Dataset3-Boston_output_8

November 17, 2021

1 Dataset 4 - Boston

1.1 Import Libraries

[1]:
```
import warnings
import sys
sys.path.insert(0, '../src')
warnings.filterwarnings('ignore')
```

[2]:
```
import train_test
import ABC_train_test
import bostonDataset
import network
import statsModel
import performanceMetrics
import dataset
import sanityChecks
import torch
import matplotlib.pyplot as plt
import seaborn as sns
from torch.utils.data import random_split
#import pycuda.driver as cuda
```

1.2 Parameters

General Parameters

1. Number of Samples
2. Number of features

ABC-Generator parameters are as mentioned below: 1. mean : 1 ($\beta \sim N(\beta^*, \sigma)$ where β^* are coefficients of statistical model) or 1 ($\beta \sim N(0, \sigma)$ 2. std : $\sigma = 1, 0.1, 0.01$ (standard deviation)

[3]:
```
n_features = 13
n_samples= 506

#ABC Generator Parameters
mean = 1
variance = 0.01
```

```
#Hyper-parameters
n_epochs = 5000
```

[4]:
```
# Parameters
mean = 1
variance = 0.01
n_epochs = 8000
```

1.3 Dataset

[5]:
```
X,Y = bostonDataset.boston_data()
```

```
        X1    X2    X3   X4     X5     X6    X7      X8   X9    X10   X11  \
0  0.00632  18.0  2.31  0.0  0.538  6.575  65.2  4.0900  1.0  296.0  15.3
1  0.02731   0.0  7.07  0.0  0.469  6.421  78.9  4.9671  2.0  242.0  17.8
2  0.02729   0.0  7.07  0.0  0.469  7.185  61.1  4.9671  2.0  242.0  17.8
3  0.03237   0.0  2.18  0.0  0.458  6.998  45.8  6.0622  3.0  222.0  18.7
4  0.06905   0.0  2.18  0.0  0.458  7.147  54.2  6.0622  3.0  222.0  18.7

      X12   X13     Y
0  396.90  4.98  24.0
1  396.90  9.14  21.6
2  392.83  4.03  34.7
3  394.63  2.94  33.4
4  396.90  5.33  36.2
```

1.4 Stats Model

[6]:
```
[coeff,y_pred] = statsModel.statsModel(X,Y)
```

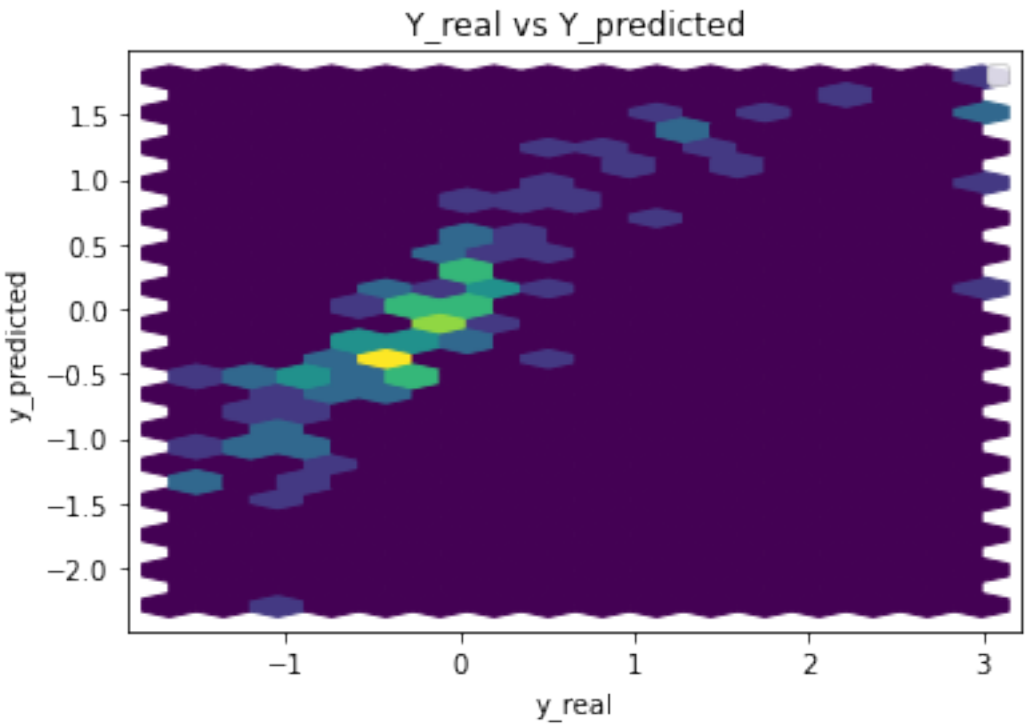
```
No handles with labels found to put in legend.
                                 OLS Regression Results
==============================================================================
=======
Dep. Variable:                      Y   R-squared (uncentered):
0.750
Model:                            OLS   Adj. R-squared (uncentered):
0.742
Method:                 Least Squares   F-statistic:
90.16
Date:                Wed, 17 Nov 2021   Prob (F-statistic):
7.02e-109
Time:                        20:30:21   Log-Likelihood:
-293.74
No. Observations:                 404   AIC:
613.5
Df Residuals:                     391   BIC:
```

665.5
Df Model: 13
Covariance Type: nonrobust

	coef	std err	t	P>|t|	[0.025	0.975]
x1	-0.1075	0.031	-3.494	0.001	-0.168	-0.047
x2	0.1357	0.038	3.618	0.000	0.062	0.209
x3	-0.0048	0.051	-0.095	0.925	-0.105	0.095
x4	0.0737	0.026	2.850	0.005	0.023	0.125
x5	-0.2121	0.054	-3.920	0.000	-0.318	-0.106
x6	0.2709	0.034	7.926	0.000	0.204	0.338
x7	-0.0193	0.044	-0.442	0.659	-0.105	0.067
x8	-0.3452	0.049	-6.989	0.000	-0.442	-0.248
x9	0.3005	0.070	4.280	0.000	0.163	0.439
x10	-0.2472	0.077	-3.231	0.001	-0.398	-0.097
x11	-0.2267	0.035	-6.490	0.000	-0.295	-0.158
x12	0.0819	0.030	2.742	0.006	0.023	0.141
x13	-0.3823	0.042	-9.043	0.000	-0.465	-0.299

Omnibus:	133.075	Durbin-Watson:	2.048
Prob(Omnibus):	0.000	Jarque-Bera (JB):	540.291
Skew:	1.406	Prob(JB):	4.76e-118
Kurtosis:	7.918	Cond. No.	10.0

Notes:
[1] R^2 is computed without centering (uncentered) since the model does not contain a constant.
[2] Standard Errors assume that the covariance matrix of the errors is correctly specified.
Parameters: x1 -0.107537
x2 0.135738
x3 -0.004815
x4 0.073699
x5 -0.212116
x6 0.270886
x7 -0.019273
x8 -0.345157
x9 0.300543
x10 -0.247171
x11 -0.226677
x12 0.081897
x13 -0.382278
dtype: float64




```
Performance Metrics
Mean Squared Error: 0.301684162167567
Mean Absolute Error: 0.3462564198347245
Manhattan distance: 35.31815482314189
Euclidean distance: 5.547232151360877
```

1.5 Common Training Parameters (GAN & ABC_GAN)

[7]:
```
threshold_mse = 0.99
batch_size = 100
```

[8]:
```
# Train test split for dataset
real_dataset = dataset.CustomDataset(X,Y)
train_size = round(0.8 * n_samples)
test_size = n_samples - train_size
train_data, test_data = random_split(real_dataset,[train_size,test_size])
```

[9]:
```
# cuda.init()
# ## Get Id of default device
# torch.cuda.current_device()
# #0
# cuda.Device(0).name()
```

[10]:
```
#Select the device
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
```

1.6 GAN Model

Training GAN for n_epochs number of epochs

[11]:
```
generator = network.Generator(n_features+1).to(device)
discriminator = network.Discriminator(n_features+1).to(device)

criterion = torch.nn.BCELoss()
gen_opt = torch.optim.Adam(generator.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(discriminator.parameters(), lr=0.01, betas=(0.5, 0.
↪999))
```

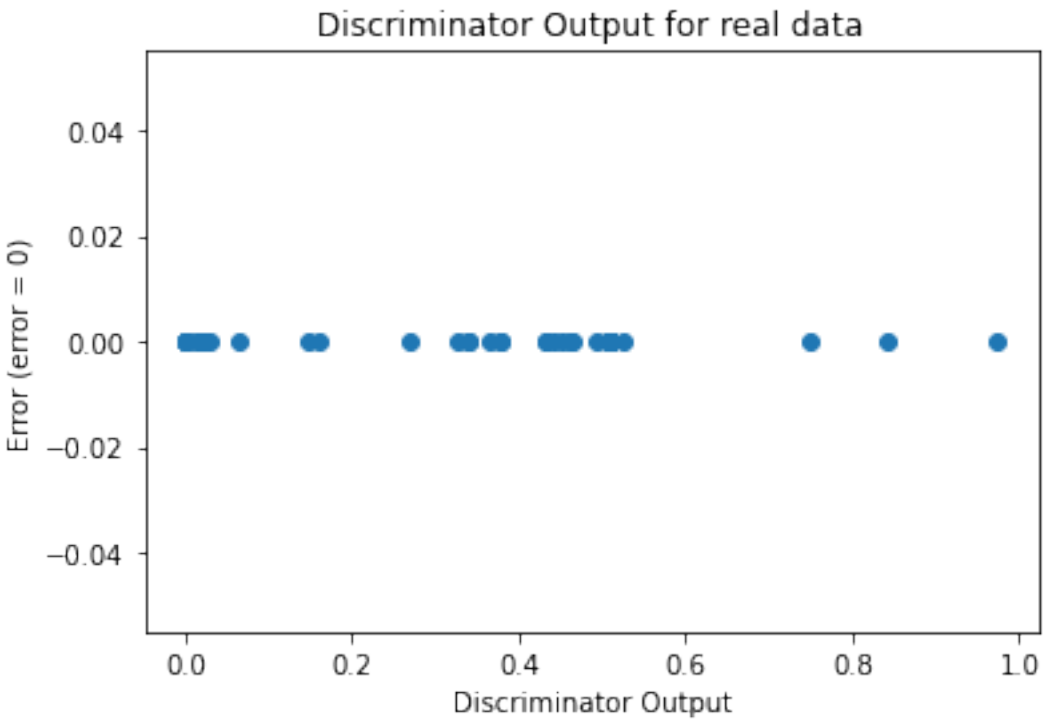
[12]:
```
print(generator)
print(discriminator)
```

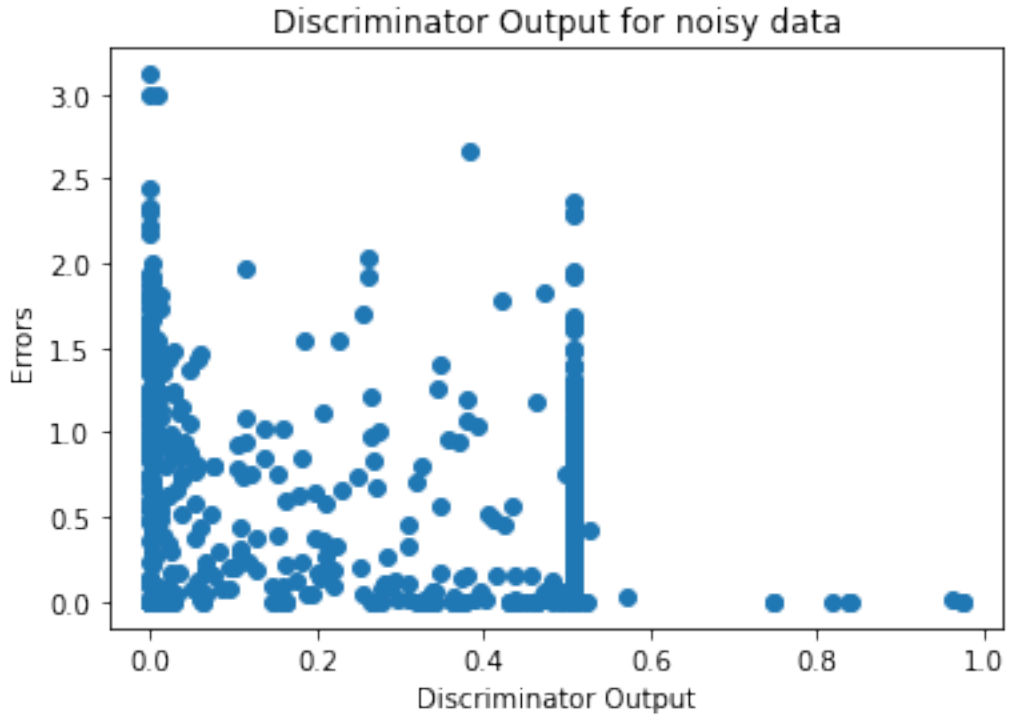
```
Generator(
  (hidden1): Linear(in_features=14, out_features=100, bias=True)
  (hidden2): Linear(in_features=100, out_features=100, bias=True)
  (output): Linear(in_features=100, out_features=1, bias=True)
  (relu): ReLU()
)
Discriminator(
  (hidden1): Linear(in_features=14, out_features=25, bias=True)
  (hidden2): Linear(in_features=25, out_features=50, bias=True)
  (output): Linear(in_features=50, out_features=1, bias=True)
  (relu): ReLU()
  (sigmoid): Sigmoid()
)
```

[13]:
```
discLossG1,genLossG1 = train_test.
↪training_GAN(discriminator,generator,disc_opt,gen_opt,train_data,batch_size,␣
↪n_epochs,criterion,device)
```

[14]:
```
GAN1_metrics = train_test.test_generator(generator,test_data,device)
```

[15]:
```
sanityChecks.discProbVsError(real_dataset,discriminator,device)
```


Discriminator Output for real data
Error (error = 0)
0.04
0.02
0.00
−0.02
−0.04
0.0
0.2
0.4
0.6
0.8
1.0
Discriminator Output


Discriminator Output for noisy data
Errors
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Discriminator Output

Training GAN until mse of y_pred is > baseline_mse or n_epochs < 5000

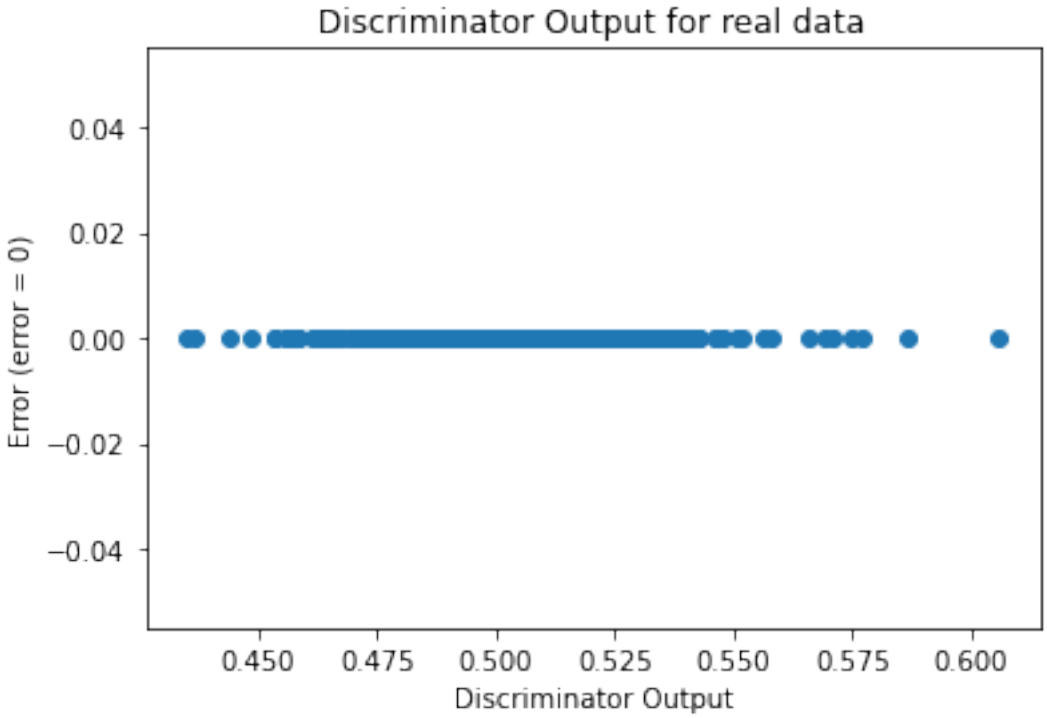
[16]:
```
generator2 = network.Generator(n_features+1).to(device)
discriminator2 = network.Discriminator(n_features+1).to(device)
criterion = torch.nn.BCELoss()
gen_opt = torch.optim.Adam(generator2.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(discriminator2.parameters(), lr=0.01, betas=(0.5, 0.
↪999))
```

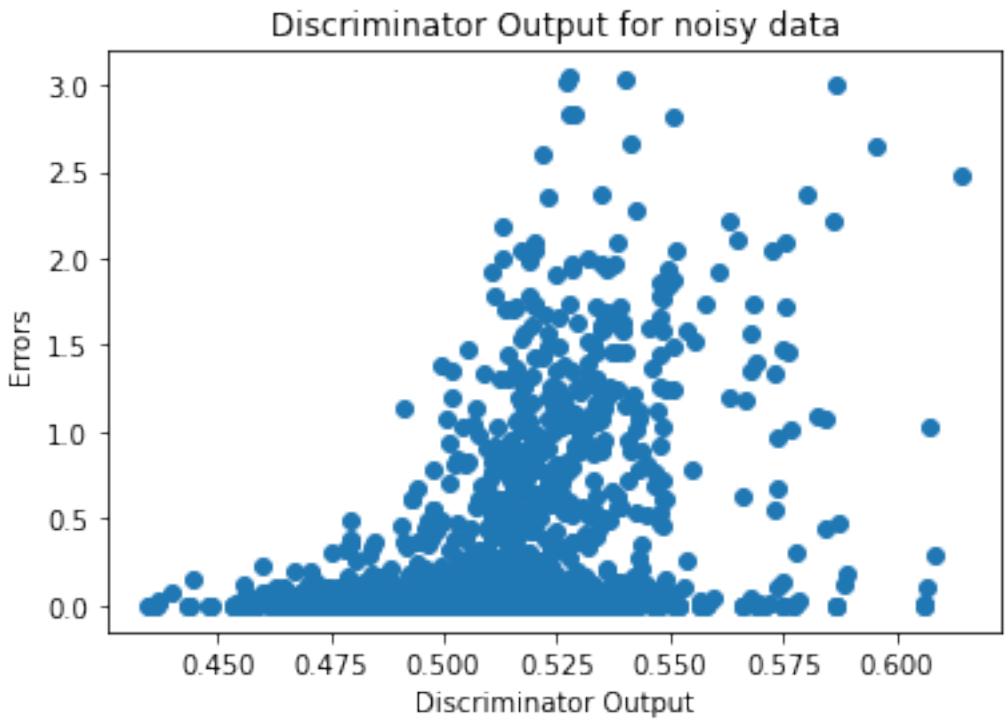
[17]:
```
discLossG2,genLossG2 = train_test.
↪training_GAN_2(discriminator2,generator2,disc_opt,gen_opt,train_data,test_data,batch_size,t
```

```
Number of epochs needed 4
```

[18]:
```
GAN2_metrics=train_test.test_generator_2(generator2,test_data,device)
```

[19]:
```
sanityChecks.discProbVsError(real_dataset,discriminator2,device)
```





2 ABC GAN Model

2.0.1 Training the network

Training ABC-GAN for n_epochs number of epochs

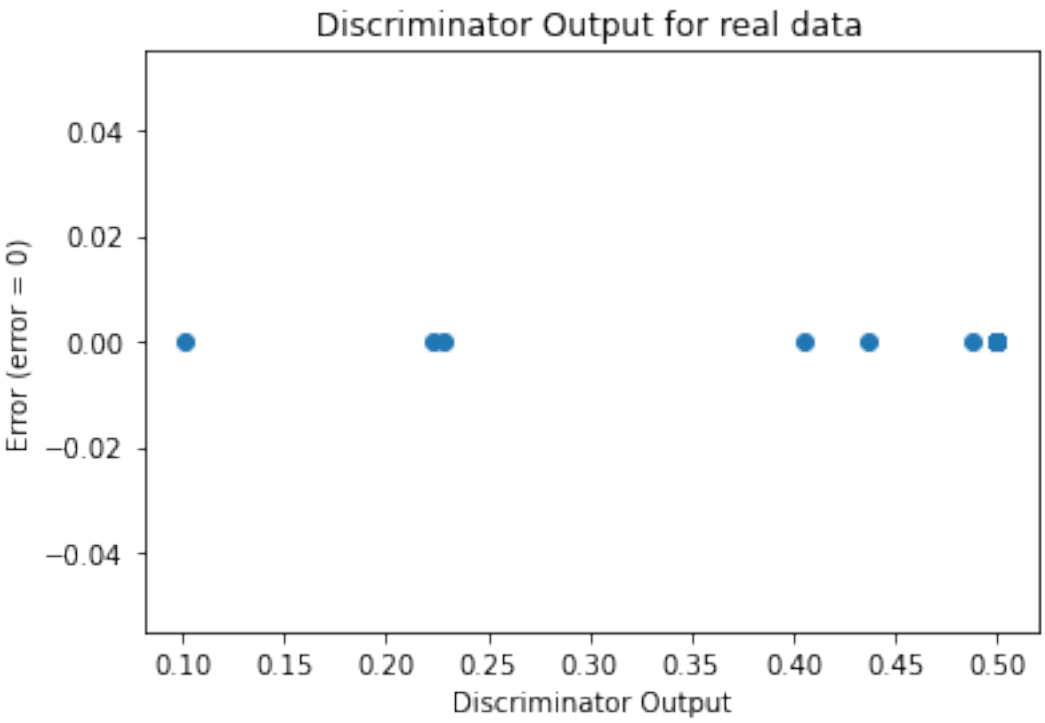
[20]:
```
gen = network.Generator(n_features+1).to(device)
disc = network.Discriminator(n_features+1).to(device)

criterion = torch.nn.BCELoss()
gen_opt = torch.optim.Adam(gen.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(disc.parameters(), lr=0.01, betas=(0.5, 0.999))
```

