
exp86=np.cos(2*np.pi*(85/129))+i*np.sin(2*np.pi*(85/129))
exp87=np.cos(2*np.pi*(86/129))+i*np.sin(2*np.pi*(86/129))
exp88=np.cos(2*np.pi*(87/129))+i*np.sin(2*np.pi*(87/129))
exp89=np.cos(2*np.pi*(88/129))+i*np.sin(2*np.pi*(88/129))
exp90=np.cos(2*np.pi*(89/129))+i*np.sin(2*np.pi*(89/129))
exp91=np.cos(2*np.pi*(90/129))+i*np.sin(2*np.pi*(90/129))
exp92=np.cos(2*np.pi*(91/129))+i*np.sin(2*np.pi*(91/129))
exp93=np.cos(2*np.pi*(92/129))+i*np.sin(2*np.pi*(92/129))
exp94=np.cos(2*np.pi*(93/129))+i*np.sin(2*np.pi*(93/129))
exp95=np.cos(2*np.pi*(94/129))+i*np.sin(2*np.pi*(94/129))
exp96=np.cos(2*np.pi*(95/129))+i*np.sin(2*np.pi*(95/129))
exp97=np.cos(2*np.pi*(96/129))+i*np.sin(2*np.pi*(96/129))
exp98=np.cos(2*np.pi*(97/129))+i*np.sin(2*np.pi*(97/129))
exp99=np.cos(2*np.pi*(98/129))+i*np.sin(2*np.pi*(98/129))
exp100=np.cos(2*np.pi*(99/129))+i*np.sin(2*np.pi*(99/129))
exp101=np.cos(2*np.pi*(100/129))+i*np.sin(2*np.pi*(100/129))
exp102=np.cos(2*np.pi*(101/129))+i*np.sin(2*np.pi*(101/129))
exp103=np.cos(2*np.pi*(102/129))+i*np.sin(2*np.pi*(102/129))
exp104=np.cos(2*np.pi*(103/129))+i*np.sin(2*np.pi*(103/129))
exp105=np.cos(2*np.pi*(104/129))+i*np.sin(2*np.pi*(104/129))
exp106=np.cos(2*np.pi*(105/129))+i*np.sin(2*np.pi*(105/129))
exp107=np.cos(2*np.pi*(106/129))+i*np.sin(2*np.pi*(106/129))
exp108=np.cos(2*np.pi*(107/129))+i*np.sin(2*np.pi*(107/129))
exp109=np.cos(2*np.pi*(108/129))+i*np.sin(2*np.pi*(108/129))
exp110=np.cos(2*np.pi*(109/129))+i*np.sin(2*np.pi*(109/129))
exp111=np.cos(2*np.pi*(110/129))+i*np.sin(2*np.pi*(110/129))
exp112=np.cos(2*np.pi*(111/129))+i*np.sin(2*np.pi*(111/129))
exp113=np.cos(2*np.pi*(112/129))+i*np.sin(2*np.pi*(112/129))
exp114=np.cos(2*np.pi*(113/129))+i*np.sin(2*np.pi*(113/129))
exp115=np.cos(2*np.pi*(114/129))+i*np.sin(2*np.pi*(114/129))
exp116=np.cos(2*np.pi*(115/129))+i*np.sin(2*np.pi*(115/129))
exp117=np.cos(2*np.pi*(116/129))+i*np.sin(2*np.pi*(116/129))
exp118=np.cos(2*np.pi*(117/129))+i*np.sin(2*np.pi*(117/129))
exp119=np.cos(2*np.pi*(118/129))+i*np.sin(2*np.pi*(118/129))
```

```
exp120=np.cos(2*np.pi*(119/129))+i*np.sin(2*np.pi*(119/129))
exp121=np.cos(2*np.pi*(120/129))+i*np.sin(2*np.pi*(120/129))
exp122=np.cos(2*np.pi*(121/129))+i*np.sin(2*np.pi*(121/129))
exp123=np.cos(2*np.pi*(122/129))+i*np.sin(2*np.pi*(122/129))
exp124=np.cos(2*np.pi*(123/129))+i*np.sin(2*np.pi*(123/129))
exp125=np.cos(2*np.pi*(124/129))+i*np.sin(2*np.pi*(124/129))
exp126=np.cos(2*np.pi*(125/129))+i*np.sin(2*np.pi*(125/129))
exp127=np.cos(2*np.pi*(126/129))+i*np.sin(2*np.pi*(126/129))
exp128=np.cos(2*np.pi*(127/129))+i*np.sin(2*np.pi*(127/129))
exp129=np.cos(2*np.pi*(128/129))+i*np.sin(2*np.pi*(128/129))

exp=[exp1,exp2,exp3,exp4,exp5,exp6,exp7,exp8,exp9,exp10,exp11
,exp12,exp13,exp14,exp15,exp16,exp17,exp18,exp19,exp20,exp21,
exp22,exp23,exp24,exp25,exp26,exp27,exp28,exp29,exp30,exp31,e
xp32,exp33,exp34,exp35,exp36,exp37,exp38,exp39,exp40,exp41,ex
p42,exp43,exp44,exp45,exp46,exp47,exp48,exp49,exp50,exp51,exp
52,exp53,exp54,exp55,exp56,exp57,exp58,exp59,exp60,exp61,exp6
2,exp63,exp64,exp65,exp66,exp67,exp68,exp69,exp70,exp71,exp72
,exp73,exp74,exp75,exp76,exp77,exp78,exp79,exp80,exp81,exp82,
exp83,exp84,exp85,exp86,exp87,exp88,exp89,exp90,exp91,exp92,e
xp93,exp94,exp95,exp96,exp97,exp98,exp99,exp100,exp101,exp102
,exp103,exp104,exp105,exp106,exp107,exp108,exp109,exp110,exp1
11,exp112,exp113,exp114,exp115,exp116,exp117,exp118,exp119,ex
p120,exp121,exp122,exp123,exp124,exp125,exp126,exp127,exp128,
exp129]
exp

#transformasi Hilbert untuk
#Untuk K=1
sgn1=-i*np.sign(1-129/2)
rk1=x1*exp
sig1=sum(rk1)
hdr1=sgn1*sig1
z1t=x1+i*hdr1
z1t

plt.figure(figsize=(10, 6))
plt.plot(z1t, label=z1t)
plt.legend()
plt.title('BBRI KOMPLEKS')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()
```

```
# E[z1t-E(z1t)]*[(z1t-E(z1t))*]
e1=sum(z1t)/129
ze1=z1t-e1
z1tk=np.conj(z1t)
ze1k=np.conj(ze1)
z1tot=ze1*ze1k
ez1t=sum(z1tot)/129
ez1t

#transformasi Hilbert
#untuk k=2
sgn2=-i*np.sign(2-129/2)
rk2=x2*exp
sig2=sum(rk2)
hdr2=sgn2*sig2
z2t=x2+i*hdr2
z2t

plt.figure(figsize=(10, 6))
plt.plot(z2t, label=z2t)
plt.legend()
plt.title('KLBF KOMPLEKS')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()


#ekspektasi [z2t-E(z2t)]*[(z2t-E(z2t))*]
e2=sum(z2t)/129
ze2=z2t-e2
z2tk=np.conj(z2t)
ze2k=np.conj(ze2)
z2tot=ze2*ze2k
ez2t=sum(z2tot)/129
ez2t


#transformasi hilbert untuk k=3
sgn3=-i*np.sign(3-129/2)
rk3=x3*exp
sig3=sum(rk3)
hdr3=sgn3*sig3
z3t=x3+i*hdr3
z3t
```

```
plt.figure(figsize=(10, 6))
plt.plot(z3t, label=z3t)
plt.legend()
plt.title('AUD-IDR KOMPLEKS')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()

#ekspektasi [z2t-E(z2t)]*[(z2t-E(z2t))*]
e3=sum(z3t)/129
ze3=z3t-e3
z3tk=np.conj(z3t)
ze3k=np.conj(ze3)
z3tot=ze3*ze3k
ez3t=sum(z3tot)/129
ez3t


#transformasi hilbert
sgn4=-i*np.sign(4-129/2)
rk4=x4*exp
sig4=sum(rk4)
hdr4=sgn4*sig4
z4t=x4+i*hdr4
z4t

plt.figure(figsize=(10, 6))
plt.plot(z4t, label=z4t)
plt.legend()
plt.title('GBP-USD KOMPLEKS')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()

#ekspektasi [z4t-E(z4t)]*[(z4t-E(z4t))*]
e4=sum(z4t)/129
ze4=z4t-e4
z4tk=np.conj(z4t)
ze4k=np.conj(ze4)
z4tot=ze4*ze4k
ez4t=sum(z4tot)/129
ez4t
```

```
#transformasi hilbert
sgn5=-i*np.sign(5-129/2)
rk5=x5*exp
sig5=sum(rk5)
hdr5=sgn5*sig5
z5t=x5+i*hdr5
z5t

plt.figure(figsize=(10, 6))
plt.plot(z5t, label=z5t)
plt.legend()
plt.title('PLATINUM_F KOMPLEKS')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()

#ekspektasi [z5t-E(z5t)]*[(z5t-E(z5t))*]
e5=sum(z5t)/129
ze5=z5t-e5
z5tk=np.conj(z5t)
ze5k=np.conj(ze5)
z5tot=ze5*ze5k
ez5t=sum(z5tot)/129
ez5t

#transformasi hilbert
sgn6=-i*np.sign(6-129/2)
rk6=x6*exp
sig6=sum(rk6)
hdr6=sgn6*sig6
z6t=x6+i*hdr6
z6t

plt.figure(figsize=(10, 6))
plt.plot(z6t, label=z6t)
plt.legend()
plt.title('COPPER-F')
plt.xlabel('Date')
plt.ylabel('Portfolio Value')
plt.show()

#ekspektasi [z5t-E(z5t)]*[(z5t-E(z5t))*]
e6=sum(z6t)/129
```

```
ze6=z6t-e6
z6tk=np.conj(z6t)
ze6k=np.conj(ze6)
z6tot=ze6*ze6k
ez6t=sum(z6tot)/129
ez6t
```

untuk membuat matriks var-cov nilai ez1t dan ez2t digunakan sebagai nilai diagonal, sedangkan untuk nilai non diagonal dihitung dari nilai simetris antara z1t dan z2t

```
#ekpektasi [z1t-E(z1t)].(z2t-E[z2t])
z7tot=ze1*ze2
ez7t=sum(z7tot)/129
ez7t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z12tot=ze2*ze1
ez12t=sum(z12tot)/129
ez12t
#ekpektasi [z1t-E(z1t)].(z2t-E[z2t])*
z8tot=ze1*ze3
ez8t=sum(z8tot)/129
ez8t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z17tot=ze3*ze1
ez17t=sum(z17tot)/129
ez17t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z9tot=ze1*ze4
ez9t=sum(z9tot)/129
ez9t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z22tot=ze4*ze1
ez22t=sum(z22tot)/129
ez22t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z10tot=ze1*ze5
ez10t=sum(z10tot)/129
ez10t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z27tot=ze5*ze1
ez27t=sum(z27tot)/129
ez27t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z11tot=ze1*ze6
ez11t=sum(z11tot)/129
```

```
ez11t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z32tot=ze6*ze1
ez32t=sum(z32tot)/129
ez32t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z13tot=ze2*ze3
ez13t=sum(z13tot)/129
ez13t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z18tot=ze3*ze2
ez18t=sum(z18tot)/129
ez18t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z14tot=ze2*ze4
ez14t=sum(z14tot)/129
ez14t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z23tot=ze4*ze2
ez23t=sum(z23tot)/129
ez23t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z15tot=ze2*ze5
ez15t=sum(z15tot)/129
ez15t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z28tot=ze5*ze2
ez28t=sum(z28tot)/129
ez28t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z16tot=ze2*ze6
ez16t=sum(z16tot)/129
ez16t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z33tot=ze6*ze2
ez33t=sum(z33tot)/129
ez33t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z19tot=ze3*ze4
ez19t=sum(z19tot)/129
ez19t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z24tot=ze4*ze3
ez24t=sum(z24tot)/129
```

```
ez24t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z20tot=ze3*ze5
ez20t=sum(z20tot)/129
ez20t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z29tot=ze5*ze3
ez29t=sum(z29tot)/129
ez29t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z21tot=ze3*ze6
ez21t=sum(z21tot)/129
ez21t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z34tot=ze6*ze3
ez34t=sum(z34tot)/129
ez34t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z25tot=ze4*ze5
ez25t=sum(z25tot)/129
ez25t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z30tot=ze5*ze4
ez30t=sum(z30tot)/129
ez30t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z26tot=ze4*ze6
ez26t=sum(z26tot)/129
ez26t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z35tot=ze6*ze4
ez35t=sum(z35tot)/129
ez35t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z31tot=ze5*ze6
ez31t=sum(z31tot)/129
ez31t
#ekpektasi [z2t-E(z2t)].(z1t-E[z1t])*
z36tot=ze6*ze5
ez36t=sum(z36tot)/129
ez36t
print(z1t,z2t,z3t,z4t,z5t,z6t)
matrix=np.matrix([[ez1t,ez7t,ez8t,ez9t,ez10t,ez11t],[ez12t,ez
2t,ez13t,ez14t,ez15t,ez16t],[ez17t,ez18t,ez3t,ez19t,ez20t,ez2
```

```
1t],[ez22t,ez23t,ez24t,ez4t,ez25t,ez26t],[ez27t,ez28t,ez29t,e
z30t,ez5t,ez31t],[ez32t,ez33t,ez34t,ez35t,ez36t,ez6t]])
print(matrix)
```

```
matriks=np.matrix([[6.02459894e-03, 1.85680264e-03, -
1.47752110e-04, 2.24987946e-04, 1.20842282e-03, 7.79647292e-
04],
 [ 1.85680264e-03,  3.91820341e-03, -2.54887666e-04, -
3.41777273e-05, 5.68644054e-04, -2.15436657e-04],
 [-1.47752110e-04, -2.54887666e-04,  7.53113978e-
04,  2.74989814e-04, 3.78728775e-04, 5.47235663e-04],
 [ 2.24987946e-04, -3.41777273e-05, 2.74989814e-
04,  5.74913800e-04, 5.64124298e-04, 5.38447188e-04],
 [ 1.20842282e-03,  5.68644054e-04, 3.78728775e-
04,  5.64124298e-04, 6.54770579e-03,  1.63883233e-03],
 [ 7.79647292e-04, -2.15436657e-04, 5.47235663e-
04,   5.38447188e-04, 1.63883233e-03, 3.27643653e-03]])
df_wide = pd.DataFrame(
    {"BBRI": [6.02459894e-03, 1.85680264e-03, -1.47752110e-
04, 2.24987946e-04, 1.20842282e-03, 7.79647292e-04],
    "KALBE": [ 1.85680264e-03,  3.91820341e-03, -2.54887666e-
04, -3.41777273e-05, 5.68644054e-04, -2.15436657e-04],
     "AUD_IDR": [-1.47752110e-04, -2.54887666e-04,
7.53113978e-04,  2.74989814e-04, 3.78728775e-04, 5.47235663e-
04],
     "GBP_USD": [ 2.24987946e-04, -3.41777273e-05,
2.74989814e-04,  5.74913800e-04, 5.64124298e-04, 5.38447188e-
04],
    "PLATINUM_F" : [ 1.20842282e-03,  5.68644054e-04,
3.78728775e-04,  5.64124298e-04, 6.54770579e-
03,  1.63883233e-03],
      "COPPER_F" :  [ 7.79647292e-04, -2.15436657e-04,
5.47235663e-04,   5.38447188e-04, 1.63883233e-03,
3.27643653e-03]}
)
df_wide
noa = len(data.columns)
noa

phi = np.array(noa * [1 / noa])
phi

# Calculate the portfolio variance
port_variance = np.dot(phi.T,np.dot(df_wide,phi))
```

```
port_variance

# Calculate the portfolio volatility aka standard deviation
port_volatility = np.sqrt(port_variance)
port_volatility

port_volatility / noa  # "average" risk contribution\

#calculate the annual portfolio return
portfolio_simple_annual_return = np.sum(data.mean()*phi)*12
portfolio_simple_annual_return

percent_var = str(round(port_variance,2)*100)+'%'
percent_vola = str(round(port_volatility,2)*100)+'%'
percent_ret =
str(round(portfolio_simple_annual_return,2)*100)+'%'

print('Expected annual return: '+percent_ret)
print('Annual volatility/ risk: '+percent_vola)
print('Annual Variance: '+percent_var)

np.dot(df_wide, phi)

mvols = np.dot(df_wide, phi) / port_volatility  # marginal
volatilities
mvols
rc = mvols * phi  # risk contributions (%-points)
rc

rc.sum()
rrc = rc / rc.sum()  # relative risk contributions (%)
rrc

rrc.sum()
import matplotlib.pyplot as plt
plt.pie(rrc, labels=data.columns, autopct='%1.1f%%')
plt.title('CEW Relative Risk Contributions');
plt.bar(x=range(len(rrc)), height=rrc)
plt.title("Relative Risk Contributions'");
plt.show()
sum(rc / rc.sum())  # checking for sum of relative risk
contribution
def rel_risk_contributions(phi, data=data):
  port_variance
```

```
  df_wide
  mvols = np.dot(df_wide, phi) / port_volatility
  rc = mvols * phi
  rrc = rc / rc.sum()
  return rrc
rrc = rel_risk_contributions(phi)
rrc
plt.pie(rrc, labels=data.columns, autopct='%1.1f%%')
plt.title(' CEW COMPLEX Relative risk Contribution');
plt.bar(x=range(len(rrc)), height=rrc)
plt.title("Relative Risk Contributions'");
plt.show()
def mse_risk_contributions(phi, target, data=data):
    rc = rel_risk_contributions(phi, data)
    mse = ((rc - target) ** 2).mean()
    return mse * 100
mse_risk_contributions(phi, phi)
bnds = noa * [(0, 1),]
cons = {'type': 'eq', 'fun': lambda weights: weights.sum() -
1}

target = noa * [1 / noa,]  # risk parity as target
target
target = noa * [1 / noa,]  # risk parity as target
target = [0.1, 0.1, 0.1, 0.1,0.1,0.1]  # example risk budget
as target
target
opt = minimize(lambda w: mse_risk_contributions(w,
target=target), phi, bounds=bnds, constraints=cons)
opt
phi_ = opt['x']
phi_
plt.pie(phi_, labels=data.columns, autopct='%1.1f%%')
plt.title('Complex Optimal Portfolio Weights');
rrc=rel_risk_contributions(opt['x'])
rrc
plt.pie(rrc, labels=data.columns, autopct='%1.1f%%')
plt.title('Complex Relative Risk Contributions');
```