

In [2]: `from cmdstanpy import CmdStanModel`

```
import arviz as az
import numpy as np
import scipy.stats as stats

import pandas as pd

import matplotlib.pyplot as plt
import matplotlib as mpl
```

Read data from CVS file

In [3]: `data = pd.read_csv('logistic_reg_data.csv')`
`data.describe()`

Out[3]:

	Unnamed: 0	x1	x2	x3	x4	x5	
count	500.000000	500.000000	500.000000	500.000000	5.000000e+02	5.000000e+02	500.0000
mean	249.500000	-0.015777	0.334002	-0.001484	2.022817e-01	2.770684e-03	0.494000
std	144.481833	0.578292	0.301507	0.383111	2.738984e-01	3.107472e-01	0.500000
min	0.000000	-0.997592	0.000005	-0.992794	2.276756e-11	-9.880191e-01	0.000000
25%	124.750000	-0.515144	0.064052	-0.136718	4.102616e-03	-3.628888e-02	0.000000
50%	249.500000	-0.026042	0.254724	-0.000018	6.488454e-02	-1.278838e-08	0.000000
75%	374.250000	0.475396	0.555544	0.107440	3.086316e-01	2.428165e-02	1.000000
max	499.000000	0.999652	0.999305	0.998957	9.986100e-01	9.982628e-01	1.000000

Prior selection

In [30]: `model_ppc1 = CmdStanModel(stan_file='logistic_regression_ppc.stan')`
`R=1000`
`data_ppc= dict(N = data.shape[0],`
`M = 5,`
`X = data.iloc[:,0:5].values,`
`sigma=10)`
`sim_ppc1=model_ppc1.sample(data=data_ppc,`
`iter_sampling=R, iter_warmup=0,`
`chains=1,`
`refresh=R,`
`fixed_param=True,`
`seed=29042020)`

```

INFO:cmdstanpy:compiling stan file /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.stan to exe file /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc
INFO:cmdstanpy:compiled model executable: /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc
WARNING:cmdstanpy:Stan compiler has produced 1 warnings:
WARNING:cmdstanpy:
--- Translating Stan model to C++ code ---
bin/stanc --o=/home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.hpp /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.stan
Warning in '/home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.stan', line 16, column 1: Declaration
    of arrays by placing brackets after a variable name is deprecated and
    will be removed in Stan 2.32.0. Instead use the array keyword before
the
    type. This can be changed automatically using the auto-format flag to
    stanc

--- Compiling, linking C++ code ---
g++ -std=c++1y -pthread -D_REENTRANT -Wno-sign-compare -Wno-ignored-attributes -I stan/lib/stan_math/lib/tbb_2020.3/include -O3 -I src -I stan/src -I lib/rapidjson_1.1.0/ -I lib/CLI11-1.9.1/ -I stan/lib/stan_math/ -I stan/lib/stan_math/lib/eigen_3.3.9 -I stan/lib/stan_math/lib/boost_1.75.0 -I stan/lib/stan_math/lib/sundials_6.0.0/include -I stan/lib/stan_math/lib/sundials_6.0.0/src/sundials -DBOOST_DISABLE_ASSERTS -c -Wno-ignored-attributes -x c++ -o /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.o /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.hpp
g++ -std=c++1y -pthread -D_REENTRANT -Wno-sign-compare -Wno-ignored-attributes -I stan/lib/stan_math/lib/tbb_2020.3/include -O3 -I src -I stan/src -I lib/rapidjson_1.1.0/ -I lib/CLI11-1.9.1/ -I stan/lib/stan_math/ -I stan/lib/stan_math/lib/eigen_3.3.9 -I stan/lib/stan_math/lib/boost_1.75.0 -I stan/lib/stan_math/lib/sundials_6.0.0/include -I stan/lib/stan_math/lib/sundials_6.0.0/src/sundials -DBOOST_DISABLE_ASSERTS -WL,-L,/home/kasia/.cmdstan/cmdstan-2.29.1/stan/lib/stan_math/lib/tbb" -WL,-rpath,/home/kasia/.cmdstan/cmdstan-2.29.1/stan/lib/stan_math/lib/tbb" /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.o src/cmdstan/main.o -WL,-L,/home/kasia/.cmdstan/cmdstan-2.29.1/stan/lib/stan_math/lib/tbb" -WL,-rpath,/home/kasia/.cmdstan/cmdstan-2.29.1/stan/lib/stan_math/lib/tbb" stan/lib/stan_math/lib/sundials_6.0.0/lib/libsundials_nvecserial.a stan/lib/stan_math/lib/sundials_6.0.0/lib/libsundials_cvodes.a stan/lib/stan_math/lib/sundials_6.0.0/lib/libsundials_idea.a stan/lib/stan_math/lib/sundials_6.0.0/lib/libsundials_kinsol.a stan/lib/stan_math/lib/tbb/libtbb.so.2 -o /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc
rm -f /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression_ppc.o

```

```

INFO:cmdstanpy:CmdStan start processing
chain 1 | | 00:00 Status

```

```

INFO:cmdstanpy:CmdStan done processing.

```

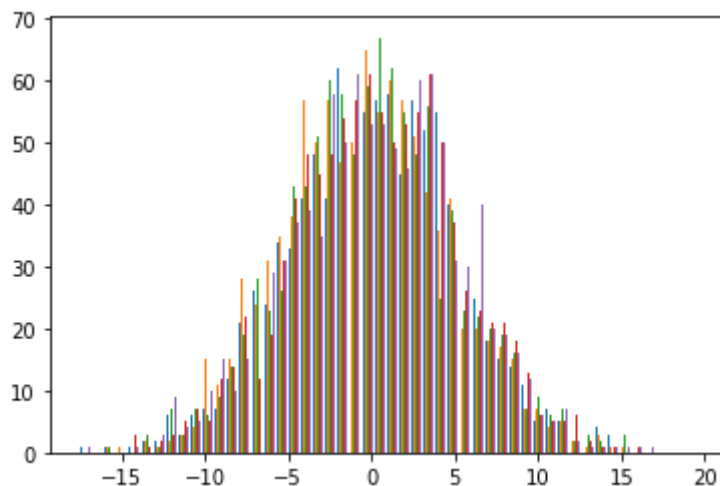
Task 1. Plot histograms of beta for prior model Plot again the same histograms but this time with other sigma values. For instance use values: 5, 2, 0.75. Consider which result should be taken into account when selecting prior.

```

In [42]: beta = sim_ppc1.stan_variable(var='beta')
plt.hist(beta, bins = 50)

```

```
Out[42]: (array([[ 1.,  0.,  1.,  0.,  1.,  2.,  2.,  6.,  3.,  6.,  7.,  7., 12.,
                21., 26., 24., 34., 33., 41., 48., 41., 62., 56., 55., 57., 58.,
                45., 57., 52., 55., 40., 36., 25., 18., 15., 14., 11.,  5.,  7.,
                5.,  3.,  0.,  4.,  3.,  0.,  0.,  0.,  0.,  0.,  1.],
               [ 0.,  0.,  1.,  1.,  0.,  2.,  1.,  2.,  3.,  4., 15., 11., 15.,
                28., 24., 31., 35., 38., 57., 50., 57., 47., 50., 65., 55., 60.,
                57., 51., 42., 36., 41., 20., 20., 18., 17., 15.,  7.,  7.,  4.,
                5.,  2.,  1.,  3.,  1.,  1.,  0.,  0.,  0.,  0.,  0.],
               [ 0.,  0.,  1.,  0.,  0.,  3.,  1.,  7.,  3.,  7.,  6.,  9., 14.,
                19., 28., 23., 26., 43., 43., 51., 60., 58., 48., 59., 67., 62.,
                55., 48., 56., 25., 39., 23., 22., 20., 19., 16.,  7.,  9.,  6.,
                7.,  2.,  3.,  2.,  0.,  3.,  0.,  0.,  0.,  0.,  0.],
               [ 0.,  0.,  0.,  0.,  3.,  1.,  2.,  3.,  5.,  7.,  5., 12., 14.,
                22., 12., 19., 31., 41., 48., 45., 48., 54., 57., 61., 55., 50.,
                53., 55., 61., 50., 37., 26., 23., 21., 21., 18., 13.,  6.,  5.,
                5.,  6.,  2.,  1.,  1.,  0.,  1.,  0.,  0.,  0.,  0.],
               [ 1.,  0.,  0.,  0.,  1.,  2.,  3.,  9.,  4.,  5., 10., 15., 10.,
                15., 19., 29., 31., 37., 39., 35., 58., 50., 61., 53., 53., 49.,
                46., 60., 61., 50., 31., 30., 40., 20., 19., 16., 12.,  6.,  5.,
                7.,  2.,  1.,  1.,  1.,  1.,  1.,  1.,  0.,  0.,  0.])),
          array([-17.5553, -16.819264, -16.083228, -15.347192, -14.611156,
                -13.87512, -13.139084, -12.403048, -11.667012, -10.930976,
                -10.19494, -9.458904, -8.722868, -7.986832, -7.250796,
                -6.51476, -5.778724, -5.042688, -4.306652, -3.570616,
                -2.83458, -2.098544, -1.362508, -0.626472,  0.109564,
                 0.8456,  1.581636,  2.317672,  3.053708,  3.789744,
                 4.52578,  5.261816,  5.997852,  6.733888,  7.469924,
                 8.20596,  8.941996,  9.678032, 10.414068, 11.150104,
                11.88614, 12.622176, 13.358212, 14.094248, 14.830284,
                15.56632, 16.302356, 17.038392, 17.774428, 18.510464,
                19.2465 ]),
          <a list of 5 BarContainer objects>)
```



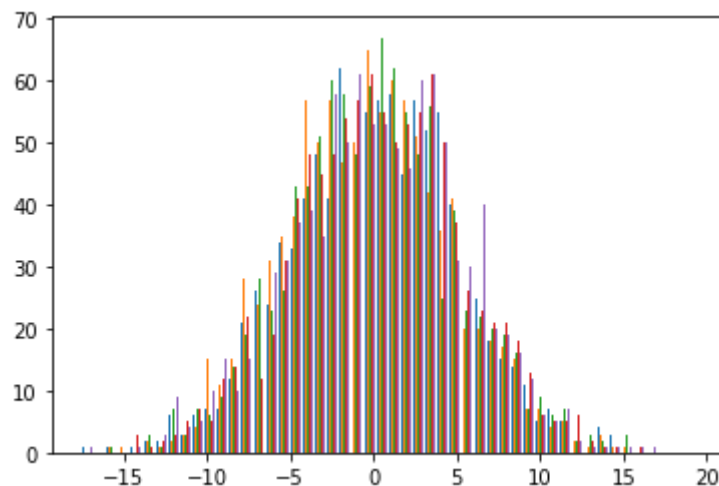
```
In [41]: data_ppc= dict(N = data.shape[0],
                        M = 5,
                        X = data.iloc[:,0:5].values,
                        sigma=5)
sim_ppc1=model_ppc1.sample(data=data_ppc,
                           iter_sampling=R, iter_warmup=0,
                           chains=1,
                           refresh=R,
                           fixed_param=True,
                           seed=29042020)

beta = sim_ppc1.stan_variable(var='beta')
plt.hist(beta, bins = 50)
```

```
INFO:cmdstanpy:CmdStan start processing
chain 1 | | 00:00 Status
```

```
INFO:cmdstanpy:CmdStan done processing.
```

```
Out[41]: (array([[ 1.,  0.,  1.,  0.,  1.,  2.,  2.,  6.,  3.,  6.,  7.,  7., 12.,
                21., 26., 24., 34., 33., 41., 48., 41., 62., 56., 55., 57., 58.,
                45., 57., 52., 55., 40., 36., 25., 18., 15., 14., 11.,  5.,  7.,
                5.,  3.,  0.,  4.,  3.,  0.,  0.,  0.,  0.,  0.,  1.],
                [ 0.,  0.,  1.,  1.,  0.,  2.,  1.,  2.,  3.,  4., 15., 11., 15.,
                28., 24., 31., 35., 38., 57., 50., 57., 47., 50., 65., 55., 60.,
                57., 51., 42., 36., 41., 20., 20., 18., 17., 15.,  7.,  7.,  4.,
                5.,  2.,  1.,  3.,  1.,  1.,  0.,  0.,  0.,  0.,  0.],
                [ 0.,  0.,  1.,  0.,  0.,  3.,  1.,  7.,  3.,  7.,  6.,  9., 14.,
                19., 28., 23., 26., 43., 43., 51., 60., 58., 48., 59., 67., 62.,
                55., 48., 56., 25., 39., 23., 22., 20., 19., 16.,  7.,  9.,  6.,
                7.,  2.,  3.,  2.,  0.,  3.,  0.,  0.,  0.,  0.,  0.],
                [ 0.,  0.,  0.,  0.,  3.,  1.,  2.,  3.,  5.,  7.,  5., 12., 14.,
                22., 12., 19., 31., 41., 48., 45., 48., 54., 57., 61., 55., 50.,
                53., 55., 61., 50., 37., 26., 23., 21., 21., 18., 13.,  6.,  5.,
                5.,  6.,  2.,  1.,  1.,  0.,  1.,  0.,  0.,  0.,  0.],
                [ 1.,  0.,  0.,  0.,  1.,  2.,  3.,  9.,  4.,  5., 10., 15., 10.,
                15., 19., 29., 31., 37., 39., 35., 58., 50., 61., 53., 53., 49.,
                46., 60., 61., 50., 31., 30., 40., 20., 19., 16., 12.,  6.,  5.,
                7.,  2.,  1.,  1.,  1.,  1.,  1.,  1.,  0.,  0.,  0.])),
array([-17.5553, -16.819264, -16.083228, -15.347192, -14.611156,
       -13.87512, -13.139084, -12.403048, -11.667012, -10.930976,
       -10.19494, -9.458904, -8.722868, -7.986832, -7.250796,
       -6.51476, -5.778724, -5.042688, -4.306652, -3.570616,
       -2.83458, -2.098544, -1.362508, -0.626472,  0.109564,
        0.8456,  1.581636,  2.317672,  3.053708,  3.789744,
        4.52578,  5.261816,  5.997852,  6.733888,  7.469924,
        8.20596,  8.941996,  9.678032, 10.414068, 11.150104,
        11.88614, 12.622176, 13.358212, 14.094248, 14.830284,
        15.56632, 16.302356, 17.038392, 17.774428, 18.510464,
        19.2465 ]),
<a list of 5 BarContainer objects>)
```



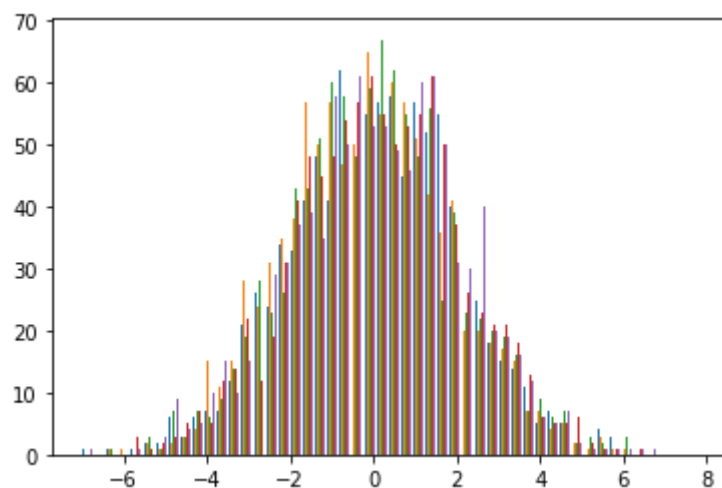
```
In [40]: data_ppc= dict(N = data.shape[0],
                        M = 5,
                        X = data.iloc[:,0:5].values,
                        sigma=2)
sim_ppc1=model_ppc1.sample(data=data_ppc,
                           iter_sampling=R, iter_warmup=0,
                           chains=1,
                           refresh=R,
                           fixed_param=True,
                           seed=29042020)

beta = sim_ppc1.stan_variable(var='beta')
plt.hist(beta, bins = 50)
```

```
INFO:cmdstanpy:CmdStan start processing
chain 1 | 00:00 Status
```

```
INFO:cmdstanpy:CmdStan done processing.
```

```
Out[40]: (array([[ 1.,  0.,  1.,  0.,  1.,  2.,  2.,  6.,  3.,  6.,  7.,  7., 12.,
                21., 26., 24., 34., 33., 41., 48., 41., 62., 56., 55., 57., 58.,
                45., 57., 52., 55., 40., 36., 25., 18., 15., 14., 11.,  5.,  7.,
                5.,  3.,  0.,  4.,  3.,  0.,  0.,  0.,  0.,  0.,  1.],
              [ 0.,  0.,  1.,  1.,  0.,  2.,  1.,  2.,  3.,  4., 15., 11., 15.,
                28., 24., 31., 35., 38., 57., 50., 57., 47., 50., 65., 55., 60.,
                57., 51., 42., 36., 41., 20., 20., 18., 17., 15.,  7.,  7.,  4.,
                5.,  2.,  1.,  3.,  1.,  1.,  0.,  0.,  0.,  0.,  0.],
              [ 0.,  0.,  1.,  0.,  0.,  3.,  1.,  7.,  3.,  7.,  6.,  9., 14.,
                19., 28., 23., 26., 43., 43., 51., 60., 58., 48., 59., 67., 62.,
                55., 48., 56., 25., 39., 23., 22., 20., 19., 16.,  7.,  9.,  6.,
                7.,  2.,  3.,  2.,  0.,  3.,  0.,  0.,  0.,  0.,  0.],
              [ 0.,  0.,  0.,  0.,  3.,  1.,  2.,  3.,  5.,  7.,  5., 12., 14.,
                22., 12., 19., 31., 41., 48., 45., 48., 54., 57., 61., 55., 50.,
                53., 55., 61., 50., 37., 26., 23., 21., 21., 18., 13.,  6.,  5.,
                5.,  6.,  2.,  1.,  1.,  0.,  1.,  0.,  0.,  0.,  0.],
              [ 1.,  0.,  0.,  0.,  1.,  2.,  3.,  9.,  4.,  5., 10., 15., 10.,
                15., 19., 29., 31., 37., 39., 35., 58., 50., 61., 53., 53., 49.,
                46., 60., 61., 50., 31., 30., 40., 20., 19., 16., 12.,  6.,  5.,
                7.,  2.,  1.,  1.,  1.,  1.,  1.,  1.,  0.,  0.,  0.]]),
          array([-7.02212 , -6.7277054, -6.4332908, -6.1388762, -5.8444616,
                -5.550047 , -5.2556324, -4.9612178, -4.6668032, -4.3723886,
                -4.077974 , -3.7835594, -3.4891448, -3.1947302, -2.9003156,
                -2.605901 , -2.3114864, -2.0170718, -1.7226572, -1.4282426,
                -1.133828 , -0.8394134, -0.5449988, -0.2505842,  0.0438304,
                 0.338245 ,  0.6326596,  0.9270742,  1.2214888,  1.5159034,
                 1.810318 ,  2.1047326,  2.3991472,  2.6935618,  2.9879764,
                 3.282391 ,  3.5768056,  3.8712202,  4.1656348,  4.4600494,
                 4.754464 ,  5.0488786,  5.3432932,  5.6377078,  5.9321224,
                 6.226537 ,  6.5209516,  6.8153662,  7.1097808,  7.4041954,
                 7.69861  ]),
          <a list of 5 BarContainer objects>)
```



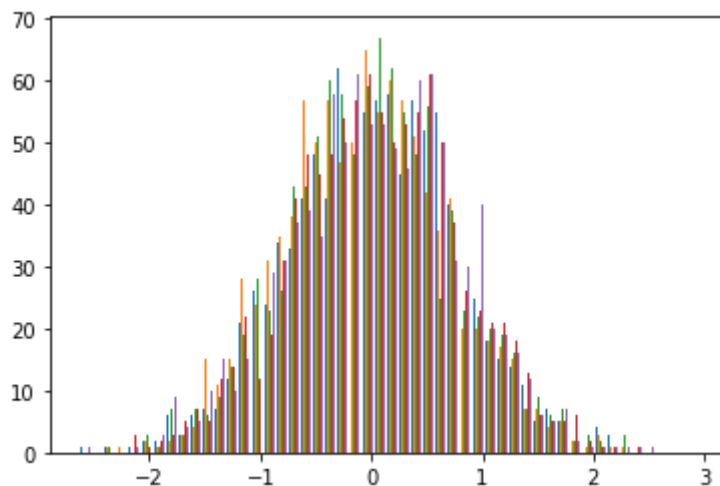
```
In [39]: data_ppc= dict(N = data.shape[0],
                        M = 5,
                        X = data.iloc[:,0:5].values,
                        sigma=0.75)
sim_ppc1=model_ppc1.sample(data=data_ppc,
                           iter_sampling=R, iter_warmup=0,
                           chains=1,
                           refresh=R,
                           fixed_param=True,
                           seed=29042020)

beta = sim_ppc1.stan_variable(var='beta')
plt.hist(beta, bins = 50)
```

```
INFO:cmdstanpy:CmdStan start processing
chain 1 |           | 00:00 Status
```

```
INFO:cmdstanpy:CmdStan done processing.
```

```
Out[39]: (array([[ 1.,  0.,  1.,  0.,  1.,  2.,  2.,  6.,  3.,  6.,  7.,  7., 12.,
                21., 26., 24., 34., 33., 41., 48., 41., 62., 56., 55., 57., 58.,
                45., 57., 52., 55., 40., 36., 25., 18., 15., 14., 11.,  5.,  7.,
                5.,  3.,  0.,  4.,  3.,  0.,  0.,  0.,  0.,  0.,  1.],
               [ 0.,  0.,  1.,  1.,  0.,  2.,  1.,  2.,  3.,  4., 15., 11., 15.,
                28., 24., 31., 35., 38., 57., 50., 57., 47., 50., 65., 55., 60.,
                57., 51., 42., 36., 41., 20., 20., 18., 17., 15.,  7.,  7.,  4.,
                5.,  2.,  1.,  3.,  1.,  1.,  0.,  0.,  0.,  0.,  0.],
               [ 0.,  0.,  1.,  0.,  0.,  3.,  1.,  7.,  3.,  7.,  6.,  9., 14.,
                19., 28., 23., 26., 43., 43., 51., 60., 58., 48., 59., 67., 62.,
                55., 48., 56., 25., 39., 23., 22., 20., 19., 16.,  7.,  9.,  6.,
                7.,  2.,  3.,  2.,  0.,  3.,  0.,  0.,  0.,  0.,  0.],
               [ 0.,  0.,  0.,  0.,  3.,  1.,  2.,  3.,  5.,  7.,  5., 12., 14.,
                22., 12., 19., 31., 41., 48., 45., 48., 54., 57., 61., 55., 50.,
                53., 55., 61., 50., 37., 26., 23., 21., 21., 18., 13.,  6.,  5.,
                5.,  6.,  2.,  1.,  1.,  0.,  1.,  0.,  0.,  0.,  0.],
               [ 1.,  0.,  0.,  0.,  1.,  2.,  3.,  9.,  4.,  5., 10., 15., 10.,
                15., 19., 29., 31., 37., 39., 35., 58., 50., 61., 53., 53., 49.,
                46., 60., 61., 50., 31., 30., 40., 20., 19., 16., 12.,  6.,  5.,
                7.,  2.,  1.,  1.,  1.,  1.,  1.,  1.,  0.,  0.,  0.])),
          array([-2.63329, -2.5228846, -2.4124792, -2.3020738, -2.1916684,
                -2.081263, -1.9708576, -1.8604522, -1.7500468, -1.6396414,
                -1.529236, -1.4188306, -1.3084252, -1.1980198, -1.0876144,
                -0.977209, -0.8668036, -0.7563982, -0.6459928, -0.5355874,
                -0.425182, -0.3147766, -0.2043712, -0.0939658,  0.0164396,
                 0.126845,  0.2372504,  0.3476558,  0.4580612,  0.5684666,
                 0.678872,  0.7892774,  0.8996828,  1.0100882,  1.1204936,
                 1.230899,  1.3413044,  1.4517098,  1.5621152,  1.6725206,
                 1.782926,  1.8933314,  2.0037368,  2.1141422,  2.2245476,
                 2.334953,  2.4453584,  2.5557638,  2.6661692,  2.7765746,
                 2.88698 ]),
          <a list of 5 BarContainer objects>)
```



Posterior inference

Task 2. Edit stan model and create models with different priors. Use original setting and some priors from task 1. Fit the model Plot the probability of individual outcome: plot generated parameter theta (prob_pcc): mean with its error bars (plt.errorbar) to plot its error bars take into consider its 25th, 50th and 75th percentile also mark the real value of y, by different colored dots (for mean values) Consider if the probability was well captured by each setting

```
In [44]: model = CmdStanModel(stan_file='logistic_regression.stan')
data_dict = dict(N = data.shape[0],
                  M = 5,
                  X = data.iloc[:,0:5].values,
                  y = data.y.values
                )
fit = model.sample(data=data_dict, seed=4938483)
#plot
med_prob_ppc = np.percentile(fit.stan_variable('prob_ppc'), [25, 50, 75], axis=0)
estimate_ppc_df = pd.DataFrame(med_prob_ppc.T, columns = ['lo', 'med', 'hi'])
```



```

INFO:cmdstanpy:compiling stan file /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression.stan to exe file /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression
INFO:cmdstanpy:compiled model executable: /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression
WARNING:cmdstanpy:Stan compiler has produced 2 warnings:
WARNING:cmdstanpy:
--- Translating Stan model to C++ code ---
bin/stanc --o=/home/kasia/Documents/DataAnalytics/Lab5/logistic_regression.hpp /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression.stan
Warning in '/home/kasia/Documents/DataAnalytics/Lab5/logistic_regression.stan', line 5, column 1: Declaration
    of arrays by placing brackets after a variable name is deprecated and
    will be removed in Stan 2.32.0. Instead use the array keyword before
the
    type. This can be changed automatically using the auto-format flag to
    stanc
Warning in '/home/kasia/Documents/DataAnalytics/Lab5/logistic_regression.stan', line 28, column 1: Declaration
    of arrays by placing brackets after a variable name is deprecated and
    will be removed in Stan 2.32.0. Instead use the array keyword before
the
    type. This can be changed automatically using the auto-format flag to
    stanc

--- Compiling, linking C++ code ---
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rm -f /home/kasia/Documents/DataAnalytics/Lab5/logistic_regression.o

INFO:cmdstanpy:CmdStan start processing
chain 1 | | 00:00 Status
chain 2 | | 00:00 Status
chain 3 | | 00:00 Status
chain 4 | | 00:00 Status

INFO:cmdstanpy:CmdStan done processing.

```

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In [47]: plt.plot(med_prob_ppc)
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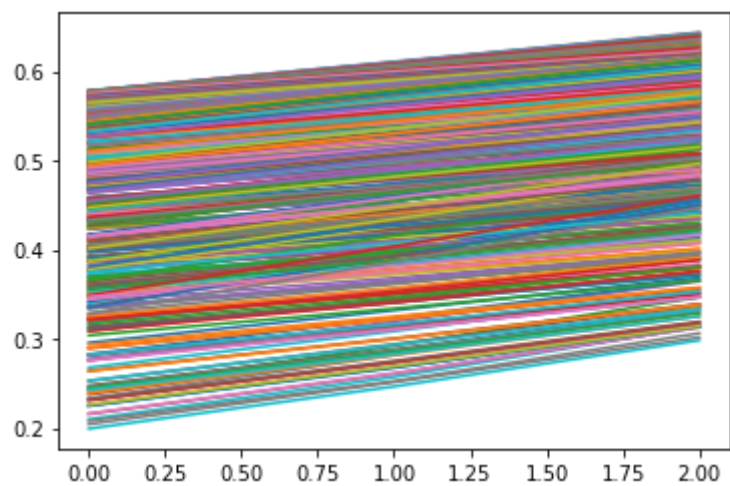
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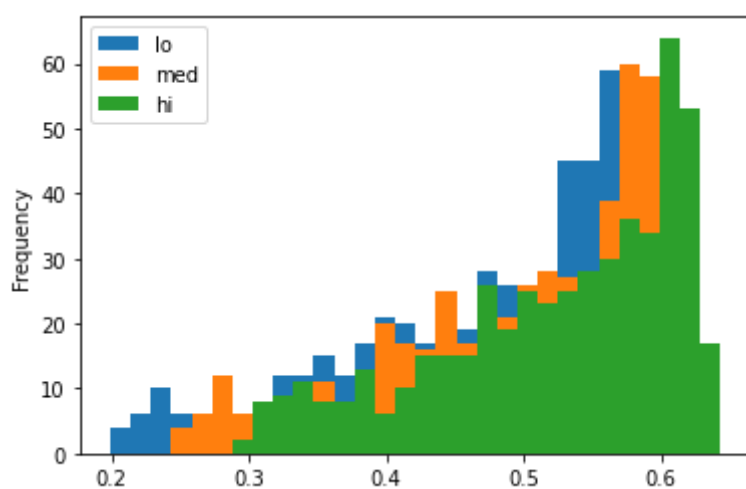

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In [58]: `estimate_ppc_df.plot.hist(bins = 30)`

Out[58]: `<AxesSubplot:ylabel='Frequency'>`



In [51]: `prob_ppc= fit.stan_variable('prob_ppc')
#df = pd.DataFrame({'theta': prob_ppc.mean()})
#df.plot.hist()
#plt.show()
print(type(prob_ppc))`

`<class 'numpy.ndarray'>`

In [61]: `theta = []
for i in prob_ppc:
 theta.append(np.mean(i))
print(theta)`

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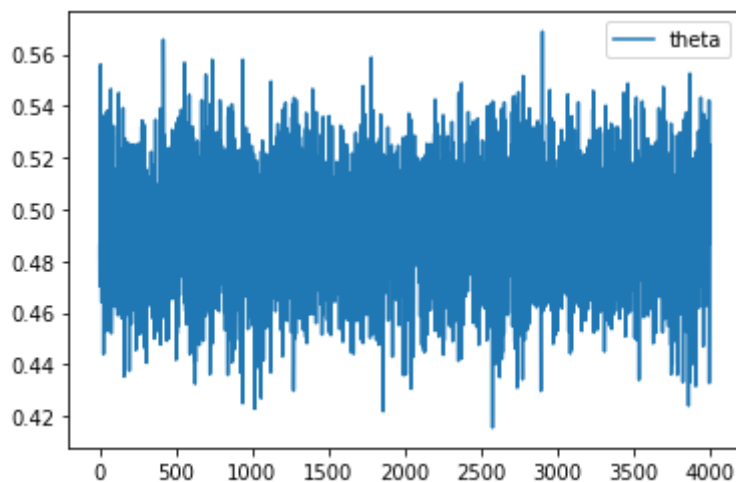

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```

```
In [68]: df_theta=pd.DataFrame({'theta':theta})
df_theta.plot()
```

```
Out[68]: <AxesSubplot:>
```



```
In [85]: x=np.arange(0, 50, 1)

ax = plt.gca()
ax.errorbar(x, theta[0:50],0.02, 0.01)
plt.draw()
```