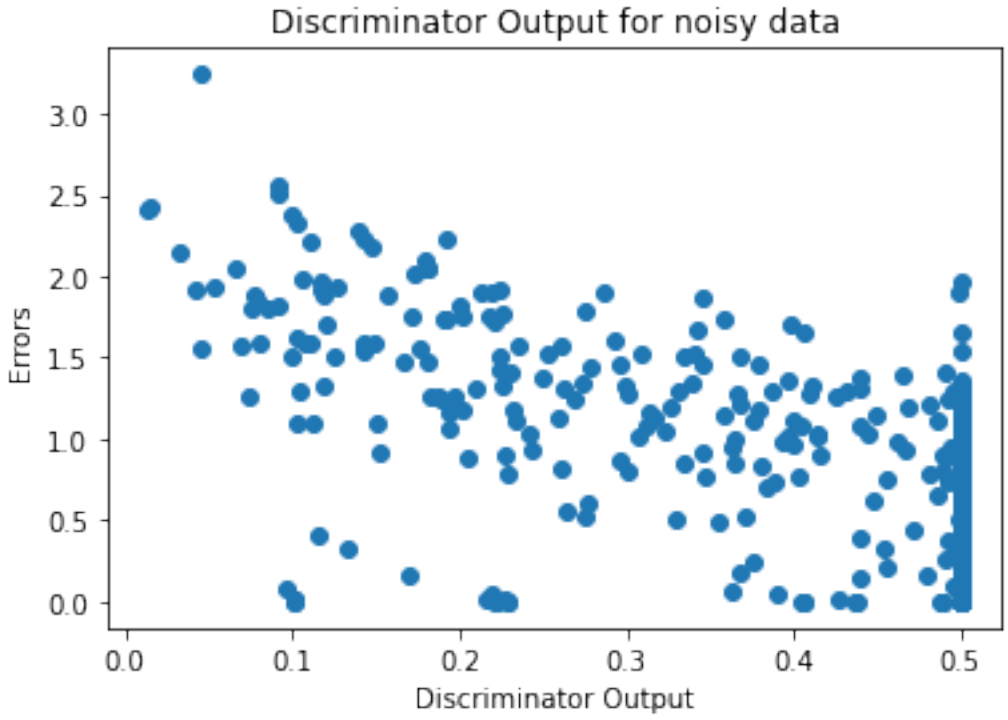
[21]:
```
discLossA1,genLossA1 = ABC_train_test.training_GAN(disc,␣
↪gen,disc_opt,gen_opt,train_data,batch_size,␣
↪n_epochs,criterion,coeff,mean,variance,device)
```

[22]:
```
ABC_GAN1_metrics=ABC_train_test.
↪test_generator(gen,test_data,coeff,mean,variance,device)
```

Sanity Checks

[23]:
```
sanityChecks.discProbVsError(real_dataset,disc,device)
```


Discriminator Output for real data
Error (error = 0)
0.04
0.02
0.00
−0.02
−0.04
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Discriminator Output


Discriminator Output for noisy data
Errors
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
Discriminator Output

Training ABC-GAN until mse of y_pred is > baseline_mse or n_epochs < 5000

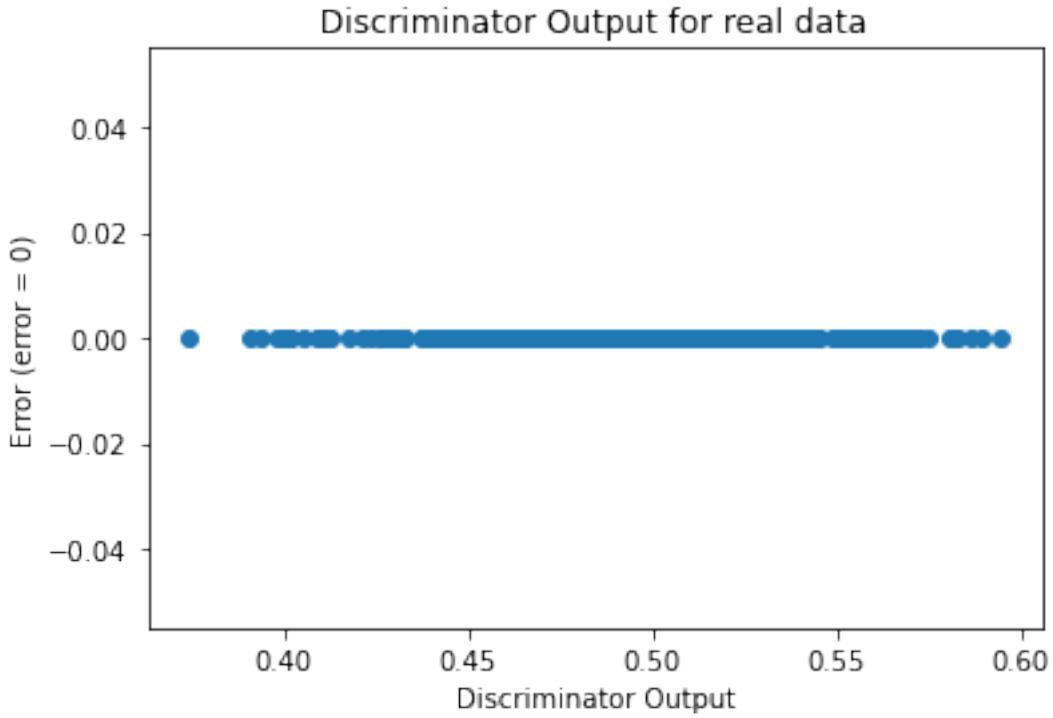
[24]:
```
gen2 = network.Generator(n_features+1).to(device)
disc2 = network.Discriminator(n_features+1).to(device)

criterion = torch.nn.BCELoss()
gen_opt = torch.optim.Adam(gen2.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(disc2.parameters(), lr=0.01, betas=(0.5, 0.999))
```

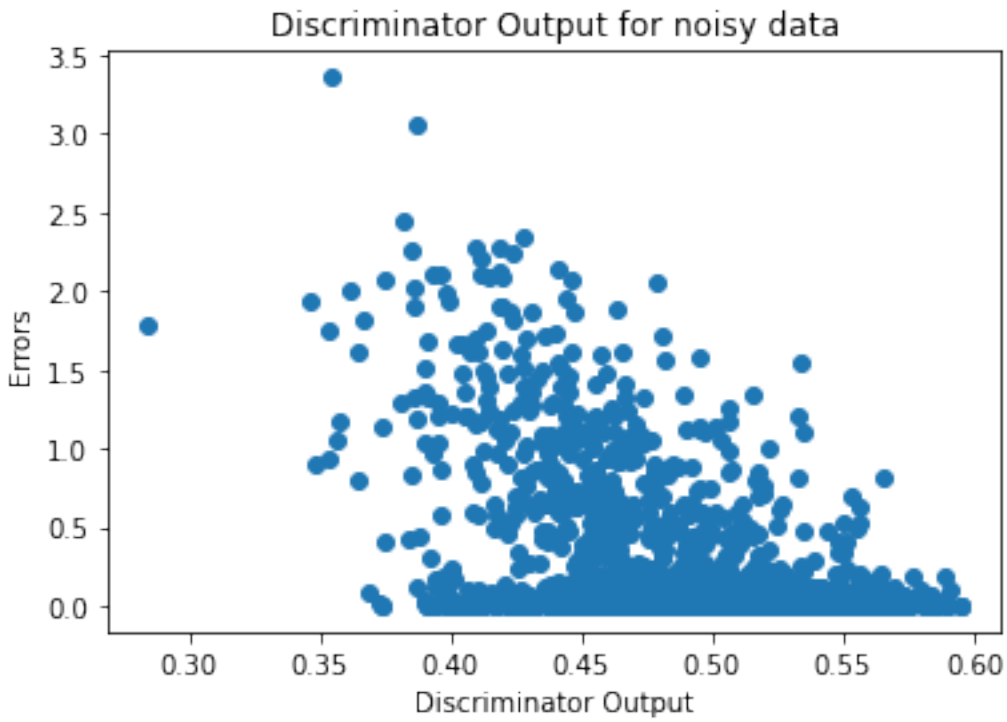
[25]:
```
discLossA2,genLossA2 = ABC_train_test.
↪training_GAN_2(disc2,gen2,disc_opt,gen_opt,train_data,test_data,batch_size,threshold_mse,cr
```

```
Number of epochs 2
```

[26]:
```
ABC_GAN2_metrics=ABC_train_test.
↪test_generator_2(gen2,test_data,coeff,mean,variance,device)
```

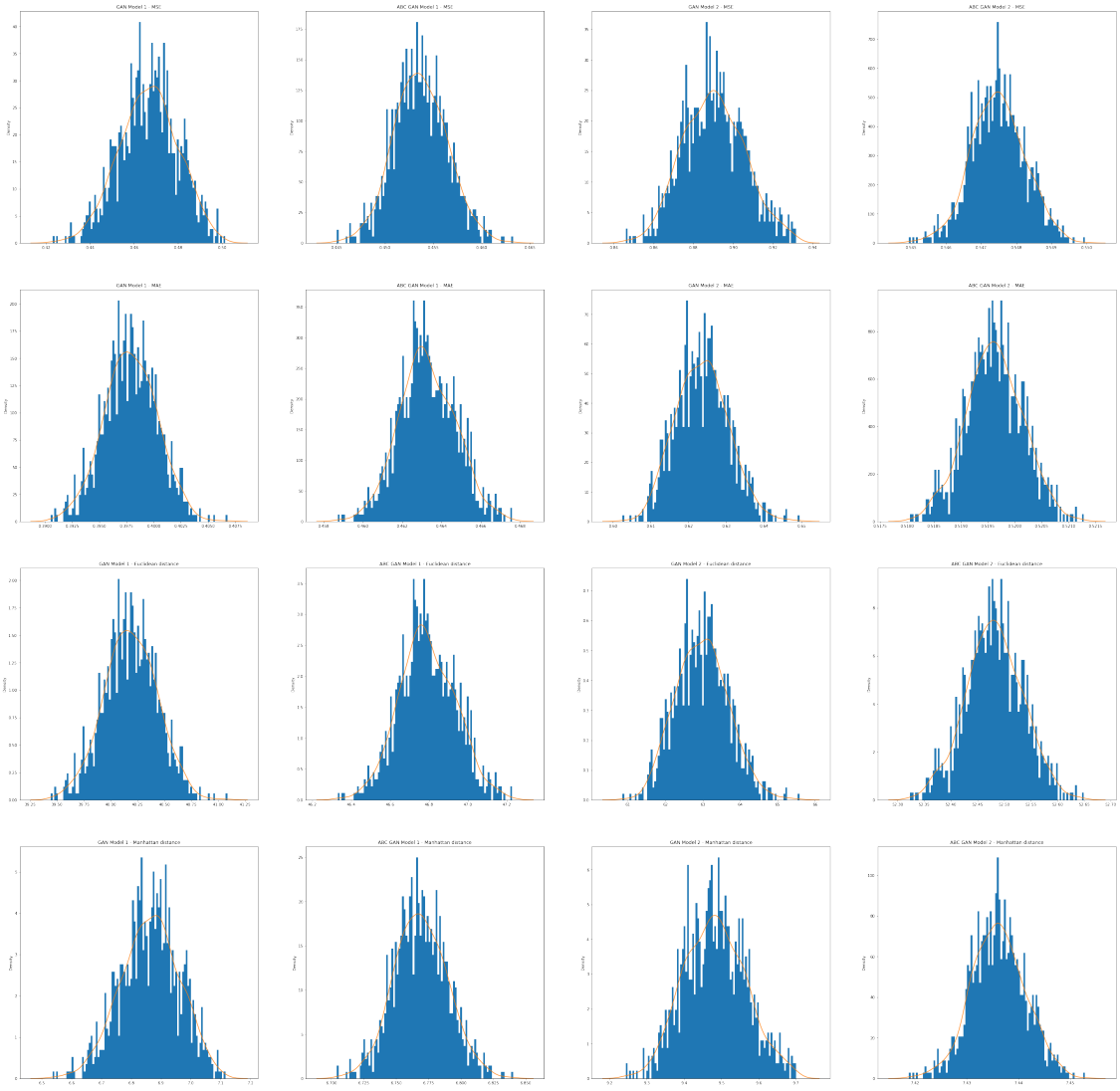
[27]:
```
sanityChecks.discProbVsError(real_dataset,disc2,device)
```



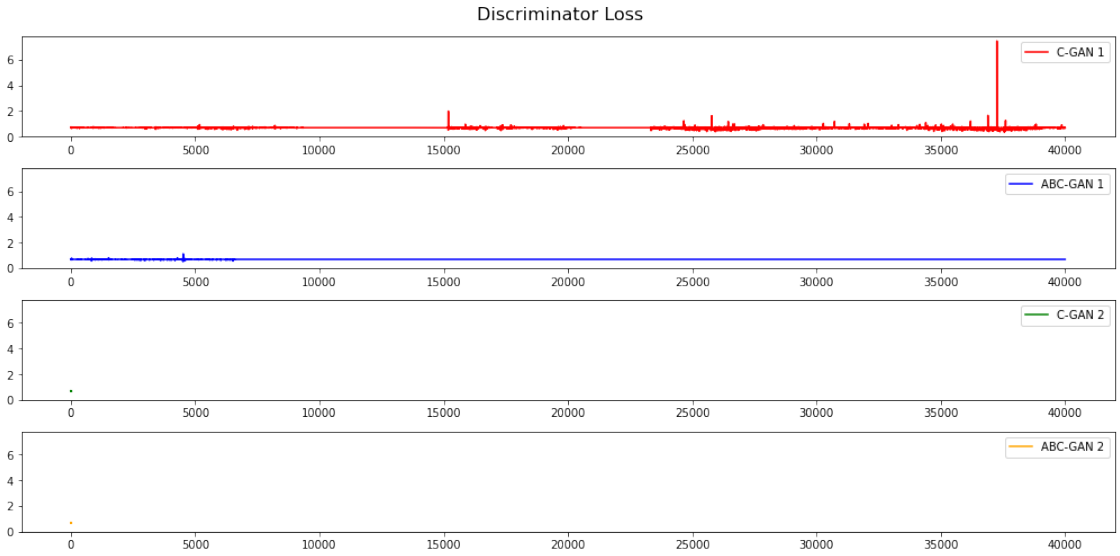


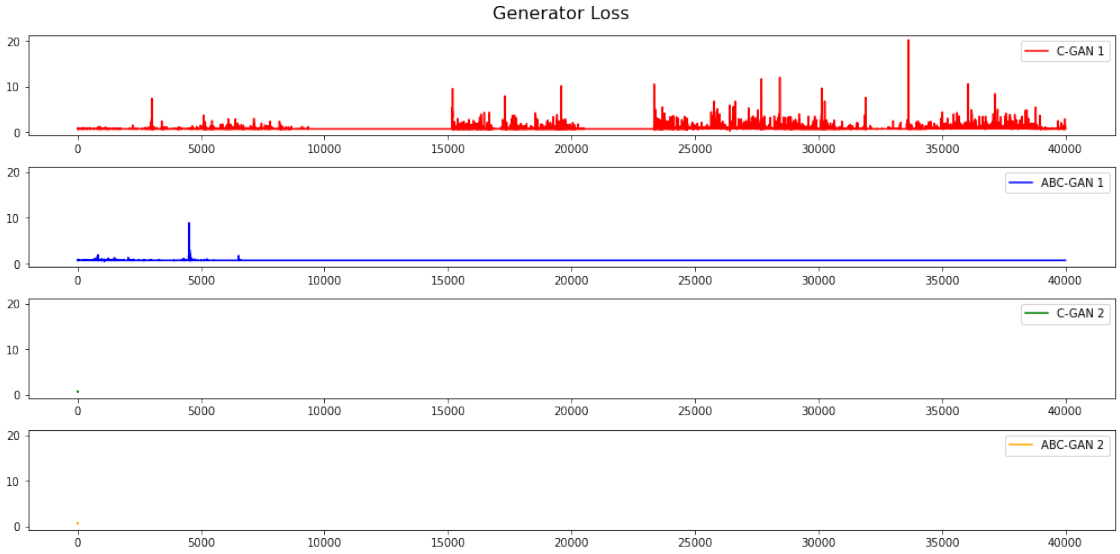
3 Model Analysis

[28]:
```
performanceMetrics.
↪modelAnalysis(GAN1_metrics,ABC_GAN1_metrics,GAN2_metrics,ABC_GAN2_metrics)
```



[29]:
```
performanceMetrics.
↪plotTrainingLoss(discLossG1,genLossG1,discLossA1,genLossA1,discLossG2,genLossG2,discLossA2,
```





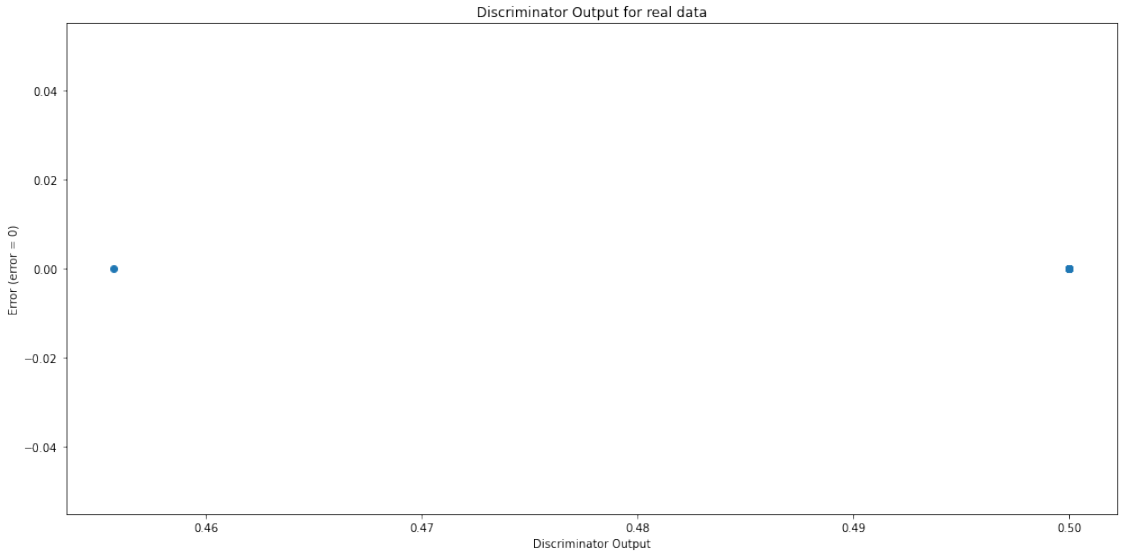
3.1 GAN Model with skip connection

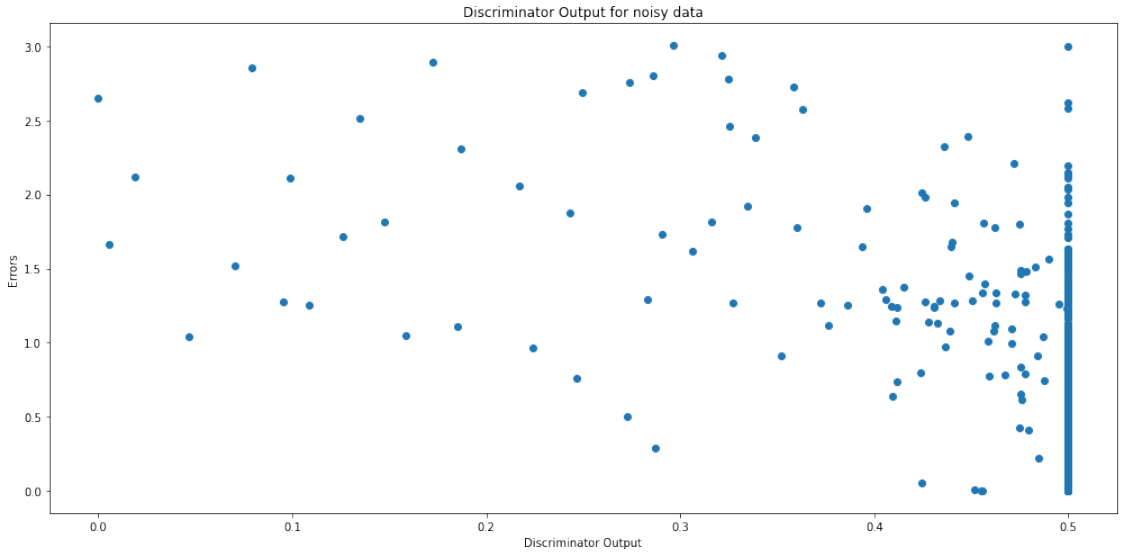
[30]:
```
generator3 = network.GeneratorWithSkipConnection(n_features+1).to(device)
discriminator3 = network.Discriminator(n_features+1).to(device)

criterion = torch.nn.BCELoss()
gen_opt = torch.optim.Adam(generator3.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(discriminator3.parameters(), lr=0.01, betas=(0.5, 0.
↪999))
```

[31]:
```
discLossG3,genLossG3 = train_test.training_GAN(discriminator3,generator3,
    ↪,disc_opt,gen_opt,train_data,batch_size, n_epochs,criterion,device)
```

[32]:
```
GAN3_metrics=ABC_train_test.
    ↪test_generator(generator3,test_data,coeff,mean,variance,device)
```

[33]:
```
sanityChecks.discProbVsError(real_dataset,discriminator3,device)
```





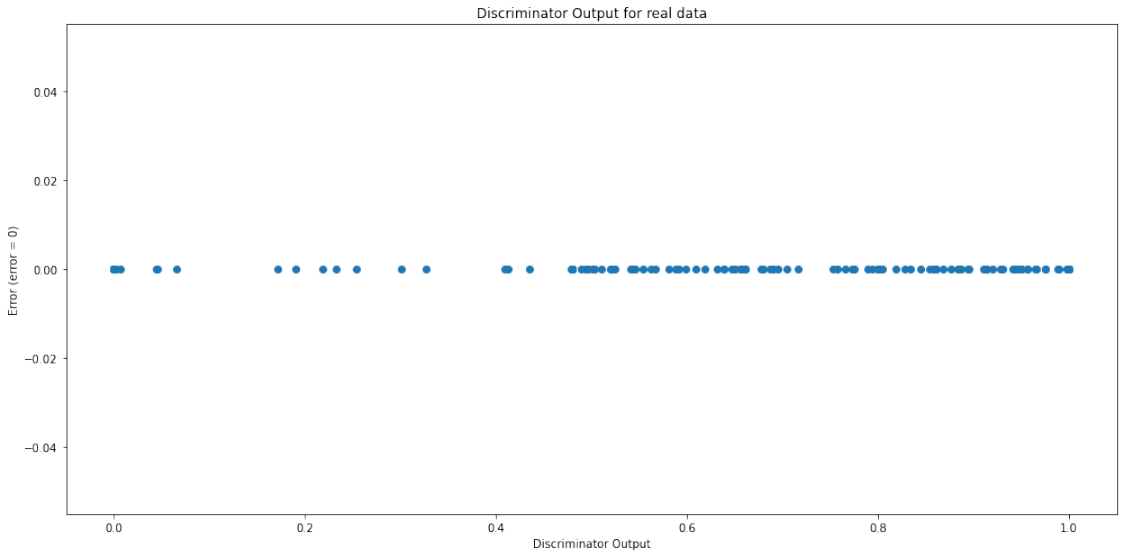
3.2 ABC - GAN Model with skip connection

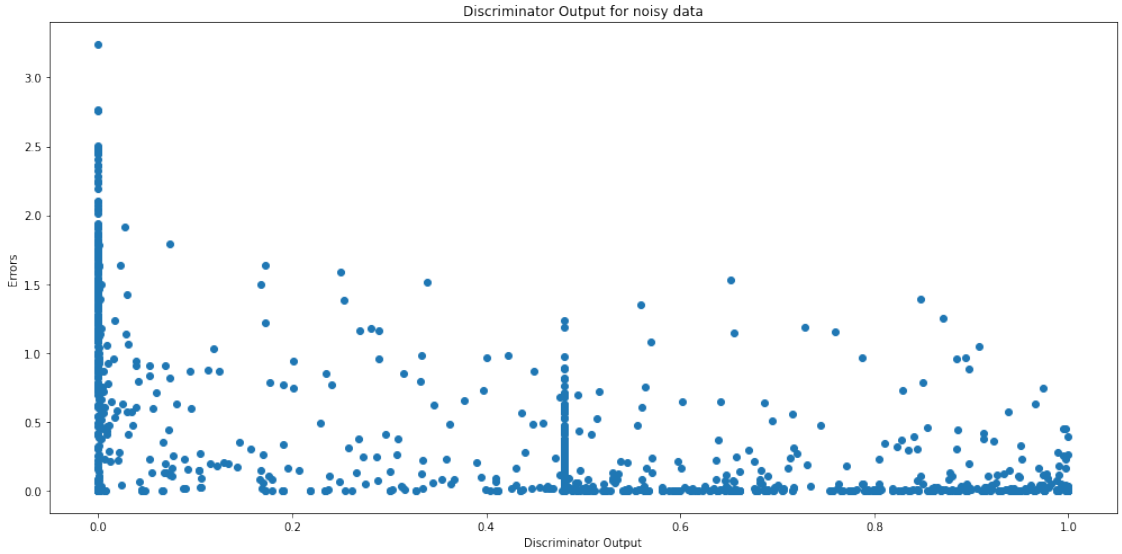
[34]:
```
gen3 = network.GeneratorWithSkipConnection(n_features+1).to(device)
disc3 = network.Discriminator(n_features+1).to(device)

criterion = torch.nn.BCELoss()
gen_opt = torch.optim.Adam(gen3.parameters(), lr=0.01, betas=(0.5, 0.999))
disc_opt = torch.optim.Adam(disc3.parameters(), lr=0.01, betas=(0.5, 0.999))
```

[35]:
```
discLossA3,genLossA3 = ABC_train_test.training_GAN(disc3,␣
↪gen3,disc_opt,gen_opt,train_data,batch_size,␣
↪n_epochs,criterion,coeff,mean,variance,device)
```

[36]:
```
ABC_GAN3_metrics=ABC_train_test.
↪test_generator(gen3,test_data,coeff,mean,variance,device)
```

[37]:
```
sanityChecks.discProbVsError(real_dataset,disc3,device)
```





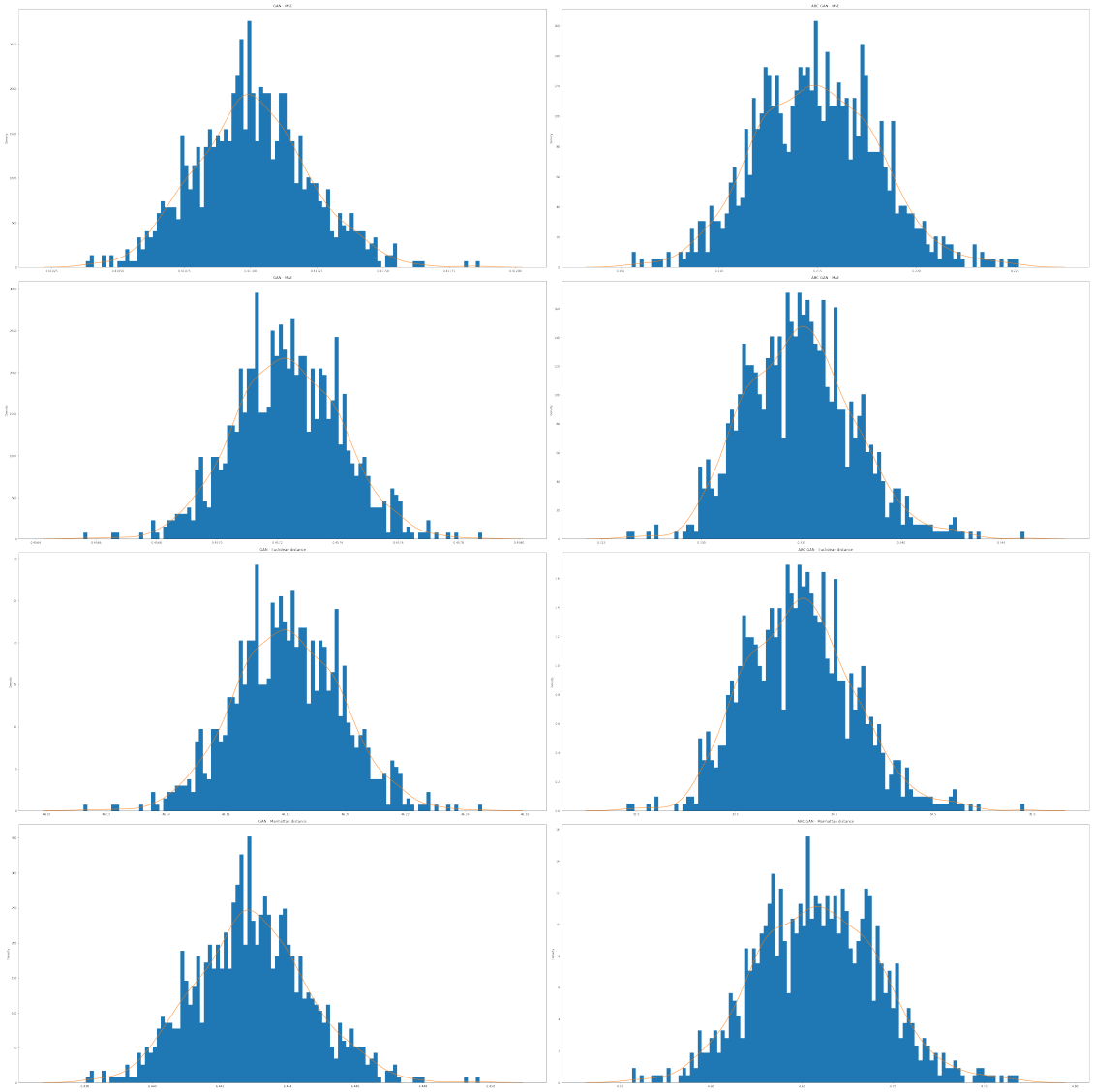
[38]:
```
## Skip Connection Model Analysis - GAN and ABC-GAN
```

[39]:
```
### Weight Analysis

##Study the weights of the skip connection layer
```

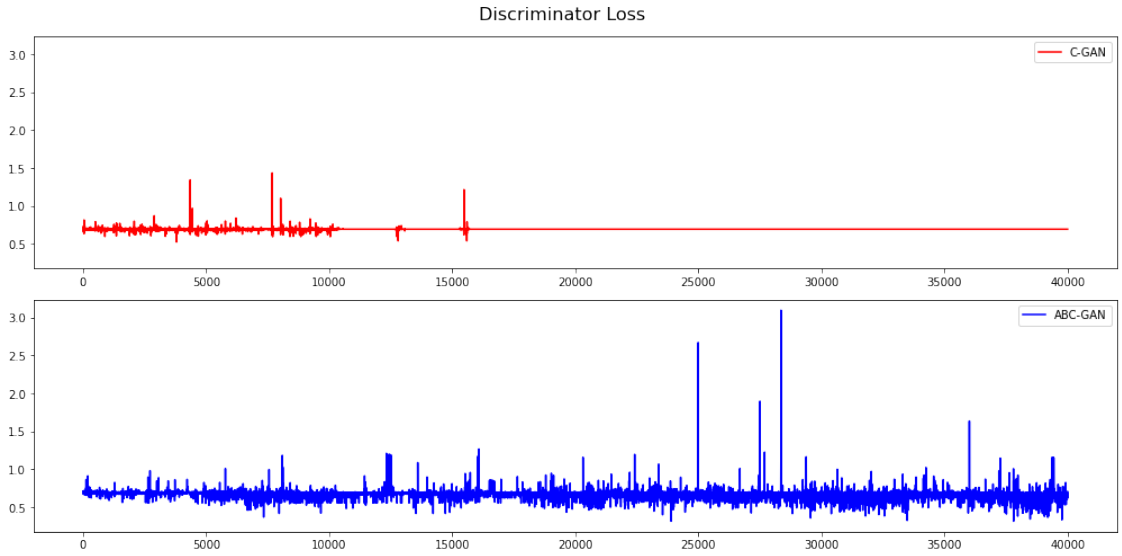
[40]:
```
print("GAN Weights")
for name,param in generator3.named_parameters():
    if(name == "skipNode.weight"):
        print(param)
print("ABC-GAN Weights")
for name,param in gen3.named_parameters():
    if(name == "skipNode.weight"):
        print(param)
```

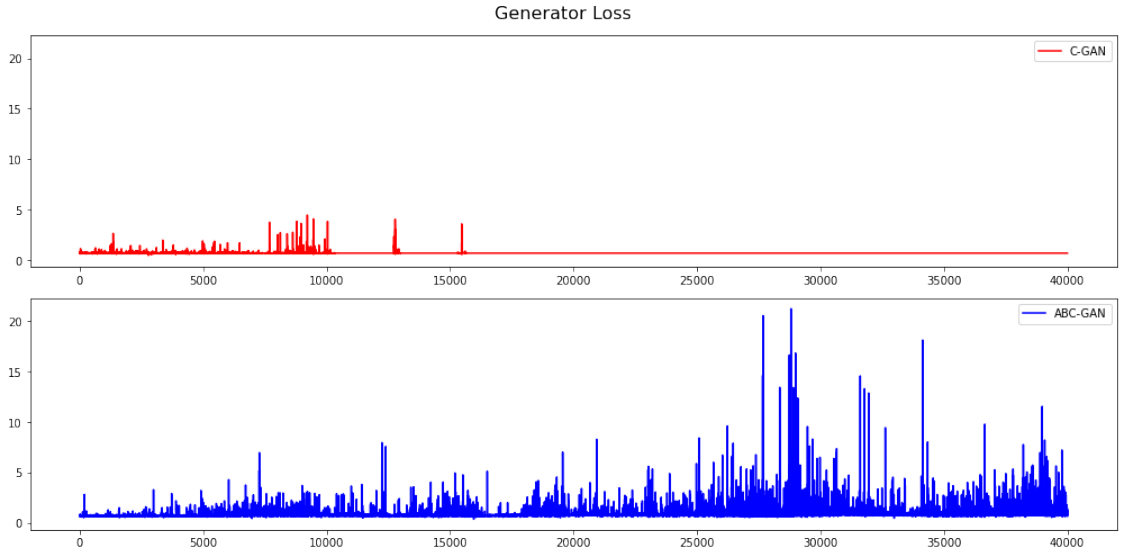
```
GAN Weights
Parameter containing:
tensor([[-0.1147, -0.0218]], requires_grad=True)
ABC-GAN Weights
Parameter containing:
tensor([[0.1232, 0.7255]], requires_grad=True)
```

[41]:
```
performanceMetrics.modelAnalysis2(GAN3_metrics,ABC_GAN3_metrics)
```



[42]:
```
performanceMetrics.plotTrainingLoss2(discLossG3,genLossG3,discLossA3,genLossA3)
```


Discriminator Loss
C-GAN
ABC-GAN
3.0
2.5
2.0
1.5
1.0
0.5
0
5000
10000
15000
20000
25000
30000
35000
40000


Generator Loss
C-GAN
ABC-GAN
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000

[ ]: