Explainable AutoML - Titanic Survival Classification Demo

In [1]:
```
# Author Hussain Abbas
# Copyright © Stats AI 2021. All Rights Reserved

import tensorflow as tf
import autokeras as ak
from tensorflow.keras import backend as K
import keras_tuner
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import re
from sklearn.model_selection import cross_val_score, KFold, train_test_split
from sklearn.metrics import roc_auc_score, precision_score, recall_score, fbeta_score, roc_curve
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from tqdm import tqdm
```

In [2]:
```
# Verify GPU is detected and working
print("Num GPUs Available: ", len(tf.config.list_physical_devices('GPU')))
```

```
Num GPUs Available:  1
```

In [3]:
```
TRAIN_DATA_URL = "https://storage.googleapis.com/tf-datasets/titanic/train.csv"
TEST_DATA_URL = "https://storage.googleapis.com/tf-datasets/titanic/eval.csv"

#datasets located in C:/Users/USER/.keras/datasets

train_file_path = tf.keras.utils.get_file("train.csv", TRAIN_DATA_URL)
test_file_path = tf.keras.utils.get_file("eval.csv", TEST_DATA_URL)

train_data = pd.read_csv(train_file_path)
test_data = pd.read_csv(test_file_path)

df = pd.concat([train_data, test_data])
df.drop_duplicates(inplace=True)
df = df.reset_index()
df = df.drop(['index'], axis=1)

print('All Data Summary')
print(df.describe())
print('\n')

print('Train Data Summary')
print(train_data.describe())
print('\n')

print('Test Data Summary')
print(test_data.describe())
```

```
All Data Summary
         survived         age  n_siblings_spouses       parch        fare
count  781.000000  781.000000          781.000000  781.000000  781.000000
mean     0.413572   29.622817            0.524968    0.417414   34.750464
std      0.492789   13.764671            0.987592    0.838132   52.237906
min      0.000000    0.420000            0.000000    0.000000    0.000000
25%      0.000000   22.000000            0.000000    0.000000    8.050000
50%      0.000000   28.000000            0.000000    0.000000   15.900000
75%      1.000000   36.000000            1.000000    1.000000   34.020800
max      1.000000   80.000000            8.000000    6.000000  512.329200


Train Data Summary
         survived         age  n_siblings_spouses       parch        fare
count  627.000000  627.000000          627.000000  627.000000  627.000000
mean     0.387560   29.631308            0.545455    0.379585   34.385399
std      0.487582   12.511818            1.151090    0.792999   54.597730
min      0.000000    0.750000            0.000000    0.000000    0.000000
25%      0.000000   23.000000            0.000000    0.000000    7.895800
50%      0.000000   28.000000            0.000000    0.000000   15.045800
75%      1.000000   35.000000            1.000000    0.000000   31.387500
max      1.000000   80.000000            8.000000    5.000000  512.329200


Test Data Summary
         survived         age  n_siblings_spouses       parch        fare
count  264.000000  264.000000          264.000000  264.000000  264.000000
mean     0.375000   28.720985            0.469697    0.386364   27.023880
std      0.485042   14.157538            0.978393    0.837775   34.973108
min      0.000000    0.420000            0.000000    0.000000    0.000000
25%      0.000000   21.000000            0.000000    0.000000    7.925000
50%      0.000000   28.000000            0.000000    0.000000   13.250000
75%      1.000000   35.250000            1.000000    0.000000   27.900000
max      1.000000   74.000000            8.000000    6.000000  263.000000
```

In [4]:
```
print('Train Data')
train_data.head()
```

Train Data

Out[4]:

	survived	sex	age	n_siblings_spouses	parch	fare	class	deck	embark_town	alone
0	0	male	22.0	1	0	7.2500	Third	unknown	Southampton	n
1	1	female	38.0	1	0	71.2833	First	C	Cherbourg	n
2	1	female	26.0	0	0	7.9250	Third	unknown	Southampton	y
3	1	female	35.0	1	0	53.1000	First	C	Southampton	n
4	0	male	28.0	0	0	8.4583	Third	unknown	Queenstown	y

In [5]:
```
print('Test Data')
test_data.head()
```

Test Data

Out[5]:

	survived	sex	age	n_siblings_spouses	parch	fare	class	deck	embark_town	alone
0	0	male	35.0	0	0	8.0500	Third	unknown	Southampton	y
1	0	male	54.0	0	0	51.8625	First	E	Southampton	y
2	1	female	58.0	0	0	26.5500	First	C	Southampton	y
3	1	female	55.0	0	0	16.0000	Second	unknown	Southampton	y
4	1	male	34.0	0	0	13.0000	Second	D	Southampton	y

In [6]:
```
def recall_m(y_true, y_pred):
    true_positives = K.sum(K.round(K.clip(y_true * y_pred, 0, 1)))
    possible_positives = K.sum(K.round(K.clip(y_true, 0, 1)))
    recall = true_positives / (possible_positives + K.epsilon())
    return recall

def precision_m(y_true, y_pred):
    true_positives = K.sum(K.round(K.clip(y_true * y_pred, 0, 1)))
    predicted_positives = K.sum(K.round(K.clip(y_pred, 0, 1)))
    precision = true_positives / (predicted_positives + K.epsilon())
    return precision

def f_beta_score(y_true, y_pred):

    a = 0.5 ** 2
    b = 1 + a

    precision = precision_m(y_true, y_pred)

    recall = recall_m(y_true, y_pred)

    return b*((precision*recall)/(a*precision+recall+K.epsilon()))


def ak_predict(model, data):

    pred_input = data.astype(np.compat.unicode)
    predicted = model.predict(pred_input).flatten()
    pred_result = predicted

    #cut_off = 0.5

    #pred_result = [1 if x > cut_off else 0 for x in predicted]

    return pred_result

def jdl(y_true, y_pred, smooth=100):
    """
    Jaccard = (|X & Y|)/ (|X|+ |Y| - |X & Y|)
            = sum(|A*B|)/(sum(|A|)+sum(|B|)-sum(|A*B|))

    The jaccard distance loss is usefull for unbalanced datasets. This has been
    shifted so it converges on 0 and is smoothed to avoid exploding or disapearing
    gradient.

    Ref: https://en.wikipedia.org/wiki/Jaccard_index

    @url: https://gist.github.com/wassname/f1452b748efcbeb4cb9b1d059dce6f96
    @author: wassname
    """
    intersection = K.sum(K.abs(y_true * y_pred), axis=-1)
    sum_ = K.sum(K.abs(y_true) + K.abs(y_pred), axis=-1)
    jac = (intersection + smooth) / (sum_ - intersection + smooth)
    return (1 - jac) * smooth
```

In [7]:
```python
from tensorflow.keras.utils import CustomObjectScope
from sklearn.utils import class_weight

with CustomObjectScope({'f_beta_score': f_beta_score,
                        'jdl': jdl, }):

    results = []

    # number of times we partition the data into training/test set
    outer_loop_folds = 1

    # number of times we partition the training data into training/validation set
    inner_loop_folds = 1

    #max_trials: Default= 100. The max num of different models to try
    num_trials = 20

    #epochs: If unspecified, we use epochs equal to 1000 and early stopping with patience equal to 30

    Early_Stopping = tf.keras.callbacks.EarlyStopping(monitor='val_f_beta_score', patience=101)


    for j in tqdm(range(outer_loop_folds)):

        #Randomly split df into 80% train, 20% test

        x_train, x_test, y_train, y_test = train_test_split(df.drop('survived', axis=1),
                                                             df.survived, test_size=0.2,
                                                            stratify = df.survived)

        for i in tqdm(range(inner_loop_folds)):

            # Further randomly split the 80% train into 64% train and 16% validation

            x_inner_train, x_inner_val, y_inner_train, y_inner_val = train_test_split(x_train,
                                                             y_train, test_size=0.2,
                                                            stratify = y_train)

            w = y_inner_train.value_counts(normalize = True)[0]/y_inner_train.value_counts(normalize = True)[1]
            cw = {0: 1., 1: w}
            #cw = {0: 1., 1: 0.5}


            # Try max_trial different models
            clf = ak.StructuredDataClassifier(
                overwrite=True,
                max_trials = num_trials,

                #tuner = 'random',
                #tuner = 'hyperband',
                tuner = 'bayesian',

                metrics=[jdl,
                        'binary_crossentropy',
                         tf.keras.metrics.AUC(name='auc'),
                        tf.keras.metrics.BinaryAccuracy(name='accuracy'),
                         tf.keras.metrics.Precision(name='precision'),
                         tf.keras.metrics.Recall(name='recall'),
                         f_beta_score],

                objective=keras_tuner.Objective('val_f_beta_score', direction='max'),
                #objective=keras_tuner.Objective('val_jdl', direction='min'),

                #loss = jdl,

            )

            try:
                # Fit the best model
                clf.fit(x_inner_train, y_inner_train,
                        validation_data = (x_inner_val, y_inner_val),
                        #class_weight = cw
                        epochs = 3000,
                        callbacks = [Early_Stopping]
                       )

                # Predict with the best model
                x = clf.evaluate(x_test, y_test)
                x_test_loss, x_jdl, x_bc, x_auc, x_accuracy, x_precision, x_recall, x_f_beta_score= x

                # Save the results
                model_name = 'model_autokeras_' + str(j) + '_'+ str(i)

                results.append([model_name, j, i,
                                x_test_loss, x_jdl, x_bc,
                                x_auc, x_accuracy,
                                x_precision, x_recall,
                                x_f_beta_score])

            except:
                print("Issue training model")

            try:
                # Save the model after each j, i iteration
                model = clf.export_model()
```

```
            model.save(model_name, save_format="tf")

        except:
            print("Issue saving model")


results = pd.DataFrame(results, columns = ['model_name', 'j', 'i', 'Test_loss','Loss:JDL', 'Loss:Binary Cross Entropy',
                                           'AUC', 'Accuracy', 'Precision', 'Recall', 'F_Beta_Score'])
```

```
Trial 20 Complete [00h 00m 27s]
val_f_beta_score: 0.8885974287986755

Best val_f_beta_score So Far: 0.9095396399497986
Total elapsed time: 00h 11m 39s
INFO:tensorflow:Oracle triggered exit
WARNING:tensorflow:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` wil
l be empty until you train or evaluate the model.
INFO:tensorflow:Assets written to: .\structured_data_classifier\best_model\assets
WARNING:tensorflow:Unresolved object in checkpoint: (root).optimizer.iter
WARNING:tensorflow:Unresolved object in checkpoint: (root).optimizer.beta_1
WARNING:tensorflow:Unresolved object in checkpoint: (root).optimizer.beta_2
WARNING:tensorflow:Unresolved object in checkpoint: (root).optimizer.decay
WARNING:tensorflow:Unresolved object in checkpoint: (root).optimizer.learning_rate
WARNING:tensorflow:A checkpoint was restored (e.g. tf.train.Checkpoint.restore or tf.keras.Model.load_weights) but not a
ll checkpointed values were used. See above for specific issues. Use expect_partial() on the load status object, e.g. t
f.train.Checkpoint.restore(...).expect_partial(), to silence these warnings, or use assert_consumed() to make the check
explicit. See https://www.tensorflow.org/guide/checkpoint#loading_mechanics (https://www.tensorflow.org/guide/checkpoint
#loading_mechanics) for details.
5/5 [==============================] - 1s 7ms/step - loss: 0.5867 - jdl: 0.4320 - binary_crossentropy: 0.5867 - auc: 0.8
290 - accuracy: 0.7707 - precision: 0.7736 - recall: 0.6308 - f_beta_score: 0.7413
INFO:tensorflow:Assets written to: model_autokeras_0_0\assets


100%|██████████████████████████████████████████████████| 1/1 [11:50<00:00, 710.33s/it]
100%|██████████████████████████████████████████████████| 1/1 [11:50<00:00, 710.33s/it]
```

In [8]:
```
%%capture cap --no-stderr
clf.tuner.results_summary()
```

In [9]:
```
with open('model_val_info.txt', 'w') as f:
    f.write(str(cap))

z = open('model_val_info.txt').read()
z = re.findall(r'Score: ([^/]+)', z)
z = np.array([x.split()[0] for x in z]).astype(np.float)
```

In [10]:
```
results.describe()
```

Out[10]:

	j	i	Test_loss	Loss:JDL	Loss:Binary Cross Entropy	AUC	Accuracy	Precision	Recall	F_Beta_Score
count	1.0	1.0	1.000000	1.00000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
mean	0.0	0.0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339
std	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
min	0.0	0.0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339
25%	0.0	0.0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339
50%	0.0	0.0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339
75%	0.0	0.0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339
max	0.0	0.0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339

In [11]:
```
results['F1_Beta_Val'] = z.max()
```

In [12]:
```
results
```

Out[12]:

	model_name	j	i	Test_loss	Loss:JDL	Loss:Binary Cross Entropy	AUC	Accuracy	Precision	Recall	F_Beta_Score	F1_Beta_Val
0	model_autokeras_0_0	0	0	0.586716	0.43196	0.586716	0.829013	0.770701	0.773585	0.630769	0.741339	0.90954

In [13]:
```
#best_model = results.loc[np.argmax(results.test_accuracy)].model_name

best_model = results.loc[np.argmax(results.F_Beta_Score)].model_name


best_model
```

Out[13]: 'model_autokeras_0_0'

In [14]:
```
from tensorflow.keras.models import load_model

my_custom_objects={'f_beta_score': f_beta_score,
                   'jdl': jdl, }
my_custom_objects.update(ak.CUSTOM_OBJECTS)

model_ak = load_model(best_model, custom_objects=my_custom_objects)
```

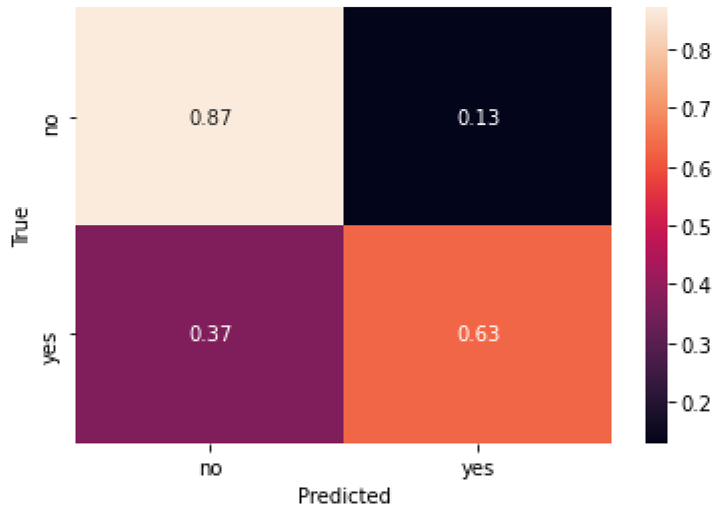
In [15]:
```
model_ak.summary()
```

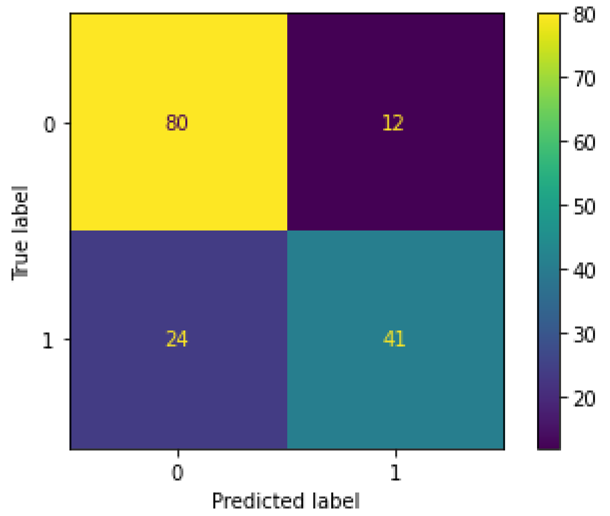
```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_1 (InputLayer)         [(None, 9)]               0         
_________________________________________________________________
multi_category_encoding (Mul (None, 9)                 0         
_________________________________________________________________
dense (Dense)                (None, 1024)              10240     
_________________________________________________________________
batch_normalization (BatchNo (None, 1024)              4096      
_________________________________________________________________
re_lu (ReLU)                 (None, 1024)              0         
_________________________________________________________________
dropout (Dropout)            (None, 1024)              0         
_________________________________________________________________
dropout_1 (Dropout)          (None, 1024)              0         
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 1025      
_________________________________________________________________
classification_head_1 (Activ (None, 1)                 0         
=================================================================
Total params: 15,361
Trainable params: 13,313
Non-trainable params: 2,048
_________________________________________________________________
```

In [16]:

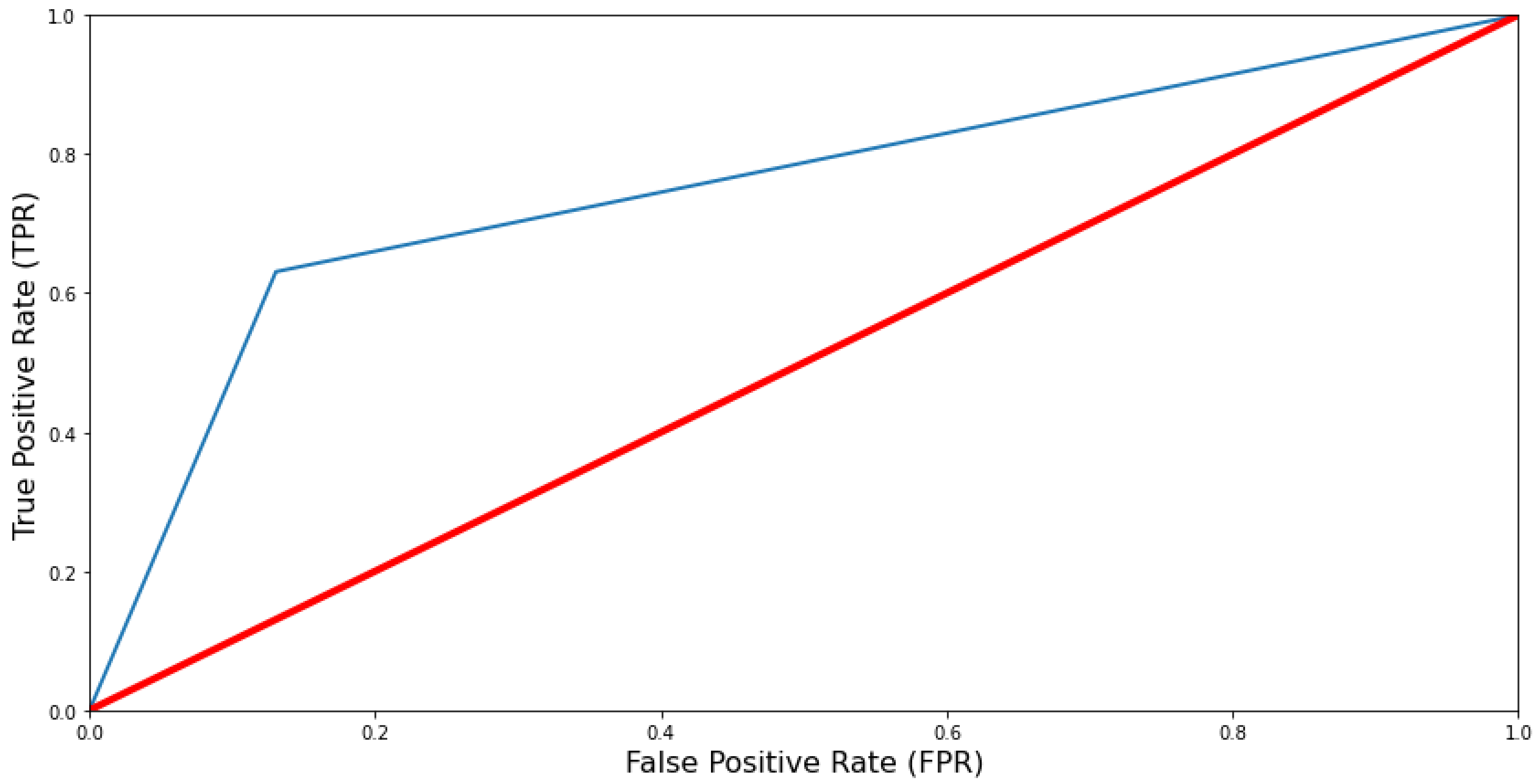
```python
# type: pandas.core.frame.DataFrame
pred_input = x_test.astype(np.compat.unicode)

# type: numpy.ndarray
predicted = model_ak.predict(pred_input).flatten()

cut_off = 0.5

pred_result = [1 if x > cut_off else 0 for x in predicted]
pred_result = np.array(pred_result)

actual = y_test.to_numpy()
actual = actual.flatten()

cm = tf.math.confusion_matrix(actual, pred_result)
cm = cm/cm.numpy().sum(axis=1)[:, tf.newaxis]

sns.heatmap(
    cm, annot=True,
    xticklabels=['no', 'yes'],
    yticklabels=['no', 'yes'])
plt.xlabel("Predicted")
plt.ylabel("True")


'''
https://towardsdatascience.com/accuracy-precision-recall-or-f1-331fb37c5cb9
https://stackoverflow.com/questions/44172162/f1-score-vs-roc-auc

- Maximize Precision when False Positives are of concern
- Maximize Recall when False Negatives are of concern
- Maximize F1 Score when both are important and classes are unbalanced

'''

auc_score = roc_auc_score(actual, pred_result)
precision = precision_score(actual, pred_result)
recall = recall_score(actual, pred_result)
f_beta = fbeta_score(actual, pred_result, beta = 0.5)

print("Cut-Off:", cut_off)
print("ROC-AUC-Score:", auc_score)
print('Precision: ' + str(precision))
print('Recall: ' + str(recall))
print('F_Beta: ' + str(f_beta))

y_test_classes = list(set(y_test))

# print Confusion Matrix from SkLearn
cm = confusion_matrix(actual, pred_result, labels = y_test_classes)

#cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels = y_test_classes)
disp.plot();
```

```
Cut-Off: 0.5
ROC-AUC-Score: 0.7501672240802675
Precision: 0.7735849056603774
Recall: 0.6307692307692307
F_Beta: 0.740072202166065
```



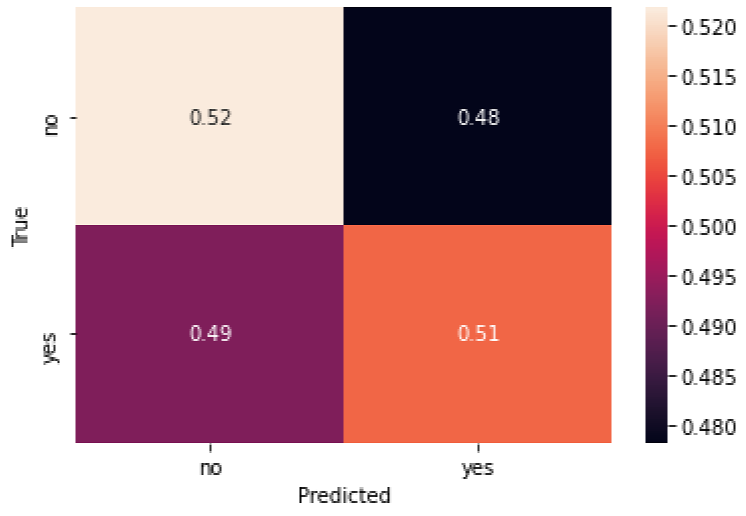


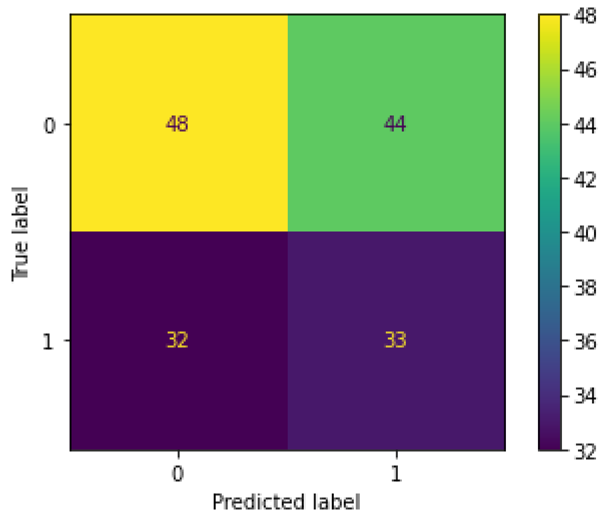
In [17]:
```
# compute true positive rate and false positive rate
false_positive_rate, true_positive_rate, thresholds = roc_curve(actual, pred_result)

# plotting them against each other
def plot_roc_curve(false_positive_rate, true_positive_rate, label=None):
    plt.plot(false_positive_rate, true_positive_rate, linewidth=2, label=label)
    plt.plot([0, 1], [0, 1], 'r', linewidth=4)
    plt.axis([0, 1, 0, 1])
    plt.xlabel('False Positive Rate (FPR)', fontsize=16)
    plt.ylabel('True Positive Rate (TPR)', fontsize=16)

plt.figure(figsize=(14, 7))
plot_roc_curve(false_positive_rate, true_positive_rate)
plt.show()

# https://towardsdatascience.com/predicting-the-survival-of-titanic-passengers-30870ccc7e8
# https://stackoverflow.com/questions/44172162/f1-score-vs-roc-auc
```



In [18]:
```
# Naive Random Coin Flip Classifier Performance

predicted = np.random.randint(0,2, size = len(y_test))
pred_result = predicted.flatten()

actual = y_test.to_numpy()
actual = actual.flatten()

cm = tf.math.confusion_matrix(actual, pred_result)
cm = cm/cm.numpy().sum(axis=1)[:, tf.newaxis]

sns.heatmap(
    cm, annot=True,
    xticklabels=['no', 'yes'],
    yticklabels=['no', 'yes'])
plt.xlabel("Predicted")
plt.ylabel("True")

#true_positives = tf.math.count_nonzero(pred_result * actual)
#true_negatives = tf.math.count_nonzero((pred_result - 1) * (actual - 1))
#false_positives = tf.math.count_nonzero(pred_result * (actual - 1))
#false_negatives = tf.math.count_nonzero((pred_result - 1) * actual)

#precision = true_positives / (true_positives + false_positives)
#recall = true_positives / (true_positives + false_negatives)
#f1 = 2 * precision * recall / (precision + recall)

#print("Precision: " + str(np.array(precision).flatten()[0]))
#print("Recall: " + str(np.array(recall).flatten()[0]))
#print("F1: " + str(np.array(f1).flatten()[0]))
#print('')

'''
https://towardsdatascience.com/accuracy-precision-recall-or-f1-331fb37c5cb9
https://stackoverflow.com/questions/44172162/f1-score-vs-roc-auc

- Maximize Precision when False Positives are of concern
- Maximize Recall when False Negatives are of concern
- Maximize F1 Score when both are important and classes are unbalanced

'''
auc_score = roc_auc_score(actual, pred_result)
precision = precision_score(actual, pred_result)
recall = recall_score(actual, pred_result)
f_beta = fbeta_score(actual, pred_result, beta = 1)

print("ROC-AUC-Score:", auc_score)
print('Precision: ' + str(precision))
print('Recall: ' + str(recall))
print('F_Beta: ' + str(f_beta))

y_test_classes = list(set(y_test))

# print Confusion Matrix from Sklearn
cm = confusion_matrix(actual, pred_result, labels = y_test_classes)

#cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels = y_test_classes)
disp.plot();
```

```
ROC-AUC-Score: 0.5147157190635451
Precision: 0.42857142857142855
Recall: 0.5076923076923077
F_Beta: 0.46478873239436613
```





Explainable AI using Dalex

In [19]:
```
import dalex as dx
```

In [20]:
```
X, y = df.drop('survived', axis=1), df.survived
n, p = X.shape
```

In [21]:
```
explainer_keras = dx.Explainer(model_ak,
                               data = X,
                               y = y,
                               predict_function = ak_predict,
                               label = 'autokeras',
                               #predict_function = dx._explainer.yhat.yhat_tf_classification,
                               model_type = 'classification'
                              )
```

```
Preparation of a new explainer is initiated

  -> data              : 781 rows 9 cols
  -> target variable   : Parameter 'y' was a pandas.Series. Converted to a numpy.ndarray.
  -> target variable   : 781 values
  -> model_class       : tensorflow.python.keras.engine.functional.Functional (default)
  -> label             : autokeras
  -> predict function  : <function ak_predict at 0x000001D1EDEE6F70> will be used
  -> predict function  : Accepts pandas.DataFrame and numpy.ndarray.
  -> predicted values  : min = 0.134, mean = 0.458, max = 1.0
  -> model type        : classification will be used
  -> residual function : difference between y and yhat (default)
  -> residuals         : min = -0.782, mean = -0.0446, max = 0.758
  -> model_info        : package tensorflow

A new explainer has been created!
```

In [22]:
```
explainer_keras.model_performance()
```

Out[22]:

	recall	precision	f1	accuracy	auc
autokeras	0.594427	0.803347	0.683274	0.772087	0.827971

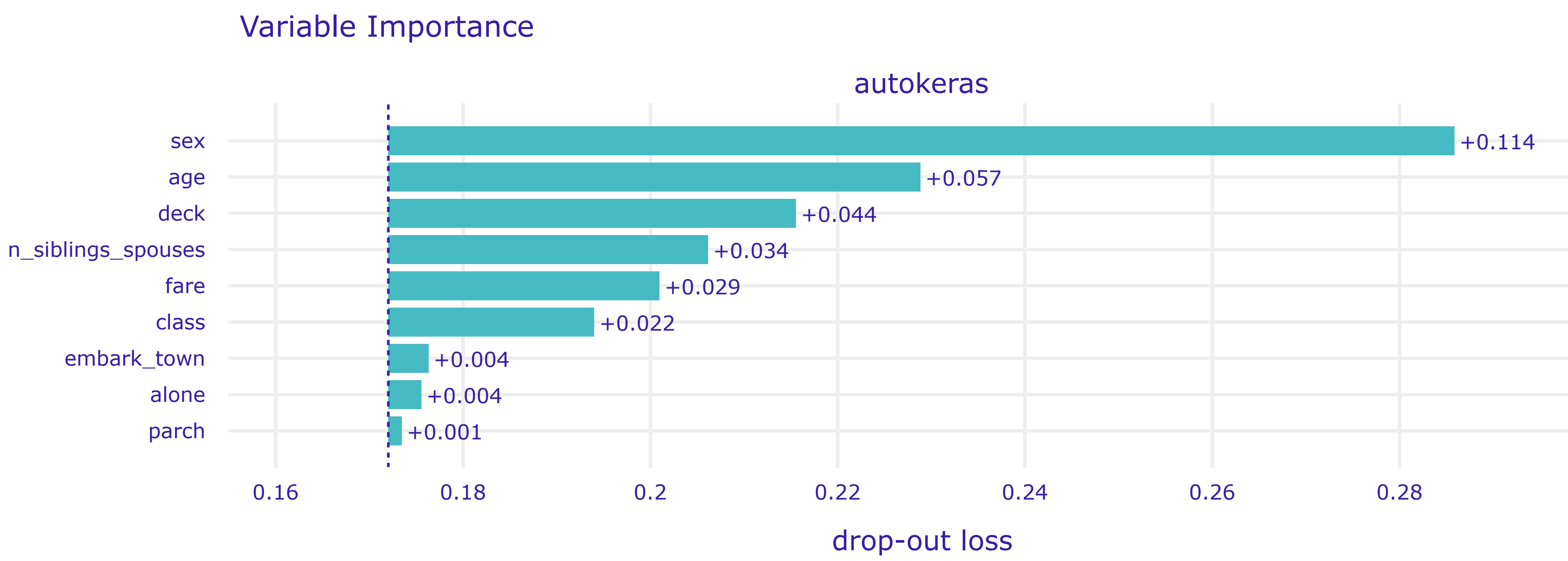
In [23]:
```
explainer_keras.model_diagnostics().result
```

Out[23]:

	sex	age	n_siblings_spouses	parch	fare	class	deck	embark_town	alone	y	y_hat	residuals	abs_residuals	label	ids
0	male	22.0	1	0	7.2500	Third	unknown	Southampton	n	0	0.334225	-0.334225	0.334225	autokeras	1
1	female	38.0	1	0	71.2833	First	C	Cherbourg	n	1	0.511104	0.488896	0.488896	autokeras	2
2	female	26.0	0	0	7.9250	Third	unknown	Southampton	y	1	0.467287	0.532713	0.532713	autokeras	3
3	female	35.0	1	0	53.1000	First	C	Southampton	n	1	0.508692	0.491308	0.491308	autokeras	4
4	male	28.0	0	0	8.4583	Third	unknown	Queenstown	y	0	0.419327	-0.419327	0.419327	autokeras	5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
776	female	56.0	0	1	83.1583	First	C	Cherbourg	n	1	0.498832	0.501168	0.501168	autokeras	777
777	female	25.0	0	1	26.0000	Second	unknown	Southampton	n	1	0.571394	0.428606	0.428606	autokeras	778
778	male	33.0	0	0	7.8958	Third	unknown	Southampton	y	0	0.369783	-0.369783	0.369783	autokeras	779
779	female	39.0	0	5	29.1250	Third	unknown	Queenstown	n	0	0.501495	-0.501495	0.501495	autokeras	780
780	male	26.0	0	0	30.0000	First	C	Cherbourg	y	1	0.463082	0.536918	0.536918	autokeras	781

781 rows × 15 columns

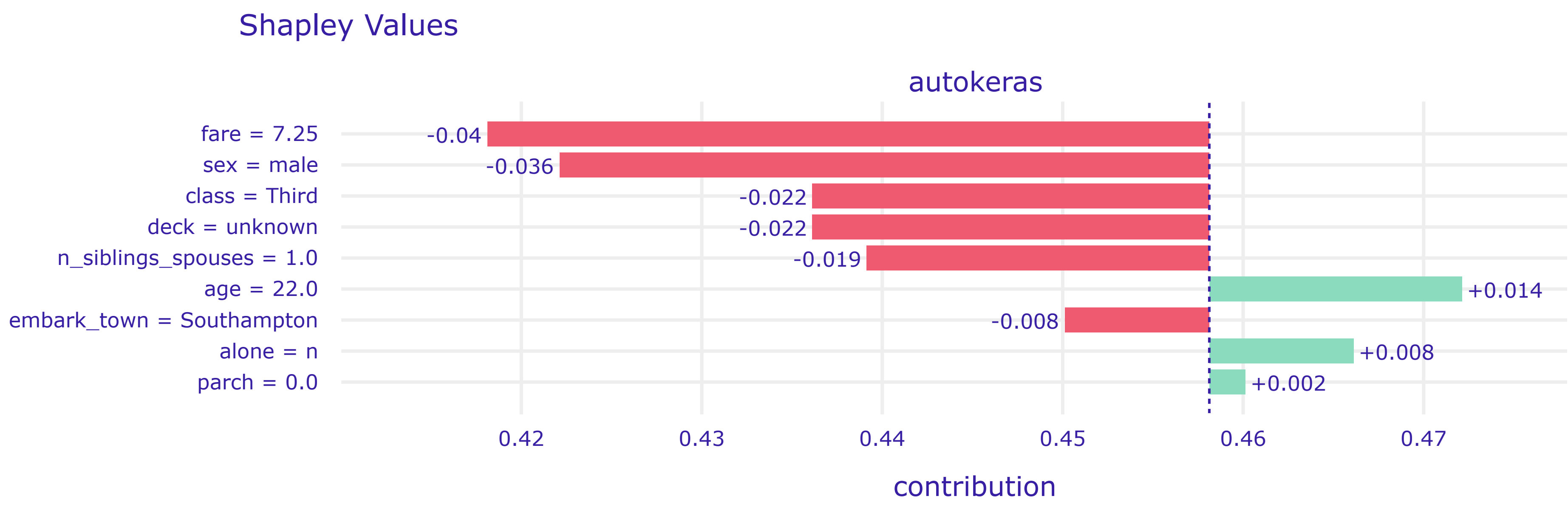
In [24]:
```
explainer_keras.model_parts().plot()
```



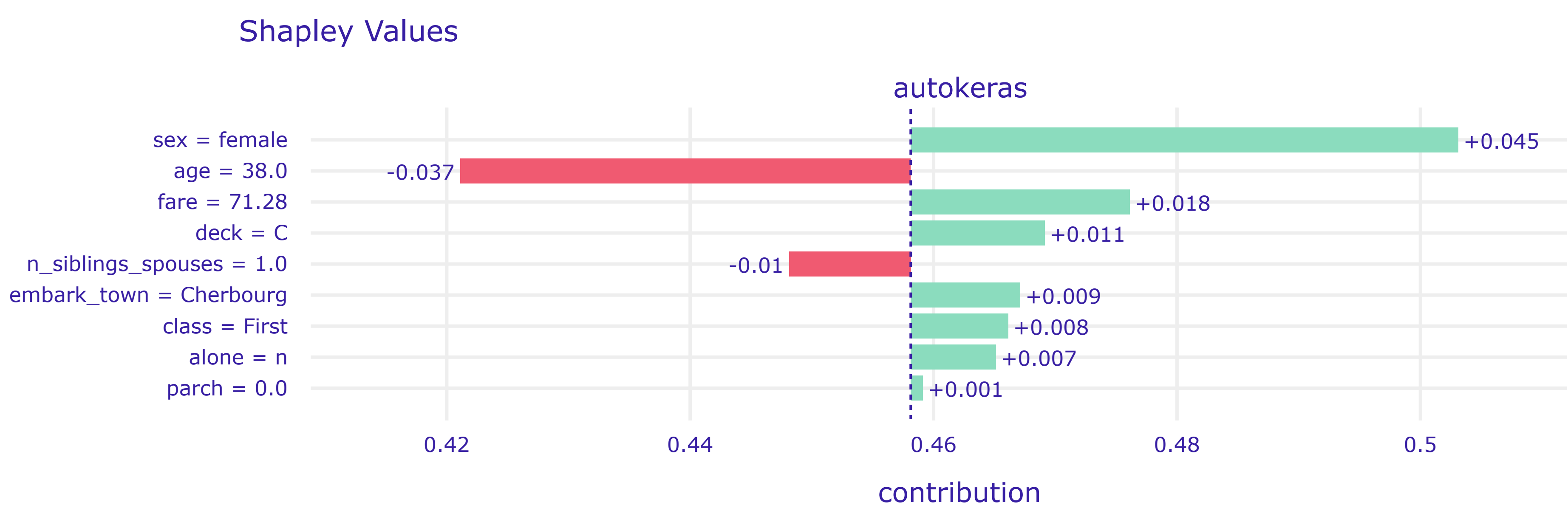
In [25]:
```
explainer_keras.model_profile().plot(variables=['sex', 'class', 'fare', 'deck',
                                                'n_siblings_spouses', 'embark_town',
                                                'parch', 'alone', 'age'])
```

```
Calculating ceteris paribus: 100%|██████████| 9/9 [00:07<00:00,  1.14it/s]
```

In [26]:
```python
explainer_keras.predict_parts(X.loc[0], type='shap').plot()
```



In [27]:
```python
explainer_keras.predict_parts(X.loc[1], type='shap').plot()
```



In [28]:
```python
X_one_hot = pd.get_dummies(X, drop_first=True)

X_one_hot
```

Out[28]:

	age	n_siblings_spouses	parch	fare	sex_male	class_Second	class_Third	deck_B	deck_C	deck_D	deck_E	deck_F	deck_G	deck_unkn
0	22.0	1	0	7.2500	1	0	1	0	0	0	0	0	0	
1	38.0	1	0	71.2833	0	0	0	0	1	0	0	0	0	
2	26.0	0	0	7.9250	0	0	1	0	0	0	0	0	0	
3	35.0	1	0	53.1000	0	0	0	0	1	0	0	0	0	
4	28.0	0	0	8.4583	1	0	1	0	0	0	0	0	0	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	
776	56.0	0	1	83.1583	0	0	0	0	1	0	0	0	0	
777	25.0	0	1	26.0000	0	1	0	0	0	0	0	0	0	
778	33.0	0	0	7.8958	1	0	1	0	0	0	0	0	0	
779	39.0	0	5	29.1250	0	0	1	0	0	0	0	0	0	
780	26.0	0	0	30.0000	1	0	0	0	1	0	0	0	0	

781 rows × 18 columns

In [29]:
```python
from sklearn import tree

clf = tree.DecisionTreeClassifier(max_features = 5, max_depth = 3)

X_one_hot = pd.get_dummies(X, drop_first=True)

clf = clf.fit(X_one_hot, y)
```

In [30]:
```python
df[df.sex == 'male'].survived.value_counts()
```

Out[30]:
```
0    382
1    106
Name: survived, dtype: int64
```

In [31]:
```python
df[df.sex == 'female'].survived.value_counts()
```

Out[31]:
```
1    217
0     76
Name: survived, dtype: int64
```

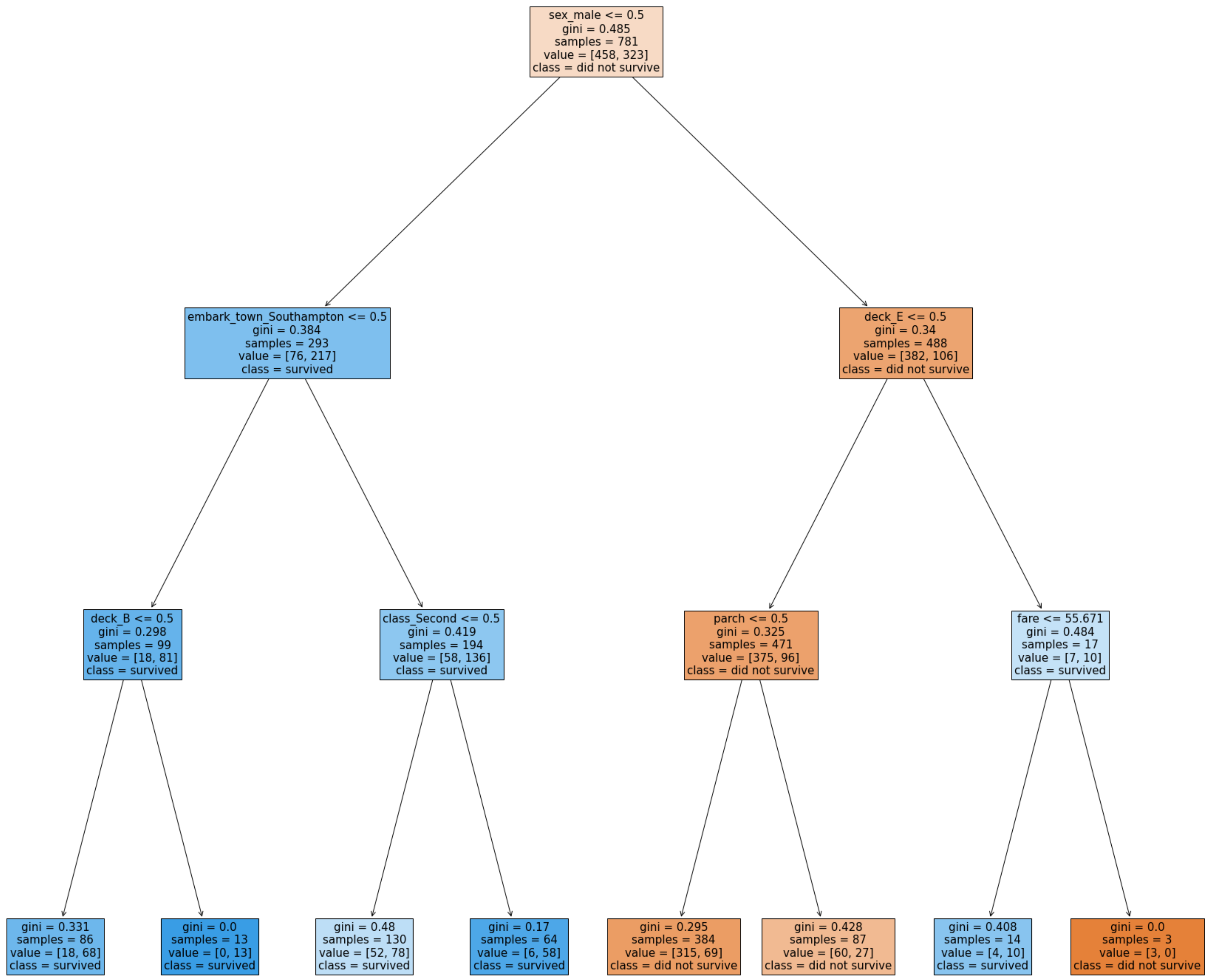
In [32]:
```
df.survived.value_counts()
```

Out[32]:
```
0    458
1    323
Name: survived, dtype: int64
```

In [33]:
```
#clf.classes_
```

In [34]:
```python
fn = list(X_one_hot.columns)

cn = ['did not survive', 'survived']

#cn = ['survived', 'did not survive']


fig, axes = plt.subplots(nrows = 1,
                         ncols = 1,
                         figsize = (30,30))
                         #dpi=500)

tree.plot_tree(clf,
               feature_names = fn,
               class_names=cn,
               filled = True, fontsize = 15)

#fig.savefig('imagename.png')
```

Out[34]:
```
[Text(837.0, 1426.95, 'sex_male <= 0.5\ngini = 0.485\nsamples = 781\nvalue = [458, 323]\nclass = did not survive'),
 Text(418.5, 1019.25, 'embark_town_Southampton <= 0.5\ngini = 0.384\nsamples = 293\nvalue = [76, 217]\nclass = survive
d'),
 Text(209.25, 611.55, 'deck_B <= 0.5\ngini = 0.298\nsamples = 99\nvalue = [18, 81]\nclass = survived'),
 Text(104.625, 203.8499999999999, 'gini = 0.331\nsamples = 86\nvalue = [18, 68]\nclass = survived'),
 Text(313.875, 203.8499999999999, 'gini = 0.0\nsamples = 13\nvalue = [0, 13]\nclass = survived'),
 Text(627.75, 611.55, 'class_Second <= 0.5\ngini = 0.419\nsamples = 194\nvalue = [58, 136]\nclass = survived'),
 Text(523.125, 203.8499999999999, 'gini = 0.48\nsamples = 130\nvalue = [52, 78]\nclass = survived'),
 Text(732.375, 203.8499999999999, 'gini = 0.17\nsamples = 64\nvalue = [6, 58]\nclass = survived'),
 Text(1255.5, 1019.25, 'deck_E <= 0.5\ngini = 0.34\nsamples = 488\nvalue = [382, 106]\nclass = did not survive'),
 Text(1046.25, 611.55, 'parch <= 0.5\ngini = 0.325\nsamples = 471\nvalue = [375, 96]\nclass = did not survive'),
 Text(941.625, 203.8499999999999, 'gini = 0.295\nsamples = 384\nvalue = [315, 69]\nclass = did not survive'),
 Text(1150.875, 203.8499999999999, 'gini = 0.428\nsamples = 87\nvalue = [60, 27]\nclass = did not survive'),
 Text(1464.75, 611.55, 'fare <= 55.671\ngini = 0.484\nsamples = 17\nvalue = [7, 10]\nclass = survived'),
 Text(1360.125, 203.8499999999999, 'gini = 0.408\nsamples = 14\nvalue = [4, 10]\nclass = survived'),
 Text(1569.375, 203.8499999999999, 'gini = 0.0\nsamples = 3\nvalue = [3, 0]\nclass = did not survive')]
```



working version

In [35]:
```
import dalex as dx

data = pd.read_csv("https://raw.githubusercontent.com/pbiecek/xai-happiness/main/happiness.csv", index_col=0)
data.head()
```

Out[35]:

	score	gdp_per_capita	social_support	healthy_life_expectancy	freedom_to_make_life_choices	generosity	perceptions_of_corruption
Afghanistan	3.203	0.350	0.517	0.361	0.000	0.158	0.025
Albania	4.719	0.947	0.848	0.874	0.383	0.178	0.027
Algeria	5.211	1.002	1.160	0.785	0.086	0.073	0.114
Argentina	6.086	1.092	1.432	0.881	0.471	0.066	0.050
Armenia	4.559	0.850	1.055	0.815	0.283	0.095	0.064

In [36]:
```
X, y = data.drop('score', axis=1), data.score
n, p = X.shape

X
```

Out[36]:

	gdp_per_capita	social_support	healthy_life_expectancy	freedom_to_make_life_choices	generosity	perceptions_of_corruption
Afghanistan	0.350	0.517	0.361	0.000	0.158	0.025
Albania	0.947	0.848	0.874	0.383	0.178	0.027
Algeria	1.002	1.160	0.785	0.086	0.073	0.114
Argentina	1.092	1.432	0.881	0.471	0.066	0.050
Armenia	0.850	1.055	0.815	0.283	0.095	0.064
...	...	...	...	...	...	...
Venezuela	0.960	1.427	0.805	0.154	0.064	0.047
Vietnam	0.741	1.346	0.851	0.543	0.147	0.073
Yemen	0.287	1.163	0.463	0.143	0.108	0.077
Zambia	0.578	1.058	0.426	0.431	0.247	0.087
Zimbabwe	0.366	1.114	0.433	0.361	0.151	0.089

156 rows × 6 columns

In [37]:
```
y
```

Out[37]:
```
Afghanistan    3.203
Albania        4.719
Algeria        5.211
Argentina      6.086
Armenia        4.559
               ...
Venezuela      4.707
Vietnam        5.175
Yemen          3.380
Zambia         4.107
Zimbabwe       3.663
Name: score, Length: 156, dtype: float64
```

In [38]:
```
#tf.random.set_seed(11)

normalizer  = tf.keras.layers.experimental.preprocessing.Normalization(input_shape=[p,])
normalizer.adapt(X.to_numpy())

model = tf.keras.Sequential([
    normalizer,
    tf.keras.Input(shape=(p,)),
    tf.keras.layers.Dense(p*2, activation='relu'),
    tf.keras.layers.Dense(p*3, activation='relu'),
    tf.keras.layers.Dense(p*2, activation='relu'),
    tf.keras.layers.Dense(p, activation='relu'),
    tf.keras.layers.Dense(1, activation='linear')
])

model.compile(
    optimizer=tf.keras.optimizers.Adam(0.001),
    loss=tf.keras.losses.mae
)

model.fit(X, y, batch_size=int(n/10), epochs=2000, verbose=False)
```

```
WARNING:tensorflow:Please add `keras.layers.InputLayer` instead of `keras.Input` to Sequential model. `keras.Input` is i
ntended to be used by Functional model.
```

Out[38]:
```
<tensorflow.python.keras.callbacks.History at 0x1d3a2287340>
```

In [39]:
```
#type(model)
```

In [40]:
```
#model.output_shape
```

In [41]:
```
explainer = dx.Explainer(model, X, y, label='happiness')
```

```
Preparation of a new explainer is initiated

  -> data              : 156 rows 6 cols
  -> target variable   : Parameter 'y' was a pandas.Series. Converted to a numpy.ndarray.
  -> target variable   : 156 values
  -> model_class       : tensorflow.python.keras.engine.sequential.Sequential (default)
  -> label             : happiness
  -> predict function  : <function yhat_tf_regression at 0x000001D1C4457790> will be used (default)
  -> predict function  : Accepts pandas.DataFrame and numpy.ndarray.
  -> predicted values  : min = 2.88, mean = 5.4, max = 7.56
  -> model type        : regression will be used (default)
  -> residual function : difference between y and yhat (default)
  -> residuals         : min = -0.63, mean = 0.0104, max = 0.697
  -> model_info        : package tensorflow

A new explainer has been created!
```

In [42]:
```
#explainer_new = dx.Explainer(model, X, y, label='happiness',
#                             predict_function = dx._explainer.yhat.yhat_tf_regression)
```

In [43]:
```
#explainer.predict_function
```

In [44]:
```
#dx._explainer.yhat.yhat_tf_regression(model, X)
```

In [45]:
```
#explainer.residual_function
```

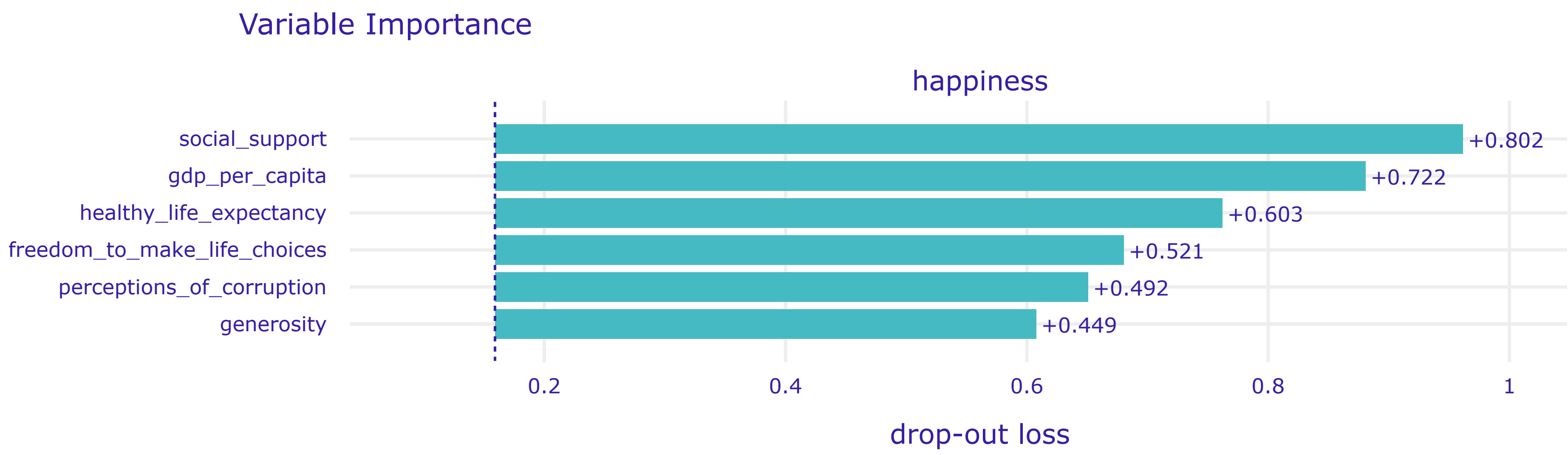
In [46]:
```
#dx._explainer.checks.check_residual_function.residual_function

#def rf(_model, _data, _y):
#    return _y - dx._explainer.yhat.yhat_tf_regression(model, X)

#rf(model, X, y)
```

In [47]:
```
explainer.model_performance()
```

Out[47]:

	mse	rmse	r2	mae	mad
happiness	0.025321	0.159127	0.979432	0.100341	0.05421

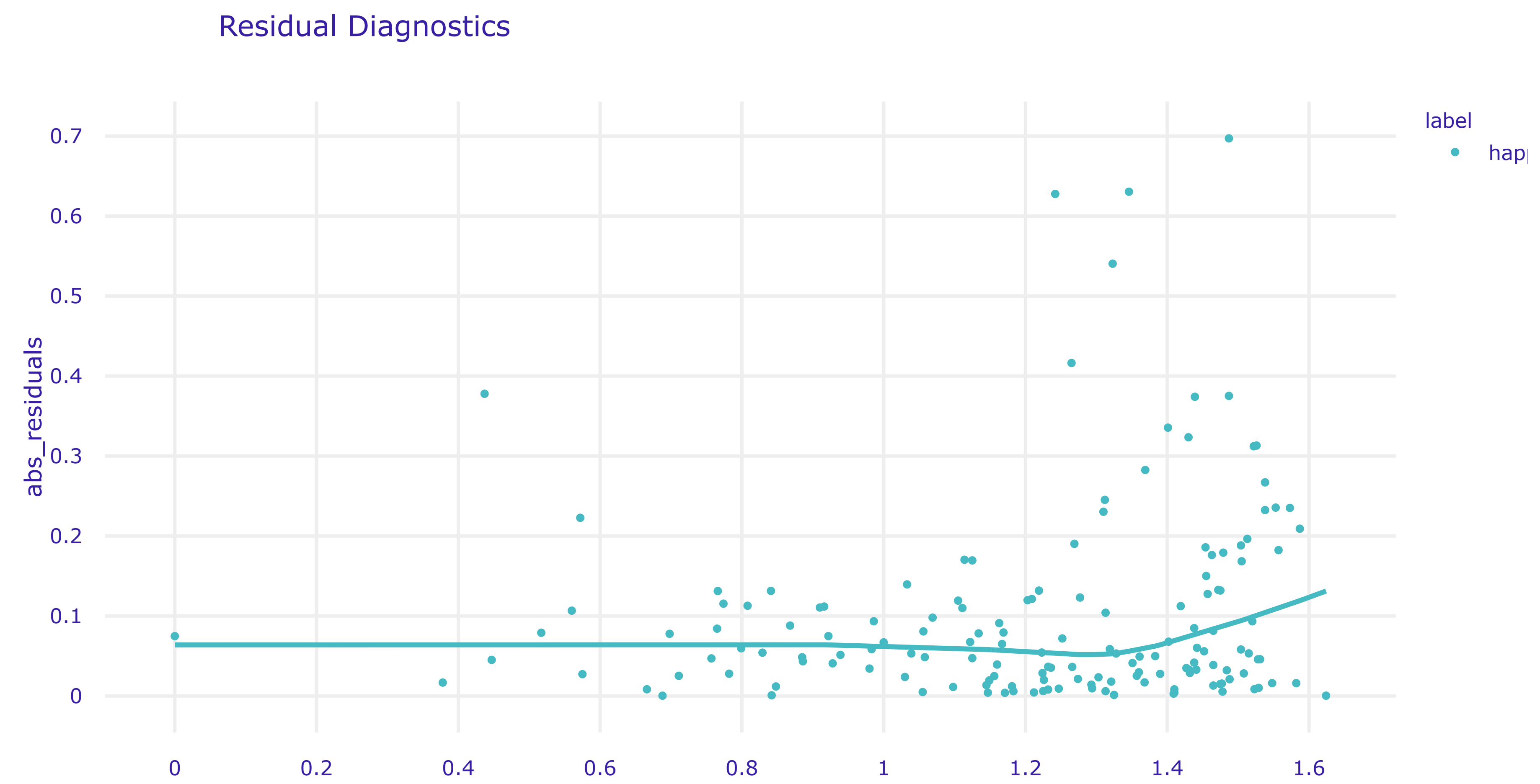
In [48]:
```
explainer.model_parts().plot()
```



In [49]:
```
explainer.model_profile().plot(variables=['social_support', 'healthy_life_expectancy',
                                          'gdp_per_capita', 'freedom_to_make_life_choices'])
```

```
Calculating ceteris paribus: 100%|██████████| 6/6 [00:03<00:00,  1.99it/s]
```

In [50]:
```
explainer.model_diagnostics().plot(variable='social_support', yvariable="abs_residuals", marker_size=5, line_width=3)
```



In [51]:
```
explainer.model_diagnostics().result
```

Out[51]:

	gdp_per_capita	social_support	healthy_life_expectancy	freedom_to_make_life_choices	generosity	perceptions_of_corruption	y	y
Afghanistan	0.350	0.517	0.361	0.000	0.158	0.025	3.203	3.28
Albania	0.947	0.848	0.874	0.383	0.178	0.027	4.719	4.73
Algeria	1.002	1.160	0.785	0.086	0.073	0.114	5.211	5.17
Argentina	1.092	1.432	0.881	0.471	0.066	0.050	6.086	6.11
Armenia	0.850	1.055	0.815	0.283	0.095	0.064	4.559	4.55
...	...	...	...	...	...	...	...	
Venezuela	0.960	1.427	0.805	0.154	0.064	0.047	4.707	4.67
Vietnam	0.741	1.346	0.851	0.543	0.147	0.073	5.175	5.80
Yemen	0.287	1.163	0.463	0.143	0.108	0.077	3.380	3.47
Zambia	0.578	1.058	0.426	0.431	0.247	0.087	4.107	4.15
Zimbabwe	0.366	1.114	0.433	0.361	0.151	0.089	3.663	3.83

156 rows × 12 columns

In [52]:
```python
explainer.predict_parts(X.loc['Poland'], type='shap').plot()
```

```
Exception ignored in: <function CapturableResource.__del__ at 0x000001D1E4C61EE0>
Traceback (most recent call last):
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\training\tracking\tracking.py", line 277, in __del_
_
    self._destroy_resource()
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 889, in __call__
    result = self._call(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 924, in _call
    results = self._stateful_fn(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3022, in __call__
    filtered_flat_args) = self._maybe_define_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3444, in _maybe_define_fun
ction
    graph_function = self._create_graph_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3279, in _create_graph_fun
ction
    func_graph_module.func_graph_from_py_func(
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\framework\func_graph.py", line 999, in func_graph_f
rom_py_func
    func_outputs = python_func(*func_args, **func_kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 672, in wrapped_fn
    out = weak_wrapped_fn().__wrapped__(*args, **kwds)
AttributeError: 'NoneType' object has no attribute '__wrapped__'
Exception ignored in: <function CapturableResource.__del__ at 0x000001D1E4C61EE0>
Traceback (most recent call last):
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Exception ignored in: <function CapturableResource.__del__ at 0x000001D1E4C61EE0>
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  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\training\tracking\tracking.py", line 277, in __del_
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  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 924, in _call
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  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3022, in __call__
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  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3279, in _create_graph_fun
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    result = self._call(*args, **kwds)
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    results = self._stateful_fn(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3022, in __call__
    filtered_flat_args) = self._maybe_define_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3444, in _maybe_define_fun
ction
    graph_function = self._create_graph_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3279, in _create_graph_fun
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    func_graph_module.func_graph_from_py_func(
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\framework\func_graph.py", line 999, in func_graph_f
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    func_outputs = python_func(*func_args, **func_kwargs)
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```

```
Exception ignored in: <function CapturableResource.__del__ at 0x000001D1E4C61EE0>
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_
    self._destroy_resource()
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 889, in __call__
    result = self._call(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 924, in _call
    results = self._stateful_fn(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3022, in __call__
    filtered_flat_args) = self._maybe_define_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3444, in _maybe_define_fun
ction
    graph_function = self._create_graph_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3279, in _create_graph_fun
ction
    func_graph_module.func_graph_from_py_func(
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\framework\func_graph.py", line 999, in func_graph_f
rom_py_func
    func_outputs = python_func(*func_args, **func_kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 672, in wrapped_fn
    out = weak_wrapped_fn().__wrapped__(*args, **kwds)
AttributeError: 'NoneType' object has no attribute '__wrapped__'
Exception ignored in: <function CapturableResource.__del__ at 0x000001D1E4C61EE0>
Traceback (most recent call last):
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\training\tracking\tracking.py", line 277, in __del_
_
    self._destroy_resource()
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 889, in __call__
    result = self._call(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 924, in _call
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  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\framework\func_graph.py", line 999, in func_graph_f
rom_py_func
    func_outputs = python_func(*func_args, **func_kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 672, in wrapped_fn
    out = weak_wrapped_fn().__wrapped__(*args, **kwds)
AttributeError: 'NoneType' object has no attribute '__wrapped__'

Exception ignored in: <function CapturableResource.__del__ at 0x000001D1E4C61EE0>
Traceback (most recent call last):
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\training\tracking\tracking.py", line 277, in __del_
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    self._destroy_resource()
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 889, in __call__
    result = self._call(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 924, in _call
    results = self._stateful_fn(*args, **kwds)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3022, in __call__
    filtered_flat_args) = self._maybe_define_function(args, kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3444, in _maybe_define_fun
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  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\function.py", line 3279, in _create_graph_fun
ction
    func_graph_module.func_graph_from_py_func(
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\framework\func_graph.py", line 999, in func_graph_f
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    func_outputs = python_func(*func_args, **func_kwargs)
  File "C:\Users\deepl\anaconda3\lib\site-packages\tensorflow\python\eager\def_function.py", line 672, in wrapped_fn
    out = weak_wrapped_fn().__wrapped__(*args, **kwds)
AttributeError: 'NoneType' object has no attribute '__wrapped__'
```
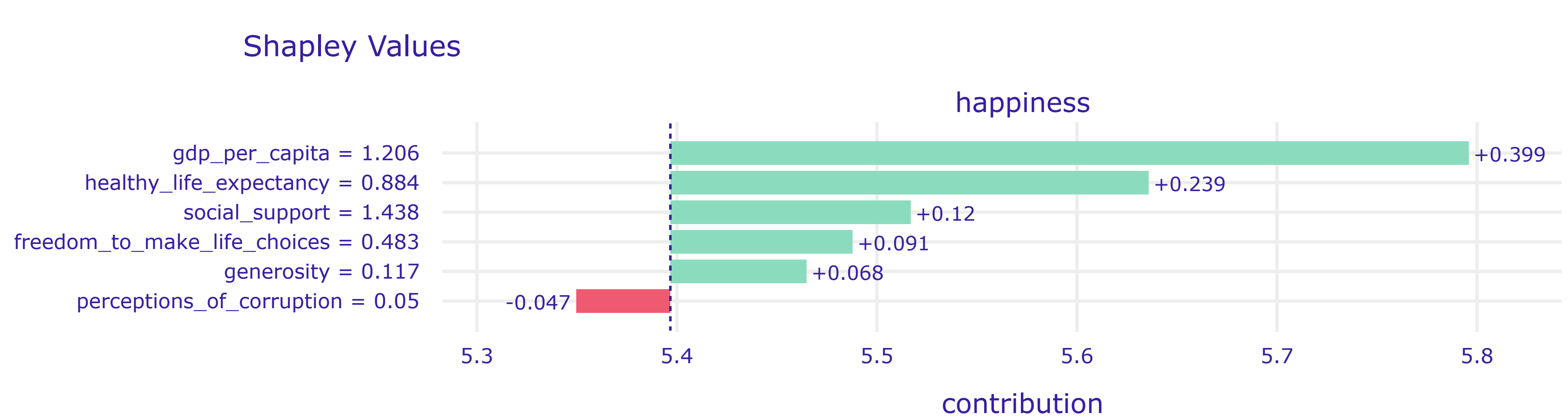
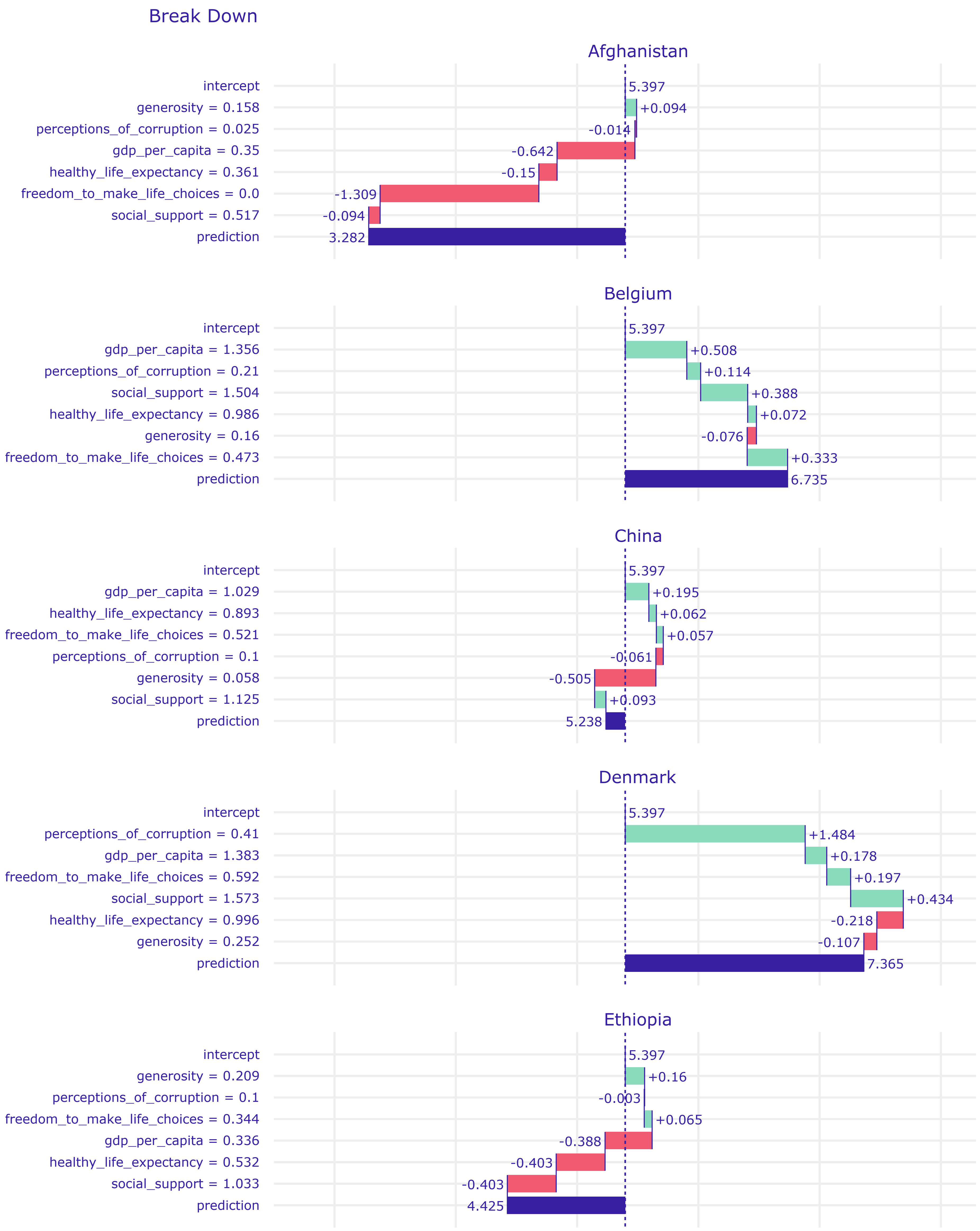
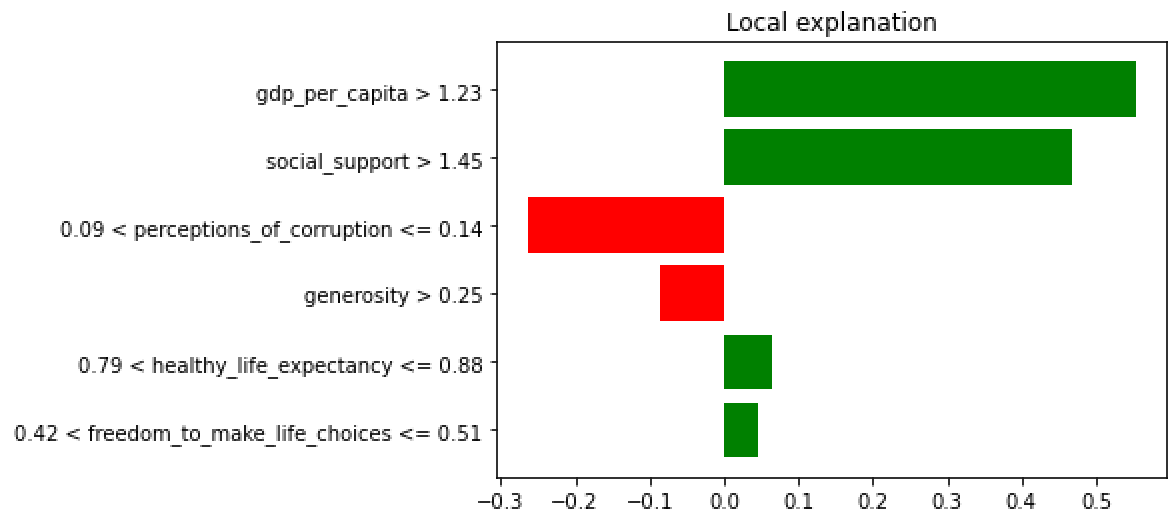



In [53]:
```
pp_list = []

for country in ['Afghanistan', 'Belgium', 'China', 'Denmark', 'Ethiopia']:
    pp = explainer.predict_parts(X.loc[country], type='break_down')
    pp.result.label = country
    pp_list += [pp]

pp_list[0].plot(pp_list[1::], min_max=[2.5, 8.5])
```



In [54]:
```
lime_explanation = explainer.predict_surrogate(X.loc['United States'], mode='regression')

lime_explanation.plot()
```



In [55]:
```
lime_explanation.result
```

Out[55]:

	variable	effect
0	gdp_per_capita > 1.23	0.553652
1	social_support > 1.45	0.467272
2	0.09 < perceptions_of_corruption <= 0.14	-0.264506
3	generosity > 0.25	-0.087135
4	0.79 < healthy_life_expectancy <= 0.88	0.065358
5	0.42 < freedom_to_make_life_choices <= 0.51	0.045682

In [56]:
```
surrogate_model = explainer.model_surrogate(max_vars=4, max_depth=3)
surrogate_model.performance
```

Out[56]:

	mse	rmse	r2	mae	mad
DecisionTreeRegressor	0.195621	0.442291	0.820771	0.353305	0.286188

In [57]:
```
surrogate_model.plot()
```