```
%load_ext autoreload
%autoreload 2
```

```
import pandas as pd
import utils.functions as f

import warnings

warnings.filterwarnings("ignore", message="Warning")
```

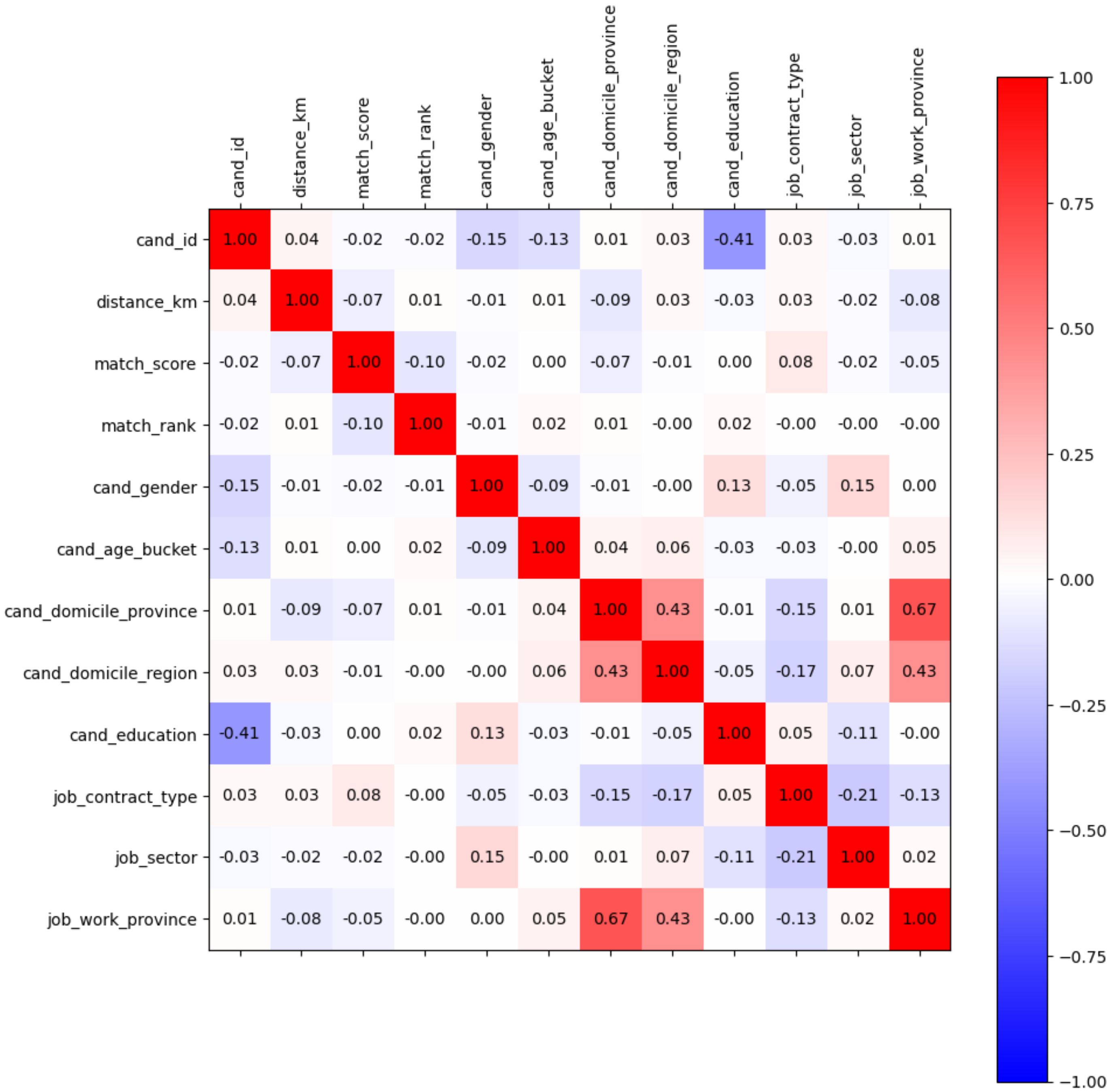
```
c:\Users\Lorenzo\miniconda3\lib\site-packages\torch\_functorch\deprecated.py:61: U
serWarning: We've integrated functorch into PyTorch. As the final step of the inte
gration, functorch.vmap is deprecated as of PyTorch 2.0 and will be deleted in a f
uture version of PyTorch >= 2.3. Please use torch.vmap instead; see the PyTorch 2.
0 release notes and/or the torch.func migration guide for more details https://pyt
orch.org/docs/master/func.migrating.html
  warn_deprecated('vmap', 'torch.vmap')
```

```
dataset = "direct_matching_20240213"  # "direct_matching_20240213" or "reverse_matc
df_processed = pd.read_csv(f"Data/{dataset}_processed.csv", sep=";")
```

```
df_lombardia = df_processed[df_processed["cand_domicile_region"] == 7]
df_emilia = df_processed[df_processed["cand_domicile_region"] == 3]
```

Correlation Matrix

```
selected_columns = [
    "cand_id",
    "distance_km",
    "match_score",
    "match_rank",
    "cand_gender",
    "cand_age_bucket",
    "cand_domicile_province",
    "cand_domicile_region",
    "cand_education",
    "job_contract_type",
    "job_sector",
    "job_work_province",
]
f.plot_correlation_matrix(df_processed, selected_columns)
```



Bias Detection

Gender Bias

Enconding:

- "Female": 0
- "Male": 1

```
df_processed.columns
```

```
Index(['cand_id', 'job_id', 'distance_km', 'match_score', 'match_rank',
       'cand_gender', 'cand_age_bucket', 'cand_domicile_province',
       'cand_domicile_region', 'cand_education', 'job_contract_type',
       'job_professional_category', 'job_sector', 'job_work_province',
       'Rumeno', 'Svedese', 'Arabo', 'Danese', 'Portoghese', 'Albanese',
       'Persiano', 'Spagnolo', 'Cinese', 'Ceco', 'Finlandese', 'Ebraico',
       'Serbo', 'Macedone', 'Croato', 'Tedesco'],
      dtype='object')
```

```
gender_bias = f.show_bias(df_processed, "cand_gender", 1, plot_histogram=True)
```

```
Skipped 3 jobs with no idoneous candidates in sector 0.
Skipped 6 jobs with no idoneous candidates in sector 4.
Skipped 7 jobs with no idoneous candidates in sector 7.
Skipped 8 jobs with no idoneous candidates in sector 2.
Skipped 3 jobs with no idoneous candidates in sector 9.
Skipped 6 jobs with no idoneous candidates in sector 3.
Skipped 5 jobs with no idoneous candidates in sector 6.
```

```
gender_bias.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	62.0	1.553677	1.951801	0.000000	0.331349	0.883598	1.988095	11.928571
1	10.0	1.283582	0.811418	0.238806	0.835821	1.432836	1.432836	3.223881
2	47.0	1.292536	1.058580	0.087636	0.481997	0.817935	1.402174	3.154891
3	34.0	1.360095	1.084921	0.144913	0.507194	0.788969	2.620504	3.043165
4	70.0	1.799874	1.379836	0.104839	0.629032	1.677419	3.774194	3.774194
5	157.0	1.609200	2.733702	0.000000	0.324982	0.731209	1.949891	26.323529
6	22.0	1.559176	1.267363	0.086683	0.462312	1.097990	3.120603	3.120603
7	276.0	1.381743	2.005795	0.000000	0.325852	0.868939	1.303409	11.730682
8	125.0	1.797275	3.000012	0.000000	0.276431	1.066234	1.658586	22.390909
9	24.0	1.211230	1.196251	0.107362	0.393661	0.644172	1.717791	3.865031

```
sector_gender_bias = gender_bias[gender_bias["Sector"] == 4]
print("Tot: ", sector_gender_bias["Job"].count())
print(
    "Less than 0.8: ",
    sector_gender_bias[sector_gender_bias["Disparate_Impact"] < 0.8]["Job"].count()
)
print(
    "Between: ",
    sector_gender_bias[
        (sector_gender_bias["Disparate_Impact"] >= 0.8)
        & (sector_gender_bias["Disparate_Impact"] < 1.3)
    ]["Job"].count(),
)
print(
    "More than 1.3",
    sector_gender_bias[sector_gender_bias["Disparate_Impact"] >= 1.3]["Job"].count(
)
```

```
Tot:  70
Less than 0.8:  22
Between:  12
More than 1.3 36
```

```
sector_gender_bias.sort_values(by="Disparate_Impact", ascending=False)
```

	Sector	Job	Disparate_Impact	Statistical_Parity_Difference	DIDI
35	4	OFF_960_1411	3.774194	0.016415	0.011565
59	4	ORD_3923_1635	3.774194	0.016415	0.011565
36	4	ORD_10703_0555	3.774194	0.016415	0.011565
27	4	OFF_3624_1635	3.774194	0.016415	0.011565
24	4	OFF_3560_1635	3.774194	0.016415	0.011565
...	...	...	...	...	...
29	4	OFF_442_1681	0.179724	-0.033976	0.023938
8	4	OFF_2730_0310	0.179724	-0.033976	0.023938
38	4	ORD_14202_0595	0.104839	-0.042374	0.029855
6	4	OFF_2172_0102	0.104839	-0.042374	0.029855
40	4	ORD_15139_0349	0.104839	-0.042374	0.029855

70 rows × 5 columns

```
gender_bias[["Disparate_Impact", "Statistical_Parity_Difference", "DIDI"]].corr()
```

	Disparate_Impact	Statistical_Parity_Difference	DIDI
Disparate_Impact	1.000000	0.475169	0.010368
Statistical_Parity_Difference	0.475169	1.000000	-0.535943
DIDI	0.010368	-0.535943	1.000000

Region comparison

```
gender_bias_lombardia = f.show_bias(df_lombardia, "cand_gender", 1, plot_histogram=
gender_bias_emilia = f.show_bias(df_emilia, "cand_gender", 1, plot_histogram=True)
```

```
gender_bias_lombardia.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	33.0	1.993002	2.895112	0.000000	0.157706	0.946237	2.365591	12.774194
1	8.0	1.053241	0.590374	0.401235	0.682099	0.962963	1.143519	2.166667
2	18.0	1.227977	1.020752	0.000000	0.383333	0.943590	1.415385	3.184615
3	20.0	1.396875	1.154942	0.250000	0.445313	0.875000	2.343750	3.375000
4	42.0	2.109434	1.659474	0.121324	0.727941	1.536765	4.367647	4.367647
5	93.0	1.462702	3.093362	0.000000	0.000000	0.692053	1.384106	24.913907
6	12.0	1.442474	1.487009	0.000000	0.258140	1.003876	2.151163	3.872093
7	126.0	1.295941	1.912911	0.000000	0.326984	0.653968	1.307937	11.771429
8	64.0	1.453834	2.286680	0.000000	0.000000	0.695489	1.715539	11.127820
9	17.0	1.215333	1.335988	0.111650	0.297735	0.558252	1.786408	4.019417

```
gender_bias_emilia.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	19.0	1.217075	1.565867	0.0	0.000000	0.366279	2.197674	5.860465
1	2.0	0.583333	0.824958	0.0	0.291667	0.583333	0.875000	1.166667
2	12.0	0.969987	1.145513	0.0	0.300805	0.549296	1.098592	3.295775
3	8.0	0.922902	0.614284	0.0	0.645408	0.829365	1.571429	1.571429
4	6.0	0.895161	0.924561	0.0	0.435484	0.580645	1.052419	2.612903
5	37.0	1.420707	2.051465	0.0	0.000000	0.716346	1.432692	6.685897
6	7.0	1.476190	1.517517	0.0	0.400000	0.933333	2.500000	3.600000
7	45.0	1.000974	1.268762	0.0	0.000000	0.468132	1.092308	4.369231
8	31.0	0.924265	0.909060	0.0	0.000000	0.967980	1.505747	3.387931
9	1.0	0.000000	NaN	0.0	0.000000	0.000000	0.000000	0.000000

Location Bias

```
location_bias = f.show_bias(df_processed, "same_location", 1, plot_histogram=True)
```

```
Skipped 4 jobs with no idoneous candidates in sector 0.
Skipped 3 jobs with no idoneous candidates in sector 4.
Skipped 6 jobs with no idoneous candidates in sector 8.
Skipped 15 jobs with no idoneous candidates in sector 5.
Skipped 24 jobs with no idoneous candidates in sector 7.
Skipped 2 jobs with no idoneous candidates in sector 2.
Skipped 3 jobs with no idoneous candidates in sector 9.
Skipped 3 jobs with no idoneous candidates in sector 3.
Skipped 6 jobs with no idoneous candidates in sector 6.
```

```
location_bias.groupby("Sector")["Disparate_Impact"].describe()
```

Sector	count	mean	std	min	25%	50%	75%	max
0	61.0	1.908632	2.664283	0.000000	0.288603	0.769608	2.693627	10.389706
1	10.0	1.630057	1.409194	0.142241	0.758621	1.327586	2.054850	5.120690
2	53.0	2.717351	3.920755	0.000000	0.155663	0.933977	3.268921	12.608696
3	37.0	1.952966	2.715943	0.000000	0.247326	0.659537	2.283688	8.903743
4	73.0	1.589397	2.450621	0.000000	0.324297	0.559908	1.945783	11.758065
5	142.0	1.847007	2.602538	0.000000	0.272174	0.729440	2.021024	9.831010
6	21.0	1.176284	1.589218	0.000000	0.196667	0.524444	1.835556	7.080000
7	259.0	2.104691	3.261898	0.000000	0.143234	0.846585	1.908632	11.474747
8	119.0	1.934512	2.963367	0.000000	0.318676	0.849802	1.912055	11.472332
9	24.0	2.256014	2.726213	0.000000	0.524571	0.864000	3.456000	7.776000

```
sector_location_bias = location_bias[location_bias["Sector"] == 4]
print("Tot: ", sector_location_bias["Job"].count())
print(
    "Less than 0.8: ",
    sector_location_bias[sector_location_bias["Disparate_Impact"] < 0.8]["Job"].cou
)
print(
    "Between: ",
    sector_location_bias[
        (sector_location_bias["Disparate_Impact"] >= 0.8)
        & (sector_location_bias["Disparate_Impact"] < 1.3)
    ]["Job"].count(),
)
print(
    "More than 1.3",
    sector_location_bias[sector_location_bias["Disparate_Impact"] >= 1.3][
        "Job"
    ].count(),
)
```

```
Tot:  73
Less than 0.8:  38
Between:  12
More than 1.3 23
```

```
sector_location_bias.sort_values(by="Disparate_Impact", ascending=False)
```

	Sector	Job	Disparate_Impact	Statistical_Parity_Difference	DIDI
67	4	ORD_4005_1635	11.758065	0.033204	0.014396
69	4	ORD_4030_1635	11.674699	0.033049	0.014387
30	4	OFF_3595_1635	11.674699	0.033049	0.014387
11	4	OFF_3394_4864	5.188755	0.025937	0.011291
32	4	OFF_4340_0035	5.188755	0.025937	0.011291
...	...	...	...	...	...
57	4	ORD_38011_3108	0.000000	-0.030960	0.013477
56	4	ORD_3750_1635	0.000000	-0.030488	0.013005
53	4	ORD_3712_1635	0.000000	-0.030675	0.013192
15	4	OFF_3428_1635	0.000000	-0.030960	0.013477
52	4	ORD_3696_1635	0.000000	-0.030488	0.013005

73 rows × 5 columns

```
location_bias[["Disparate_Impact", "Statistical_Parity_Difference", "DIDI"]].corr()
```

	Disparate_Impact	Statistical_Parity_Difference	DIDI
Disparate_Impact	1.000000	0.545539	0.100078
Statistical_Parity_Difference	0.545539	1.000000	-0.251424
DIDI	0.100078	-0.251424	1.000000

Region comparison

```
location_bias_lombardia = f.show_bias(df_lombardia, "same_location", 1, plot_histog
location_bias_emilia = f.show_bias(df_emilia, "same_location", 1, plot_histogram=Tr
```

```
location_bias_lombardia.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	32.0	1.944475	3.026007	0.000000	0.141197	0.782609	1.760870	10.565217
1	8.0	1.712435	1.466554	0.168750	0.664787	1.385791	2.193750	4.725000
2	18.0	1.804159	2.556385	0.000000	0.321597	0.977528	2.077247	9.000000
3	22.0	1.838867	2.169861	0.000000	0.332526	0.705405	2.843349	7.054054
4	41.0	1.418640	2.042375	0.000000	0.258389	0.671082	1.490132	8.707792
5	71.0	1.367978	1.773475	0.000000	0.246934	0.614865	2.114574	8.070000
6	9.0	1.102613	1.479848	0.000000	0.149351	0.746753	1.393939	4.779221
7	98.0	1.751295	2.607772	0.000000	0.235963	0.627506	1.535711	8.494652
8	55.0	2.072388	3.208145	0.000000	0.158861	0.555773	2.339367	11.484163
9	16.0	1.995458	1.889575	0.063158	0.568421	1.136842	2.842105	5.115789

```
location_bias_emilia.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	12.0	0.751134	0.736010	0.000000	0.223214	0.459184	1.004464	2.083333
1	2.0	0.571429	0.404061	0.285714	0.428571	0.571429	0.714286	0.857143
2	11.0	2.193104	3.740898	0.000000	0.320121	0.776316	1.812340	12.825000
3	6.0	0.596522	0.507482	0.098039	0.259979	0.453782	0.794118	1.470588
4	6.0	1.105159	0.928859	0.000000	0.678571	0.732143	1.875000	2.250000
5	19.0	0.687466	0.878159	0.000000	0.075817	0.341176	0.887059	3.120155
6	4.0	0.687500	0.544862	0.000000	0.375000	0.812500	1.125000	1.125000
7	28.0	1.345780	2.086660	0.000000	0.122275	0.444733	1.706055	9.687023
8	20.0	0.907457	0.969479	0.000000	0.172673	0.527268	1.554054	3.626126

Age Bias

Enconding:

- "15-24": 0
- "25-34": 1
- "35-44": 2
- "45-54": 3
- "55-74": 4

```python
age_bias = f.show_bias(df_processed, "cand_age_bucket", 1, plot_histogram=True)
```

```
Skipped 1 jobs with no idoneous candidates in sector 8.
Skipped 2 jobs with no idoneous candidates in sector 5.
Skipped 6 jobs with no idoneous candidates in sector 7.
Skipped 4 jobs with no idoneous candidates in sector 2.
Skipped 1 jobs with no idoneous candidates in sector 3.
```

```python
age_bias.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	65.0	1.493127	1.621764	0.084418	0.506507	1.139640	1.772773	6.837838
1	10.0	1.373469	1.187501	0.367347	0.571429	0.857143	1.821429	3.428571
2	51.0	1.458850	1.031153	0.140947	0.767380	1.315508	2.959893	2.959893
3	39.0	1.332807	1.009544	0.430769	0.646154	1.005128	1.723077	3.876923
4	76.0	1.407245	1.309268	0.090653	0.543915	1.223810	1.903704	7.342857
5	155.0	1.344250	1.179222	0.118405	0.710429	1.105112	1.894479	4.262577
6	27.0	1.526738	1.250524	0.288770	0.541444	1.010695	1.732620	3.898396
7	277.0	1.509060	1.166075	0.185361	0.648763	1.009187	1.730035	3.892580
8	124.0	1.464020	1.265382	0.133667	0.802000	1.247556	1.247556	4.812000
9	27.0	1.348321	0.989085	0.212302	0.849206	0.849206	1.627646	3.396825

```python
sector_age_bias = age_bias[age_bias["Sector"] == 3]
print("Tot: ", sector_age_bias["Job"].count())
print(
    "Less than 0.8: ",
    sector_age_bias[sector_age_bias["Disparate_Impact"] < 0.8]["Job"].count(),
)
print(
    "Between: ",
    sector_age_bias[
        (sector_age_bias["Disparate_Impact"] >= 0.8)
        & (sector_age_bias["Disparate_Impact"] < 1.3)
    ]["Job"].count(),
)
print(
    "More than 1.3",
    sector_age_bias[sector_age_bias["Disparate_Impact"] >= 1.3]["Job"].count(),
)
```

```
Tot:  39
Less than 0.8:  15
Between:  8
More than 1.3 16
```

```python
sector_age_bias.sort_values(by="Disparate_Impact", ascending=False)
```

	Sector	Job	Disparate_Impact	Statistical_Parity_Difference	DIDI

0	3	OFF_14847_0059	3.876923	0.025687	0.017953
14	3	OFF_3857_0382	3.876923	0.025687	0.017953
24	3	OFF_689_1363	3.876923	0.025687	0.017953
21	3	OFF_5614_1636	3.876923	0.025687	0.017953
33	3	ORD_20852_0082	1.723077	0.012912	0.009025
30	3	ORD_15646_0073	1.723077	0.012912	0.009025
28	3	OFF_8709_1176	1.723077	0.012912	0.009025
25	3	OFF_7150_0583	1.723077	0.012912	0.009025
23	3	OFF_652_1708	1.723077	0.012912	0.009025
22	3	OFF_651_1708	1.723077	0.012912	0.009025
18	3	OFF_5163_0275	1.723077	0.012912	0.009025
17	3	OFF_4767_0826	1.723077	0.012912	0.009025
19	3	OFF_5217_0344	1.723077	0.012912	0.009025
11	3	OFF_3552_0736	1.723077	0.012912	0.009025
12	3	OFF_3585_0533	1.723077	0.012912	0.009025
5	3	OFF_2429_0253	1.723077	0.012912	0.009025
13	3	OFF_3633_0533	1.005128	0.000137	0.000096
9	3	OFF_3374_0533	1.005128	0.000137	0.000096
36	3	ORD_53435_0059	1.005128	0.000137	0.000096
29	3	ORD_13808_0102	1.005128	0.000137	0.000096
7	3	OFF_3157_1698	1.005128	0.000137	0.000096
26	3	OFF_7178_0583	1.005128	0.000137	0.000096
1	3	OFF_14990_0059	1.005128	0.000137	0.000096
20	3	OFF_5591_0180	1.005128	0.000137	0.000096
10	3	OFF_3388_0533	0.646154	-0.012637	0.008833
27	3	OFF_8697_1176	0.646154	-0.012637	0.008833
16	3	OFF_4650_0018	0.646154	-0.012637	0.008833
31	3	ORD_20790_0379	0.646154	-0.012637	0.008833
32	3	ORD_20845_0082	0.646154	-0.012637	0.008833
2	3	OFF_15064_0059	0.646154	-0.012637	0.008833
8	3	OFF_3218_0533	0.430769	-0.025412	0.017761
35	3	ORD_44263_0544	0.430769	-0.025412	0.017761
37	3	ORD_7762_0583	0.430769	-0.025412	0.017761

15	3	OFF_4317_0035	0.430769	-0.025412	0.017761
3	3	OFF_15220_0059	0.430769	-0.025412	0.017761
34	3	ORD_3199_0736	0.430769	-0.025412	0.017761
4	3	OFF_1602_0072	0.430769	-0.025412	0.017761
6	3	OFF_2885_0454	0.430769	-0.025412	0.017761
38	3	ORD_7774_0583	0.430769	-0.025412	0.017761

```
age_bias[["Disparate_Impact", "Statistical_Parity_Difference", "DIDI"]].corr()
```

	Disparate_Impact	Statistical_Parity_Difference	DIDI
Disparate_Impact	1.000000	0.581954	0.101340
Statistical_Parity_Difference	0.581954	1.000000	-0.117596
DIDI	0.101340	-0.117596	1.000000

Region comparison

```
age_bias_lombardia = f.show_bias(df_lombardia, "same_location", 1, plot_histogram=T
age_bias_emilia = f.show_bias(df_emilia, "same_location", 1, plot_histogram=True)
```

```
age_bias_lombardia.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	32.0	1.944475	3.026007	0.000000	0.141197	0.782609	1.760870	10.565217
1	8.0	1.712435	1.466554	0.168750	0.664787	1.385791	2.193750	4.725000
2	18.0	1.804159	2.556385	0.000000	0.321597	0.977528	2.077247	9.000000
3	22.0	1.838867	2.169861	0.000000	0.332526	0.705405	2.843349	7.054054
4	41.0	1.418640	2.042375	0.000000	0.258389	0.671082	1.490132	8.707792
5	71.0	1.367978	1.773475	0.000000	0.246934	0.614865	2.114574	8.070000
6	9.0	1.102613	1.479848	0.000000	0.149351	0.746753	1.393939	4.779221
7	98.0	1.751295	2.607772	0.000000	0.235963	0.627506	1.535711	8.494652
8	55.0	2.072388	3.208145	0.000000	0.158861	0.555773	2.339367	11.484163
9	16.0	1.995458	1.889575	0.063158	0.568421	1.136842	2.842105	5.115789

```
age_bias_emilia.groupby("Sector")["Disparate_Impact"].describe()
```

	count	mean	std	min	25%	50%	75%	max
Sector								
0	12.0	0.751134	0.736010	0.000000	0.223214	0.459184	1.004464	2.083333
1	2.0	0.571429	0.404061	0.285714	0.428571	0.571429	0.714286	0.857143
2	11.0	2.193104	3.740898	0.000000	0.320121	0.776316	1.812340	12.825000
3	6.0	0.596522	0.507482	0.098039	0.259979	0.453782	0.794118	1.470588
4	6.0	1.105159	0.928859	0.000000	0.678571	0.732143	1.875000	2.250000
5	19.0	0.687466	0.878159	0.000000	0.075817	0.341176	0.887059	3.120155
6	4.0	0.687500	0.544862	0.000000	0.375000	0.812500	1.125000	1.125000
7	28.0	1.345780	2.086660	0.000000	0.122275	0.444733	1.706055	9.687023
8	20.0	0.907457	0.969479	0.000000	0.172673	0.527268	1.554054	3.626126