# STA130 Final Course Project (FINAL)

April 12, 2024

## 1 STA130 Final Course Project

### 1.1 Oscar Heath

We'll start by importing the data set, and adding columns of the error rate of the different models.

[1]:
```
import pandas as pd
import numpy as np
import scipy
import plotly.express as px
from sklearn.metrics import ConfusionMatrixDisplay
df_indicators = pd.read_csv('country_indicators.csv')
df_preds = pd.read_csv('test_predictions.csv')


df_preds['error_transformer'] = np.abs(df_preds['y_true_transformer'].
 ↪astype(float) - df_preds['y_pred_proba_transformer'])

df_preds['error_xgboost'] = np.abs(df_preds['y_true_xgboost'].astype(float) -␣
 ↪df_preds['y_pred_proba_xgboost'])

df_preds['error_ffnn'] = np.abs(df_preds['y_true_ffnn'].astype(float) -␣
 ↪df_preds['y_pred_proba_ffnn'])
```

This function creates indicator variables ('one hot' variables) as columns of our dataset in order for us to add some categorical variables to our model.

[2]:
```
import itertools

# Indicator variables are often called "one hot" encodings
def one_hot(df, cols):
    """ One-hot encode given `cols` and add as new columns
        to `df`

        Returns tuple of `df` with new columns and list of
        new column names.
    """
    new_cols = list()
```

```
    new_col_names = list()
    for each in cols:
        dummies = pd.get_dummies(df[each], prefix=each)
        new_cols.append(dummies)
        new_col_names.append(dummies.columns.values)

    df = pd.concat([df]+new_cols, axis=1)
    new_col_names = list(itertools.chain.from_iterable(new_col_names))
    return df, new_col_names
```

**1.2 Here we'll make an initial list of potentially useful columns for our model. We started with this whole list of variables, and then used backwards selection to eliminate the variables that caused massive colinearity. (We left in a few to show the process)**

[3]:
```
continuous_columns = [#'hdr_hdi_rank_2021',
                      #'fsi_total',
                     #'fsi_p3:_human_rights',
                     'hdr_coef_ineq_2021',
                      'hdr_hdi_m_2021',
                     ␣
 ↪'sowc_women-s-economic-empowerment__labour-force-participation-rate-2010-2020-r_male_total'
                     ␣
 ↪'sowc_women-s-economic-empowerment__labour-force-participation-rate-2010-2020-r_female_tota
                      'sowc_demographics__population-thousands-2021_under-5',
                     ␣
 ↪'sowc_demographics__annual-population-growth-rate_2000-2020',
                     ␣
 ↪'sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0',
                     ␣
 ↪'sowc_early-childhood-development__attendance-in-early-childhood-education-2013-2021-r_tota
                    ␣
 ↪#'sowc_maternal-and-newborn-health__delivery-care-2016-2021-r_c-section',
                    ␣
 ↪#'sowc_maternal-and-newborn-health__maternal-mortality-2020-c_lifetime-risk-of-maternal-dea
                     'sowc_demographics__life-expectancy-at-birth-years_2000-0',
                     #'fsi_p1:_state_legitimacy',
                     #'fsi_e3:_human_flight_and_brain_drain',
                     #'fsi_s2:_refugees_and_idps',
                     #'fsi_c1:_security_apparatus',
                     #'fsi_s1:_demographic_pressures',
                    ␣
 ↪#'sowc_demographics__annual-population-growth-rate_2020-2030-a',
                     #'hdr_gni_pc_f_2019',
                    ␣
 ↪#'sowc_migration__international-migrant-stock-2020_total-thousands',
```

```
                    #'sowc_migration__new-internal-displacements-2021_total-t',
                    ␣
 ↪#'sowc_wash__healthcare-facilities-2021_basic-hygiene-services_secondary'
]
```

### 1.3 Next, we merged df_indicators and df_preds together into one big dataset in order to more easily work with them, and added indicator variables for the 4 different fsi categories: 'Alert', 'Stable', 'Sustainable' and 'Warning.'

[4]:
```
df = df_preds.merge(df_indicators, left_on='iso3', right_on='iso3', how='inner')
df['fsi_rank'] = df['fsi_rank'].astype('string').str.replace(r'\D', '',␣
 ↪regex=True).replace('', pd.NA)
df = one_hot(df, ['fsi_category'])[0]


categorical_variables = ['fsi_category_Alert',
                         'fsi_category_Stable',
                         'fsi_category_Sustainable',
                         'fsi_category_Warning']
df
```

[4]:

| | yearmonth | fips | y_pred_transformer | y_pred_proba_transformer | \ |
|---|---|---|---|---|---|
| 0 | 202211 | FJ | False | 0.183897 | |
| 1 | 202212 | FJ | False | 0.267831 | |
| 2 | 202211 | TZ | False | 0.482585 | |
| 3 | 202212 | TZ | False | 0.187792 | |
| 4 | 202301 | TZ | True | 0.539319 | |
| .. | … | … | … | … | |
| 359 | 202211 | MJ | False | 0.182196 | |
| 360 | 202212 | MJ | False | 0.203236 | |
| 361 | 202211 | TD | True | 0.527107 | |
| 362 | 202212 | TD | True | 0.555677 | |
| 363 | 202301 | TD | True | 0.565700 | |

| | y_true_transformer | y_pred_xgboost | y_pred_proba_xgboost | y_true_xgboost | \ |
|---|---|---|---|---|---|
| 0 | False | False | 0.066500 | False | |
| 1 | False | False | 0.099643 | False | |
| 2 | False | True | 0.704086 | True | |
| 3 | False | True | 0.638444 | True | |
| 4 | True | True | 0.608380 | False | |
| .. | … | … | … | … | |
| 359 | False | False | 0.079453 | False | |
| 360 | False | False | 0.060189 | False | |
| 361 | False | True | 0.697625 | True | |
| 362 | False | True | 0.729246 | False | |
| 363 | True | True | 0.591722 | False | |

```
     y_pred_ffnn  y_pred_proba_ffnn  …  fsi_p2:_public_services  \
0          False           0.409958  …                      4.2
1          False           0.406696  …                      4.2
2           True           0.545236  …                      8.4
3           True           0.534560  …                      8.4
4           True           0.538583  …                      8.4
..           …                 …  …                    …
359        False           0.291874  …                      3.8
360        False           0.300321  …                      3.8
361        False           0.335496  …                      4.3
362        False           0.324000  …                      4.3
363        False           0.332455  …                      4.3

    fsi_p3:_human_rights  fsi_c1:_security_apparatus  \
0                    5.4                         6.4
1                    5.4                         6.4
2                    5.6                         4.6
3                    5.6                         4.6
4                    5.6                         4.6
..                   …                         …
359                  2.9                         4.0
360                  2.9                         4.0
361                  3.5                         7.3
362                  3.5                         7.3
363                  3.5                         7.3

     fsi_c2:_factionalized_elites  fsi_x1:_external_intervention  \
0                             8.2                           6.6
1                             8.2                           6.6
2                             6.5                           6.0
3                             6.5                           6.0
4                             6.5                           6.0
..                            …                           …
359                           6.5                           6.3
360                           6.5                           6.3
361                           5.6                           3.3
362                           5.6                           3.3
363                           5.6                           3.3

     fsi_category  fsi_category_Alert  fsi_category_Stable  \
0         Warning                   0                    0
1         Warning                   0                    0
2         Warning                   0                    0
3         Warning                   0                    0
4         Warning                   0                    0
..            …                   …                    …
```

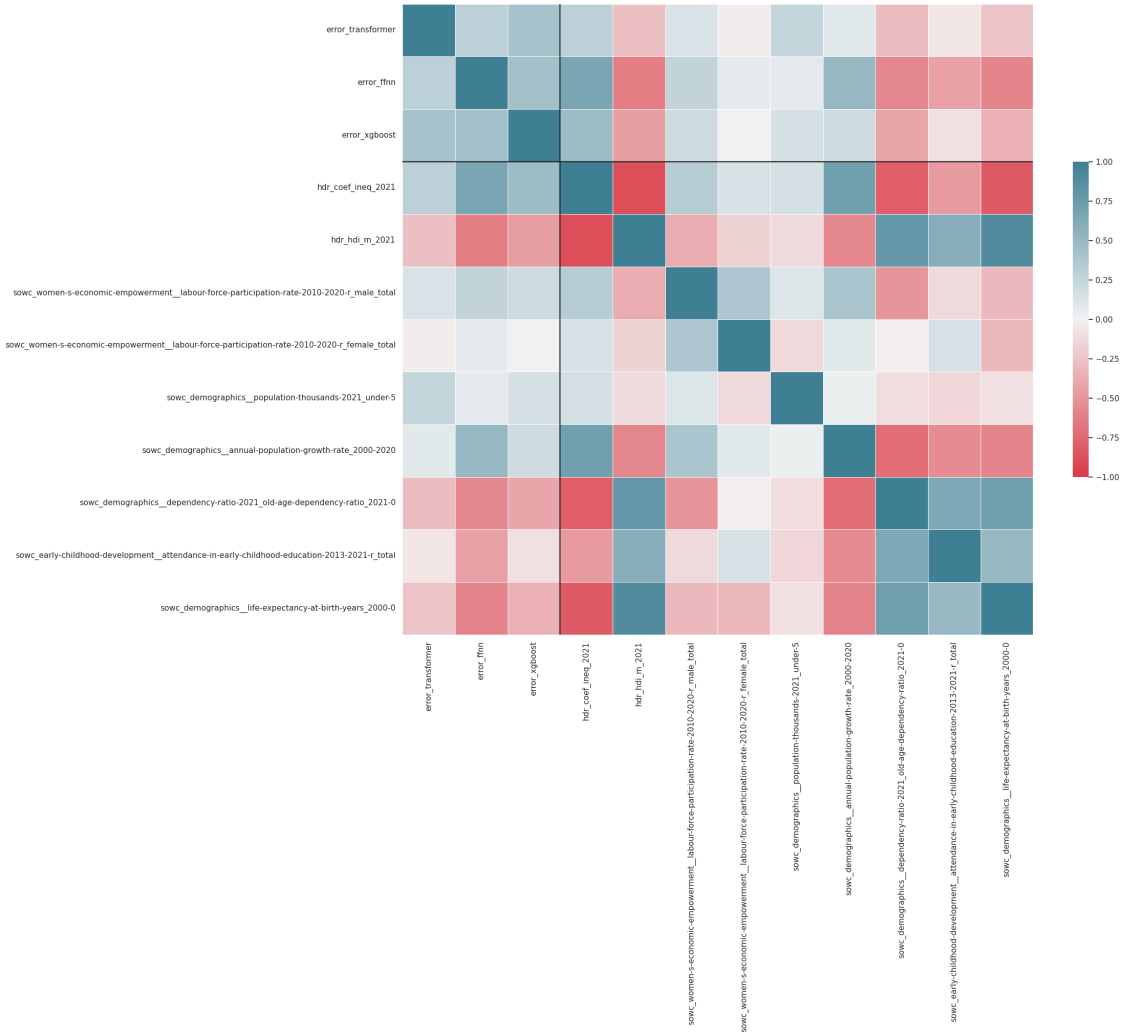
```
359        Stable                    0                    1
360        Stable                    0                    1
361        Stable                    0                    1
362        Stable                    0                    1
363        Stable                    0                    1

     fsi_category_Sustainable  fsi_category_Warning
0                           0                    1
1                           0                    1
2                           0                    1
3                           0                    1
4                           0                    1
..                        …                    …
359                         0                    0
360                         0                    0
361                         0                    0
362                         0                    0
363                         0                    0

[364 rows x 1350 columns]
```

### 1.4 We then created a correlation matrix in order to observe correlation between the variables

[5]:
```
import matplotlib.pyplot as plt
import seaborn as sns
# CODE FROM EVAN WHEELER AND SCOTT SCHWARTZ
def corr_heatmap(df):
    # plot correlation heatmap based on code from:
    # https://medium.com/@nikolh92/
 ↪helpful-visualisations-for-linear-regression-646a5648ad9d
    sns.set(style="white")
    corr = df.corr()
    mask = np.zeros_like(corr, dtype=bool)
    #mask[np.triu_indices_from(mask)] = True
    fig, ax = plt.subplots(figsize=(20, 16))

    cmap = sns.diverging_palette(10, 220, as_cmap=True)
    return sns.heatmap(corr, mask=mask, cmap=cmap, vmin=-1, vmax=1, center=0,␣
 ↪square=True,
                       linewidths=.5, annot=False, cbar_kws={"shrink": .5})
```

[6]:
```
corr_heatmap(df[['error_transformer','error_ffnn', 'error_xgboost'] +␣
 ↪continuous_columns])
_ = plt.axhline(y=3, c='k'); plt.axvline(x=3, c='k')
```

[6]: <matplotlib.lines.Line2D at 0x7fc1d10d3160>




### 1.5 There seems to be a few columns that have correlations with other columns, but we'll deal with them later...

### 1.6 Now, we standardize our continuous variables, and eliminate any unnecessary columns from our database (any columns we aren't studying). We also add a new temporary one-hot variable indicating which predictions the models made for each country.

[7]:
```
np.random.seed(1)
import statsmodels.api as sm

df[continuous_columns] = (df[continuous_columns] - df[continuous_columns].
↪mean())/df[continuous_columns].std()
```

```
df = df[['error_transformer','error_ffnn', 'error_xgboost',␣
 ↪'y_pred_transformer', 'y_pred_ffnn', 'y_pred_xgboost' ] + continuous_columns␣
 ↪+ categorical_variables]


df['model_transformer'] = df['error_transformer'].astype(str)*0+"transformer"
df['model_ffnn'] = df['error_ffnn'].astype(str)*0+"ffnn"
df['model_xgboost'] = df['error_xgboost'].astype(str)*0+"xgboost"


df['prediction_transformer'] = df.y_pred_transformer.astype(int)
df['prediction_ffnn'] = df.y_pred_ffnn.astype(int)
df['prediction_xgboost'] = df.y_pred_xgboost.astype(int)


df = df.dropna()
df
```

```
/tmp/ipykernel_63/719757629.py:9: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['model_transformer'] = df['error_transformer'].astype(str)*0+"transformer"
/tmp/ipykernel_63/719757629.py:10: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['model_ffnn'] = df['error_ffnn'].astype(str)*0+"ffnn"
/tmp/ipykernel_63/719757629.py:11: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['model_xgboost'] = df['error_xgboost'].astype(str)*0+"xgboost"
/tmp/ipykernel_63/719757629.py:14: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['prediction_transformer'] = df.y_pred_transformer.astype(int)
```

```
/tmp/ipykernel_63/719757629.py:15: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['prediction_ffnn'] = df.y_pred_ffnn.astype(int)
/tmp/ipykernel_63/719757629.py:16: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df['prediction_xgboost'] = df.y_pred_xgboost.astype(int)
```

[7]:

| | error_transformer | error_ffnn | error_xgboost | y_pred_transformer | \ |
|---|---|---|---|---|---|
| 10 | 0.708086 | 0.349594 | 0.692945 | True | |
| 11 | 0.183901 | 0.356072 | 0.662224 | False | |
| 12 | 0.539889 | 0.347548 | 0.665177 | True | |
| 16 | 0.461546 | 0.398537 | 0.480096 | False | |
| 17 | 0.346367 | 0.395459 | 0.410326 | False | |
| .. | … | … | … | … | |
| 356 | 0.184977 | 0.291478 | 0.241428 | False | |
| 357 | 0.201217 | 0.278109 | 0.189688 | False | |
| 358 | 0.202107 | 0.278429 | 0.236479 | False | |
| 359 | 0.182196 | 0.291874 | 0.079453 | False | |
| 360 | 0.203236 | 0.300321 | 0.060189 | False | |

| | y_pred_ffnn | y_pred_xgboost | hdr_coef_ineq_2021 | hdr_hdi_m_2021 | \ |
|---|---|---|---|---|---|
| 10 | False | True | -1.169841 | 0.554816 | |
| 11 | False | True | -1.169841 | 0.554816 | |
| 12 | False | True | -1.169841 | 0.554816 | |
| 16 | False | False | -0.119990 | -0.061256 | |
| 17 | False | True | -0.119990 | -0.061256 | |
| .. | … | … | … | … | |
| 356 | False | False | -0.852211 | 0.539857 | |
| 357 | False | False | -0.852211 | 0.539857 | |
| 358 | False | False | -0.852211 | 0.539857 | |
| 359 | False | False | -0.949603 | 0.759869 | |
| 360 | False | False | -0.949603 | 0.759869 | |

| | sowc_women-s-economic-empowerment__labour-force-participation-rate-2010-2020-r_male_total | \ |
|---|---|---|
| 10 | 0.348718 | |
| 11 | 0.348718 | |
| 12 | 0.348718 | |
| 16 | 1.140701 | |

```
17                                                1.140701
..                                                     …
356                                              -1.163249
357                                              -1.163249
358                                              -1.163249
359                                              -1.091251
360                                              -1.091251

     sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total  \
10                                                0.668604
11                                                0.668604
12                                                0.668604
16                                                0.098811
17                                                0.098811
..                                                     …
356                                              -0.278916
357                                              -0.278916
358                                              -0.278916
359                                              -0.285319
360                                              -0.285319

     …  fsi_category_Alert  fsi_category_Stable  fsi_category_Sustainable  \
10   …                   0                    0                         0
11   …                   0                    0                         0
12   …                   0                    0                         0
16   …                   0                    0                         0
17   …                   0                    0                         0
..   …                   …                    …                         …
356  …                   0                    0                         0
357  …                   0                    0                         0
358  …                   0                    0                         0
359  …                   0                    1                         0
360  …                   0                    1                         0

     fsi_category_Warning  model_transformer  model_ffnn  model_xgboost  \
10                      1        transformer        ffnn        xgboost
11                      1        transformer        ffnn        xgboost
12                      1        transformer        ffnn        xgboost
16                      1        transformer        ffnn        xgboost
17                      1        transformer        ffnn        xgboost
..                      …                  …           …             …
356                     1        transformer        ffnn        xgboost
357                     1        transformer        ffnn        xgboost
358                     1        transformer        ffnn        xgboost
359                     0        transformer        ffnn        xgboost
360                     0        transformer        ffnn        xgboost
```

```
     prediction_transformer  prediction_ffnn prediction_xgboost
10                        1                0                  1
11                        0                0                  1
12                        1                0                  1
16                        0                0                  0
17                        0                0                  1
..                      ...              ...                ...
356                       0                0                  0
357                       0                0                  0
358                       0                0                  0
359                       0                0                  0
360                       0                0                  0

[194 rows x 25 columns]
```

**1.7 All that's left to do for our design matrix to be done is to stack all the predictions together, and adding a indicator variables indicating whether the prediction was 1 or 0, as well as creating new variables modelling the continuous variable x our indicator variables of the model (ex: 'sowc_demographics___life-expectancy-at-birth-years_2000-0 X xgboost').**

[8]:
```
design_matrix = \
pd.concat([df[['error_transformer', 'model_transformer',␣
 ↪'prediction_transformer']+continuous_columns + categorical_variables].
 ↪rename(columns={'error_transformer':'error','model_transformer':
 ↪'model','prediction_transformer':'predicts1'}),
           df[['error_ffnn', 'model_ffnn',␣
 ↪'prediction_ffnn']+continuous_columns + categorical_variables].
 ↪rename(columns={'error_ffnn':'error','model_ffnn':'model','prediction_ffnn':
 ↪'predicts1'}),
           df[['error_xgboost', 'model_xgboost',␣
 ↪'prediction_xgboost']+continuous_columns + categorical_variables].
 ↪rename(columns={'error_xgboost':'error','model_xgboost':
 ↪'model','prediction_xgboost':'predicts1'})],
          ignore_index=True)

for x in continuous_columns:
    design_matrix[x+' X predicts1'] =␣
 ↪design_matrix[x]*design_matrix['predicts1']

design_matrix['transformer'] = (design_matrix['model']=="transformer").
 ↪astype(int)
design_matrix['xgboost'] = (design_matrix['model']=="xgboost").astype(int)
design_matrix['ffnn'] = (design_matrix['model']=="ffnn").astype(int)
```

```
for x in continuous_columns:
    design_matrix[x+' X transformer'] =␣
 ↪design_matrix[x]*design_matrix['transformer']
    design_matrix[x+' X xgboost'] = design_matrix[x]*design_matrix['xgboost']
    design_matrix[x+' X ffnn'] = design_matrix[x]*design_matrix['ffnn']

del design_matrix['model']

design_matrix
```

[8]:

| | error | predicts1 | hdr_coef_ineq_2021 | hdr_hdi_m_2021 | \ |
|---|---|---|---|---|---|
| 0 | 0.708086 | 1 | -1.169841 | 0.554816 | |
| 1 | 0.183901 | 0 | -1.169841 | 0.554816 | |
| 2 | 0.539889 | 1 | -1.169841 | 0.554816 | |
| 3 | 0.461546 | 0 | -0.119990 | -0.061256 | |
| 4 | 0.346367 | 0 | -0.119990 | -0.061256 | |
| .. | … | … | … | … | |
| 577 | 0.241428 | 0 | -0.852211 | 0.539857 | |
| 578 | 0.189688 | 0 | -0.852211 | 0.539857 | |
| 579 | 0.236479 | 0 | -0.852211 | 0.539857 | |
| 580 | 0.079453 | 0 | -0.949603 | 0.759869 | |
| 581 | 0.060189 | 0 | -0.949603 | 0.759869 | |

| | sowc_women-s-economic-empowerment__labour-force-participation-rate-2010-2020-r_male_total | \ |
|---|---|---|
| 0 | 0.348718 | |
| 1 | 0.348718 | |
| 2 | 0.348718 | |
| 3 | 1.140701 | |
| 4 | 1.140701 | |
| .. | … | |
| 577 | -1.163249 | |
| 578 | -1.163249 | |
| 579 | -1.163249 | |
| 580 | -1.091251 | |
| 581 | -1.091251 | |

| | sowc_women-s-economic-empowerment__labour-force-participation-rate-2010-2020-r_female_total | \ |
|---|---|---|
| 0 | 0.668604 | |
| 1 | 0.668604 | |
| 2 | 0.668604 | |
| 3 | 0.098811 | |
| 4 | 0.098811 | |
| .. | … | |
| 577 | -0.278916 | |
| 578 | -0.278916 | |

```
579                                          -0.278916
580                                          -0.285319
581                                          -0.285319

     sowc_demographics__population-thousands-2021_under-5  \
0                                            -0.215434
1                                            -0.215434
2                                            -0.215434
3                                             1.335775
4                                             1.335775
..                                                 …
577                                          -0.341889
578                                          -0.341889
579                                          -0.341889
580                                          -0.365332
581                                          -0.365332

     sowc_demographics__annual-population-growth-rate_2000-2020  \
0                                            -0.398971
1                                            -0.398971
2                                            -0.398971
3                                            -0.311809
4                                            -0.311809
..                                                 …
577                                          -1.050167
578                                          -1.050167
579                                          -1.050167
580                                          -1.360569
581                                          -1.360569

     sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0  \
0                                            -0.182514
1                                            -0.182514
2                                            -0.182514
3                                            -0.440773
4                                            -0.440773
..                                                 …
577                                           1.644375
578                                           1.644375
579                                           1.644375
580                                           0.970021
581                                           0.970021

     sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total  \
0                                             0.655604
1                                             0.655604
```

```
2                                                 0.655604
3                                                -0.766636
4                                                -0.766636
..                                                     …
577                                               0.856133
578                                               0.856133
579                                               0.856133
580                                               0.561015
581                                               0.561015

     …  sowc_demographics__annual-population-growth-rate_2000-2020 X ffnn  \
0    …                                                  -0.0
1    …                                                  -0.0
2    …                                                  -0.0
3    …                                                  -0.0
4    …                                                  -0.0
..   …                                                   …
577  …                                                  -0.0
578  …                                                  -0.0
579  …                                                  -0.0
580  …                                                  -0.0
581  …                                                  -0.0

     sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X
transformer  \
0                                                -0.182514
1                                                -0.182514
2                                                -0.182514
3                                                -0.440773
4                                                -0.440773
..                                                     …
577                                               0.000000
578                                               0.000000
579                                               0.000000
580                                               0.000000
581                                               0.000000

     sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X
xgboost  \
0                                                -0.000000
1                                                -0.000000
2                                                -0.000000
3                                                -0.000000
4                                                -0.000000
..                                                     …
577                                               1.644375
578                                               1.644375
```

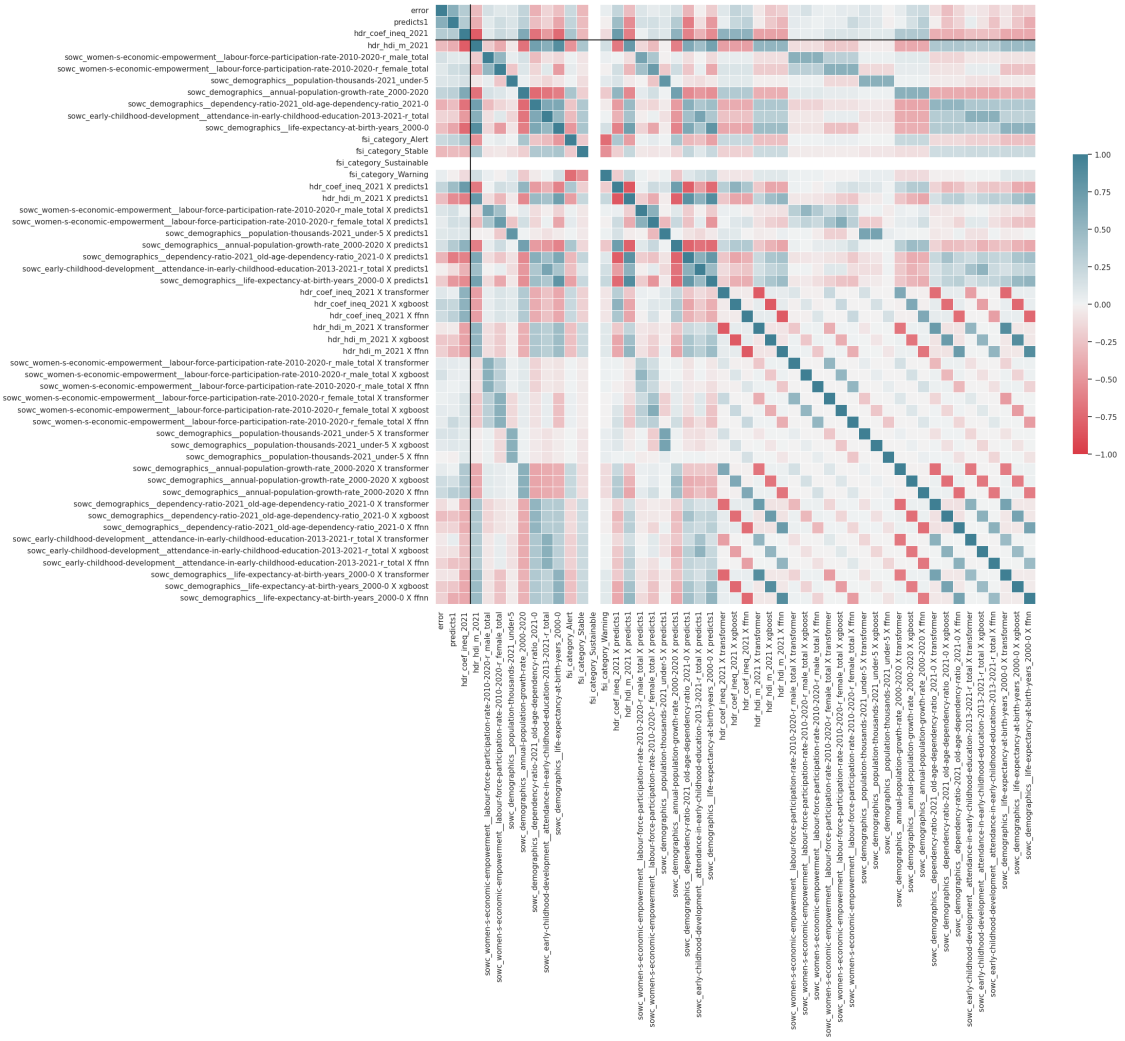
```
579                                                1.644375
580                                                0.970021
581                                                0.970021

     sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X
ffnn  \
0                                                     -0.0
1                                                     -0.0
2                                                     -0.0
3                                                     -0.0
4                                                     -0.0
..                                                     …
577                                                    0.0
578                                                    0.0
579                                                    0.0
580                                                    0.0
581                                                    0.0

     sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total X transformer  \
0                                                 0.655604
1                                                 0.655604
2                                                 0.655604
3                                                -0.766636
4                                                -0.766636
..                                                     …
577                                               0.000000
578                                               0.000000
579                                               0.000000
580                                               0.000000
581                                               0.000000

     sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total X xgboost  \
0                                                 0.000000
1                                                 0.000000
2                                                 0.000000
3                                                -0.000000
4                                                -0.000000
..                                                     …
577                                               0.856133
578                                               0.856133
579                                               0.856133
580                                               0.561015
581                                               0.561015

     sowc_early-childhood-development__attendance-in-early-childhood-
```

```
education-2013-2021-r_total X ffnn  \
0                                                0.0
1                                                0.0
2                                                0.0
3                                               -0.0
4                                               -0.0
..                                               …
577                                              0.0
578                                              0.0
579                                              0.0
580                                              0.0
581                                              0.0

     sowc_demographics__life-expectancy-at-birth-years_2000-0 X transformer  \
0                                           -0.177766
1                                           -0.177766
2                                           -0.177766
3                                            0.045545
4                                            0.045545
..                                                ...
577                                          0.000000
578                                          0.000000
579                                          0.000000
580                                          0.000000
581                                          0.000000

     sowc_demographics__life-expectancy-at-birth-years_2000-0 X xgboost  \
0                                           -0.000000
1                                           -0.000000
2                                           -0.000000
3                                            0.000000
4                                            0.000000
..                                                ...
577                                          0.541201
578                                          0.541201
579                                          0.541201
580                                          0.792712
581                                          0.792712

     sowc_demographics__life-expectancy-at-birth-years_2000-0 X ffnn
0                                               -0.0
1                                               -0.0
2                                               -0.0
3                                                0.0
4                                                0.0
..                                               …
577                                              0.0
```

```
578                                                 0.0
579                                                 0.0
580                                                 0.0
581                                                 0.0

[582 rows x 54 columns]
```

[9]:
```
design_matrix.iloc[:, 1:] # This is the ERROR of the prediction. We won't fix
 ↪it since it will change.

del design_matrix['ffnn']
del design_matrix['transformer']
del design_matrix['xgboost']

corr_heatmap(design_matrix)
_ = plt.axhline(y=3, c='k'); plt.axvline(x=3, c='k')
```

[9]:
```
<matplotlib.lines.Line2D at 0x7fc15159ee00>
```




**1.8 As this correlation matrix shows, the correlation is about the same as before (rather unsurprisingly, since the indicator variables x continuous variables only have correlation with themselves.**

[10]:
```
model1 = sm.OLS(design_matrix.error, sm.add_constant(design_matrix.iloc[:, 1:]))
design_matrix_model_1 = design_matrix.copy()
model1.fit().summary()
```

[10]:
```
<class 'statsmodels.iolib.summary.Summary'>
"""
                            OLS Regression Results
==============================================================================
Dep. Variable:                  error   R-squared:                       0.478
Model:                            OLS   Adj. R-squared:                  0.441
Method:                 Least Squares   F-statistic:                     12.74
```

```
Date:                Mon, 18 Dec 2023   Prob (F-statistic):           2.37e-54
Time:                        14:51:50   Log-Likelihood:                410.02
No. Observations:                 582   AIC:                           -740.0
Df Residuals:                     542   BIC:                           -565.4
Df Model:                          39
Covariance Type:            nonrobust
==============================================================================
==============================================================================
=============
                                coef    std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------
------------------------------------------------------------------------------
-------------
const
0.2696      0.008     33.272      0.000       0.254       0.285
predicts1
0.2110      0.019     11.310      0.000       0.174       0.248
hdr_coef_ineq_2021
0.0368      0.012      3.044      0.002       0.013       0.060
hdr_hdi_m_2021
0.0177      0.019      0.932      0.352      -0.020       0.055
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total                     0.0114      0.009      1.232
0.219      -0.007       0.030
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total                  -0.0059      0.010     -0.565
0.572      -0.026       0.015
sowc_demographics__population-thousands-2021_under-5
0.0105      0.012      0.871      0.384      -0.013       0.034
sowc_demographics__annual-population-growth-rate_2000-2020
0.0056      0.010      0.563      0.573      -0.014       0.025
sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0
-0.0473      0.014     -3.373      0.001      -0.075      -0.020
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total                     0.0198      0.009      2.269
0.024       0.003       0.037
sowc_demographics__life-expectancy-at-birth-years_2000-0
0.0049      0.018      0.271      0.786      -0.030       0.040
fsi_category_Alert
0.1302      0.013      9.868      0.000       0.104       0.156
fsi_category_Stable
0.0437      0.014      3.113      0.002       0.016       0.071
fsi_category_Sustainable
3.076e-17   1.71e-17      1.798      0.073   -2.85e-18    6.44e-17
fsi_category_Warning
0.0957      0.008     11.908      0.000       0.080       0.111
```

```
hdr_coef_ineq_2021 X predicts1
-0.0479      0.025     -1.882      0.060      -0.098       0.002
hdr_hdi_m_2021 X predicts1
-0.0404      0.036     -1.129      0.260      -0.111       0.030
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X predicts1        -0.0136      0.017     -0.790
0.430      -0.047       0.020
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X predicts1       0.0164      0.019      0.863
0.389      -0.021       0.054
sowc_demographics__population-thousands-2021_under-5 X predicts1
-0.0132      0.023     -0.574      0.566      -0.058       0.032
sowc_demographics__annual-population-growth-rate_2000-2020 X predicts1
0.0016      0.022      0.074      0.941      -0.041       0.044
sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X
predicts1                           0.0627      0.037      1.699      0.090
-0.010       0.135
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total X predicts1      -0.0199      0.019     -1.027
0.305      -0.058       0.018
sowc_demographics__life-expectancy-at-birth-years_2000-0 X predicts1
0.0495      0.031      1.577      0.115      -0.012       0.111
hdr_coef_ineq_2021 X transformer
0.0120      0.016      0.757      0.449      -0.019       0.043
hdr_coef_ineq_2021 X xgboost
0.0413      0.018      2.274      0.023       0.006       0.077
hdr_coef_ineq_2021 X ffnn
-0.0165      0.016     -1.013      0.311      -0.049       0.016
hdr_hdi_m_2021 X transformer
0.0307      0.023      1.363      0.174      -0.014       0.075
hdr_hdi_m_2021 X xgboost
0.0115      0.024      0.471      0.638      -0.037       0.060
hdr_hdi_m_2021 X ffnn
-0.0246      0.024     -1.039      0.299      -0.071       0.022
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X transformer      -0.0116      0.011     -1.058
0.291      -0.033       0.010
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X xgboost           0.0250      0.013      1.953
0.051      -0.000       0.050
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X ffnn             -0.0020      0.011     -0.173
0.862      -0.024       0.020
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X transformer     0.0183      0.012      1.529
0.127      -0.005       0.042
sowc_women-s-economic-empowerment__labour-force-participation-
```

```
rate-2010-2020-r_female_total X xgboost        -0.0139      0.014     -0.991
0.322      -0.041       0.014
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X ffnn           -0.0102      0.012     -0.841
0.401      -0.034       0.014
sowc_demographics__population-thousands-2021_under-5 X transformer
0.0209      0.013      1.641      0.101      -0.004       0.046
sowc_demographics__population-thousands-2021_under-5 X xgboost
0.0027      0.013      0.203      0.839      -0.023       0.028
sowc_demographics__population-thousands-2021_under-5 X ffnn
-0.0131      0.012     -1.069      0.286      -0.037       0.011
sowc_demographics__annual-population-growth-rate_2000-2020 X transformer
-0.0151      0.014     -1.105      0.270      -0.042       0.012
sowc_demographics__annual-population-growth-rate_2000-2020 X xgboost
0.0166      0.014      1.166      0.244      -0.011       0.045
sowc_demographics__annual-population-growth-rate_2000-2020 X ffnn
0.0040      0.014      0.290      0.772      -0.023       0.031
sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X
transformer                          -0.0375      0.019     -1.952      0.051
-0.075       0.000
sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X
xgboost                              -0.0008      0.021     -0.039      0.969
-0.042       0.040
sowc_demographics__dependency-ratio-2021_old-age-dependency-ratio_2021-0 X ffnn
-0.0090      0.020     -0.455      0.650      -0.048       0.030
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total X transformer    -0.0189      0.012     -1.638
0.102      -0.042       0.004
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total X xgboost         0.0310      0.012      2.577
0.010       0.007       0.055
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total X ffnn            0.0077      0.011      0.672
0.502      -0.015       0.030
sowc_demographics__life-expectancy-at-birth-years_2000-0 X transformer
0.0099      0.020      0.503      0.615      -0.029       0.049
sowc_demographics__life-expectancy-at-birth-years_2000-0 X xgboost
-0.0150      0.022     -0.672      0.502      -0.059       0.029
sowc_demographics__life-expectancy-at-birth-years_2000-0 X ffnn
0.0099      0.020      0.488      0.626      -0.030       0.050
==============================================================================
Omnibus:                       43.812   Durbin-Watson:                   1.993
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              183.550
Skew:                          -0.125   Prob(JB):                     1.39e-40
Kurtosis:                       5.740   Cond. No.                     1.51e+16
==============================================================================
```

```
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The smallest eigenvalue is 1.9e-29. This might indicate that there are
strong multicollinearity problems or that the design matrix is singular.
"""
```

**1.9 Here is the first run of our model. As we can see, this initial model is very flawed and suffers from strong multicolinearity, with a Condition Number of 1.51e+16, which is outrageously high.**

**1.10 First, we created Model 2 by removing all of the variables whose sum of values added up to less than 8, as these covariates were rather infrequent and so increased the condition number by a lot.**

[11]:
```
model_2variables = design_matrix.iloc[:, 1:].loc[:,design_matrix.sum()>8].
 ↪columns.tolist()

design_matrix_model_2 = design_matrix.copy()

for var in design_matrix.iloc[:, 1:].loc[:,design_matrix.sum()<= 8].columns.
 ↪tolist():
    del design_matrix[var]

model_2 = sm.OLS(design_matrix.error, sm.
 ↪add_constant(design_matrix[model_2variables]))
model_2.fit().summary()
```

[11]:
```
<class 'statsmodels.iolib.summary.Summary'>
"""
                            OLS Regression Results
==============================================================================
Dep. Variable:                  error   R-squared:                       0.448
Model:                            OLS   Adj. R-squared:                  0.424
Method:                 Least Squares   F-statistic:                     18.80
Date:                Mon, 18 Dec 2023   Prob (F-statistic):           6.42e-57
Time:                        14:51:50   Log-Likelihood:                393.33
No. Observations:                 582   AIC:                            -736.7
Df Residuals:                     557   BIC:                            -627.5
Df Model:                          24
Covariance Type:            nonrobust
==============================================================================
==============================================================================
=============
                                 coef    std err          t      P>|t|
[0.025      0.975]
------------------------------------------------------------------------------
```

```
------------------------------------------------------------------------------
-------------
const
0.2753      0.007     39.651      0.000       0.262       0.289
predicts1
0.1861      0.014     13.668      0.000       0.159       0.213
hdr_coef_ineq_2021
0.0424      0.009      4.677      0.000       0.025       0.060
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total                     0.0226      0.007      3.131
0.002       0.008       0.037
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total                  -0.0153      0.008     -1.982
0.048      -0.030      -0.000
sowc_demographics__population-thousands-2021_under-5
0.0157      0.012      1.351      0.177      -0.007       0.039
sowc_demographics__annual-population-growth-rate_2000-2020
0.0165      0.008      1.939      0.053      -0.000       0.033
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total                    0.0204      0.008      2.568
0.010       0.005       0.036
fsi_category_Alert
0.1192      0.011     10.458      0.000       0.097       0.142
fsi_category_Stable
0.0506      0.013      3.935      0.000       0.025       0.076
fsi_category_Warning
0.1055      0.007     14.339      0.000       0.091       0.120
hdr_coef_ineq_2021 X predicts1
-0.0607      0.018     -3.323      0.001      -0.097      -0.025
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X predicts1        -0.0198      0.015     -1.349
0.178      -0.049       0.009
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X predicts1       0.0053      0.015      0.361
0.718      -0.024       0.034
sowc_demographics__population-thousands-2021_under-5 X predicts1
-0.0308      0.022     -1.395      0.164      -0.074       0.013
sowc_demographics__annual-population-growth-rate_2000-2020 X predicts1
-0.0172      0.017     -1.015      0.310      -0.050       0.016
hdr_coef_ineq_2021 X transformer
0.0060      0.011      0.538      0.591      -0.016       0.028
hdr_coef_ineq_2021 X xgboost
0.0407      0.013      3.237      0.001       0.016       0.065
hdr_coef_ineq_2021 X ffnn
-0.0043      0.011     -0.387      0.699      -0.026       0.017
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X transformer       0.0002      0.009      0.023
```

```
0.982      -0.018       0.019
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X xgboost           0.0235      0.011      2.220
0.027       0.003       0.044
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X ffnn             -0.0011      0.010     -0.117
0.907      -0.020       0.018
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X transformer    -0.0012      0.009     -0.135
0.892      -0.019       0.017
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X xgboost        -0.0062      0.011     -0.580
0.562      -0.027       0.015
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total X ffnn           -0.0079      0.009     -0.838
0.402      -0.026       0.011
sowc_demographics__population-thousands-2021_under-5 X transformer
0.0274      0.012      2.238      0.026       0.003       0.051
sowc_demographics__population-thousands-2021_under-5 X xgboost
0.0101      0.013      0.809      0.419      -0.014       0.035
sowc_demographics__population-thousands-2021_under-5 X ffnn
-0.0218      0.012     -1.878      0.061      -0.045       0.001
sowc_demographics__annual-population-growth-rate_2000-2020 X transformer
-0.0002      0.011     -0.016      0.987      -0.021       0.021
sowc_demographics__annual-population-growth-rate_2000-2020 X xgboost
0.0021      0.012      0.177      0.860      -0.021       0.025
sowc_demographics__annual-population-growth-rate_2000-2020 X ffnn
0.0146      0.011      1.301      0.194      -0.007       0.037
==============================================================================
Omnibus:                       35.373   Durbin-Watson:                   1.925
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              122.822
Skew:                          -0.098   Prob(JB):                     2.14e-27
Kurtosis:                       5.242   Cond. No.                     1.27e+16
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The smallest eigenvalue is 1.37e-29. This might indicate that there are
strong multicollinearity problems or that the design matrix is singular.
"""
```

**1.11 This eliminated some of the condition number number, but it is still extremely high**

**1.12 Using backwards selection, we eliminated variables with the p-values higher than 0.3 one by one, and ended up with Model 3.**

[12]:
```
model_3variables = model_2variables.copy()
vars_to_remove = []
for i in range (1, len(model_2.fit().summary().tables[1].data)):
    covariate = model_2.fit().summary().tables[1].data[i]
    if float(covariate[4]) > 0.3:
        vars_to_remove.append(covariate[0])

for var in vars_to_remove:
    model_3variables.remove(var)
    del design_matrix[var]

model_3variables.remove('fsi_category_Warning')
del design_matrix['fsi_category_Warning']
```

[14]:
```
model3 = sm.OLS(design_matrix.error, sm.
 ↪add_constant(design_matrix[model_3variables]))
model3.fit().summary()
```

[14]:
```
<class 'statsmodels.iolib.summary.Summary'>
"""
                            OLS Regression Results
==============================================================================
Dep. Variable:                  error   R-squared:                       0.445
Model:                            OLS   Adj. R-squared:                  0.428
Method:                 Least Squares   F-statistic:                     26.60
Date:                Mon, 18 Dec 2023   Prob (F-statistic):           3.54e-61
Time:                        14:51:58   Log-Likelihood:                392.00
No. Observations:                 582   AIC:                            -748.0
Df Residuals:                     564   BIC:                            -669.4
Df Model:                          17
Covariance Type:            nonrobust
==============================================================================
==============================================================================
=========
                            coef    std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------
------------------------------------------------------------------------------
---------
const
0.3809      0.009     42.164      0.000       0.363       0.399
predicts1
```

```
0.1857      0.013     14.197      0.000       0.160       0.211
hdr_coef_ineq_2021
0.0467      0.011      4.335      0.000       0.026       0.068
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total                 0.0220      0.009      2.496
0.013       0.005       0.039
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total              -0.0190      0.007     -2.906
0.004      -0.032      -0.006
sowc_demographics__population-thousands-2021_under-5
0.0266      0.023      1.177      0.240      -0.018       0.071
sowc_demographics__annual-population-growth-rate_2000-2020
0.0141      0.010      1.410      0.159      -0.006       0.034
sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total               0.0219      0.008      2.793
0.005       0.006       0.037
fsi_category_Alert
0.0126      0.014      0.894      0.372      -0.015       0.040
fsi_category_Stable
-0.0557      0.018     -3.140      0.002      -0.091      -0.021
hdr_coef_ineq_2021 X predicts1
-0.0712      0.013     -5.353      0.000      -0.097      -0.045
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X predicts1    -0.0175      0.011     -1.555
0.121      -0.040       0.005
sowc_demographics__population-thousands-2021_under-5 X predicts1
-0.0316      0.022     -1.457      0.146      -0.074       0.011
hdr_coef_ineq_2021 X xgboost
0.0406      0.013      3.114      0.002       0.015       0.066
sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X xgboost       0.0239      0.012      2.039
0.042       0.001       0.047
sowc_demographics__population-thousands-2021_under-5 X transformer
0.0169      0.011      1.478      0.140      -0.006       0.039
sowc_demographics__population-thousands-2021_under-5 X ffnn
-0.0325      0.023     -1.441      0.150      -0.077       0.012
sowc_demographics__annual-population-growth-rate_2000-2020 X ffnn
0.0090      0.013      0.694      0.488      -0.017       0.035
==============================================================================
Omnibus:                       33.764   Durbin-Watson:                   1.915
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              113.528
Skew:                          -0.087   Prob(JB):                     2.23e-25
Kurtosis:                       5.157   Cond. No.                         12.7
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
```

```
specified.
"""
```

### 1.13 This model is looking much better, with a much lower condition number of 12.7, and maintains a reasonable $R^2$ of 0.445.

[37]:
```
design_matrix.columns.tolist()[1:]
```

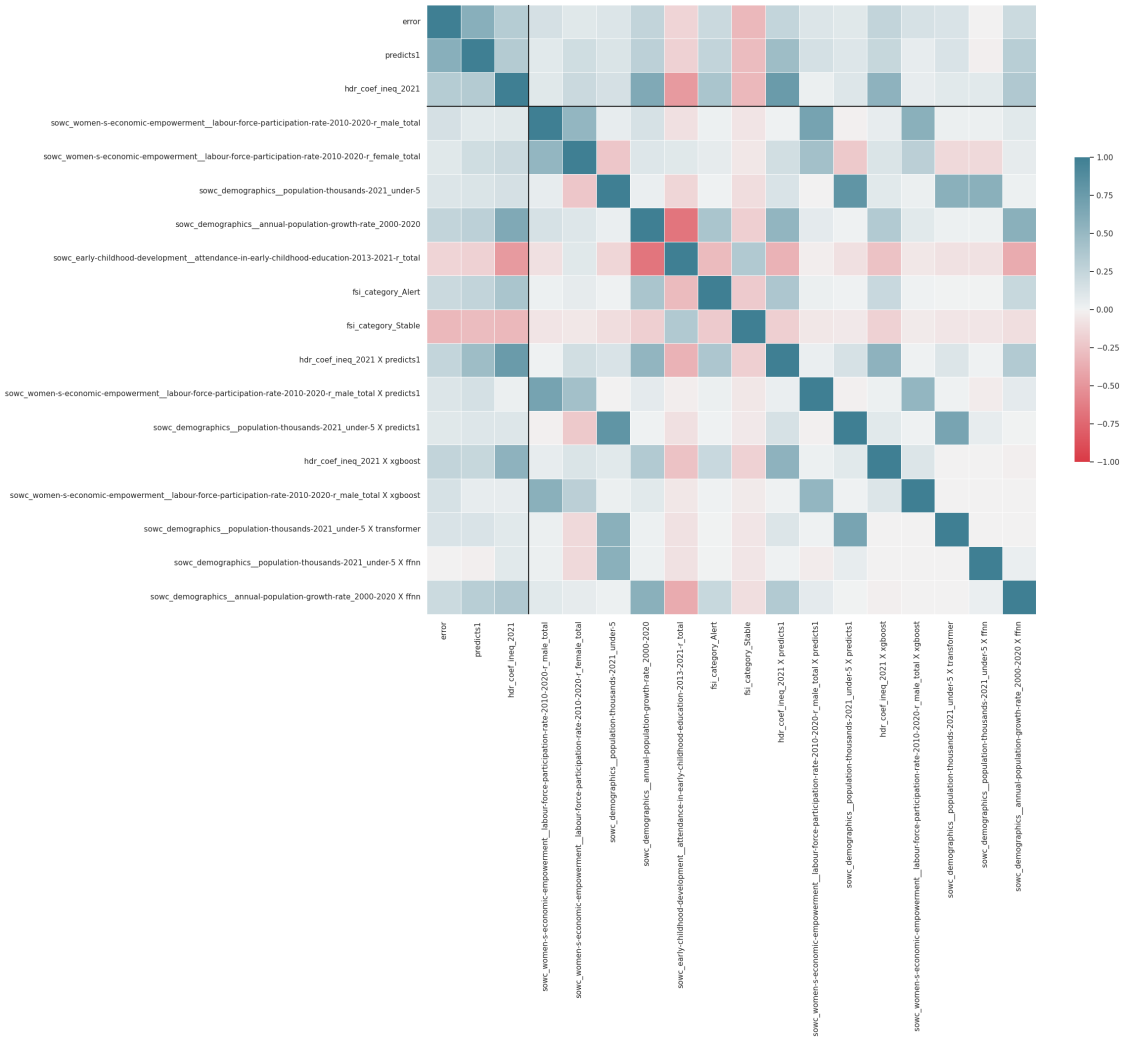
[37]:
```
['predicts1',
 'hdr_coef_ineq_2021',
 'sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total',
 'sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_female_total',
 'sowc_demographics__population-thousands-2021_under-5',
 'sowc_demographics__annual-population-growth-rate_2000-2020',
 'sowc_early-childhood-development__attendance-in-early-childhood-
education-2013-2021-r_total',
 'fsi_category_Alert',
 'fsi_category_Stable',
 'hdr_coef_ineq_2021 X predicts1',
 'sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X predicts1',
 'sowc_demographics__population-thousands-2021_under-5 X predicts1',
 'hdr_coef_ineq_2021 X xgboost',
 'sowc_women-s-economic-empowerment__labour-force-participation-
rate-2010-2020-r_male_total X xgboost',
 'sowc_demographics__population-thousands-2021_under-5 X transformer',
 'sowc_demographics__population-thousands-2021_under-5 X ffnn',
 'sowc_demographics__annual-population-growth-rate_2000-2020 X ffnn']
```

### 1.14 These are our final covariates.

[38]:
```
from sklearn import tree, model_selection
```

[39]:
```
corr_heatmap(design_matrix[['error'] + model_3variables])
_ = plt.axhline(y=3, c='k'); plt.axvline(x=3, c='k')
```

[39]:
```
<matplotlib.lines.Line2D at 0x7fb3957ff970>
```




**1.15 If we look at the correlation matrix of the final covariates model_3variables, we can see that the correlation isn't very strong anymore between the variables, which shows that there is very little multicolinearity between them.**

**1.16 Finally, we train-tested the models to show how effective each one was.**

[40]:
```
np.random.seed(7)
```

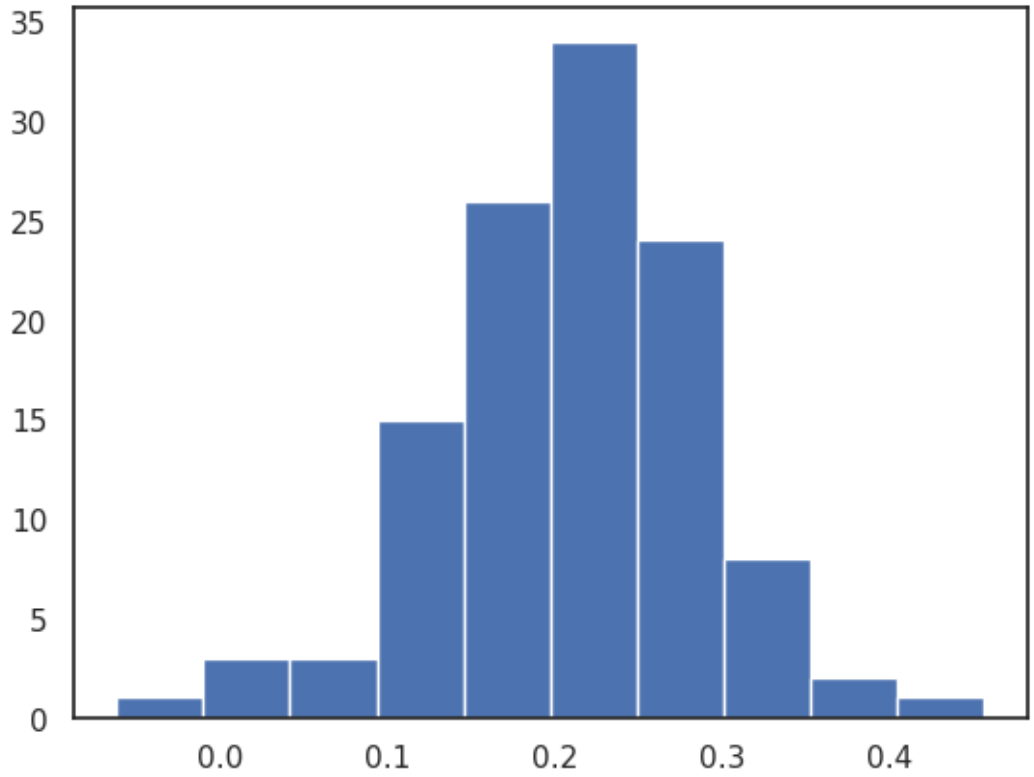
[41]:
```
from sklearn import tree, model_selection
import statistics
y = design_matrix.error

train3, test3 = model_selection.train_test_split(design_matrix, train_size=0.8)
```

```
train2, test2 = model_selection.train_test_split(design_matrix_model_2,␣
 ↪train_size=0.8)
train1, test1 = model_selection.train_test_split(design_matrix_model_1,␣
 ↪train_size=0.8)


model_3_train_test_fit = sm.OLS(train3.error, sm.add_constant(train3.iloc[:, 1:
 ↪])).fit()
model_3_train_RMSE = ((train3.error - model_3_train_test_fit.predict())**2).
 ↪mean()**.5
model_3_test_RMSE = ((test3.error -
                      model_3_train_test_fit.predict(sm.add_constant(test3.
 ↪iloc[:, 1:]))
                     )**2).mean()**.5

model_2_train_test_fit = sm.OLS(train2.error, sm.add_constant(train2.iloc[:, 1:
 ↪])).fit()
model_2_train_RMSE = ((train2.error - model_2_train_test_fit.predict())**2).
 ↪mean()**.5
model_2_test_RMSE = ((test2.error -
                      model_2_train_test_fit.predict(sm.add_constant(test2.
 ↪iloc[:, 1:]))
                     )**2).mean()**.5

model_1_train_test_fit = sm.OLS(train1.error, sm.add_constant(train1.iloc[:, 1:
 ↪])).fit()
model_1_train_RMSE = ((train1.error - model_1_train_test_fit.predict())**2).
 ↪mean()**.5
model_1_test_RMSE = ((test1.error -
                      model_1_train_test_fit.predict(sm.add_constant(test1.
 ↪iloc[:, 1:]))
                     )**2).mean()**.5


import plotly.express as px

fig = px.bar(pd.DataFrame({'RMSE': [model_1_train_RMSE, model_2_train_RMSE,␣
 ↪model_3_train_RMSE] +
                            [model_1_test_RMSE, model_2_test_RMSE,␣
 ↪model_3_test_RMSE],
                      'Score': ['Training']*3+['Testing']*3,
                      'Model': [1,2,3]+[1,2,3]}),
       y='RMSE', x='Model', color='Score', barmode='group')

fig.show()
```

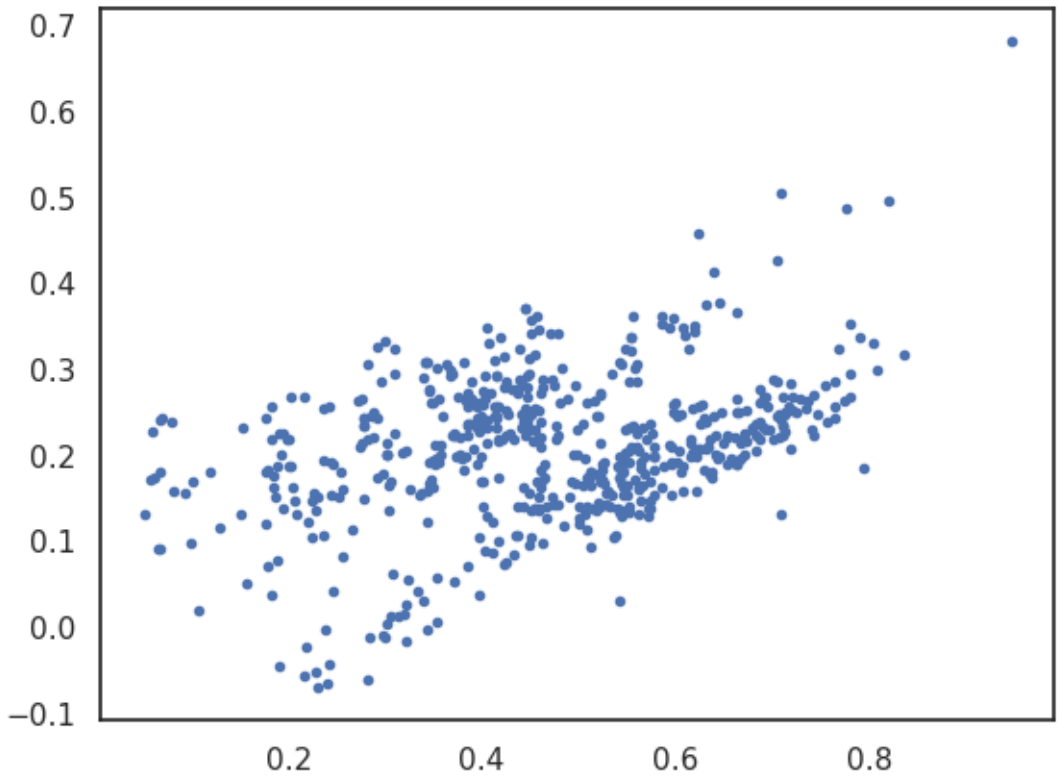
**2 As we can see, Model 1 has the highest RMSE on the test data (in red) followed by Model 2, followed by Model 3 with the lowest (which actually performed better on the test data!).**

[42]:
```
errors =[]
for i in range (len(test3)):
    errors.append(test3.error.values[i] - model_3_train_test_fit.predict(test3).
 ↪values[i])
```

[43]:
```
_ = plt.hist(y-model_3_train_test_fit.predict(test3))
```




[47]:
```
px.scatter(errors, trendline = 'ols')
#_ = plt.plot(model_3_train_test_fit.predict(test3)+0.05*np.random.
 ↪uniform(size=len(test3)), test3.error-model_3_train_test_fit.predict(test3),␣
 ↪'.')

_ = plt.plot(design_matrix.error, design_matrix.error-model_3_train_test_fit.
 ↪predict(design_matrix), '.')
```




### 2.1 As we can see, normality distribution of the errors seems good, and the homoskedasticity also seems fairly good.

### 2.2 Final thoughts / room for improvement

Our model is of course not perfect by any means. First of all, there are certainly more variables that we could find that could make our model's predictions more accurate. Additionally, our model counts the error of a prediction as the absolute value of the true outcome minus the predicted outcome without differentiating between if the prediction is a type 1 or type 2 error. For example, a prediction of 0.6 when there actually isn't conflict is weighted the same as a prediction of 0.4 when there actually is conflict. However, in this context, a prediction of 0.4 when there actually is conflict (a type 2 error or false negative) is actually worse than a prediction of 0.6 when there actually isn't conflict (a type 1 error or false positive). This is because in the context of conflict escalation, it is better to be prepared for conflict when there isn't any than to be unprepared for conflict when there is. However, this raises an ethical question: how much accuracy are we willing to sacrifice in exchange for higher sensitivity? (the capacity of the model to correctly assess true positives).

[ ]: