# Assignment3_solution

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## 1 Assignment 3

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Due Wednesday, Oct. 24 at 11:30 AM

### 1.1 Question 1

Simulations are widely used in sociology. Techniques like system dynamics, multiagent systems, cellular automata and genetic algorithms have developed in the progress. When constructing a simulation system for mapping theory to practice, the crucial characteristic of the model is matching the real-world, validity in other words. However, some techniques may fail to achieve that.

**Two limitations of multiagent system and cellular automata**

Multi-agent systems and cellular automata bear some potential weakness in validity.

For multiagent systems, Moretti (2002) believes that the following three aspects need further research. First, using theories and models concerning rationality that are realistic, understandable, and can be applied in the case of limited knowledge. In particular, theories of rationality need to be extended to learning and adaptation. Second, formalizing all the aspects of psychological theories, such as emotions, motivations, desire,intent, consciousness. Third, formalizing all types of knowledge by determine the possibility of it and the best way to acheive that.

For cellular automata, Moretti (2002) proposed two limitations for the approach. Firstly, this approach sync data at the same time. However, agents make decisions and modify their choice at different time. Evidence found that the operation order has great effect on the turnout. Therefore, arbitrarily conclude that actions in the period between two syncing happened together is dangerous. Secondly, the neighborhood of a unit is hard to define. This approach restricts each individual interacts only with a subset of the whole population which is reasonably. The problem is how to define the boundary. Back in old day, we may define the boundary by geographic location. Nowadays, with the invention of Internet, interactions can take place between two individuals on the opposite side of the earth. Consequently, it is difficult to set the line on neighborhood.

**Model with feature of dynamic feedback**

Except for this two system, there is another system called "genetic algorithm" which present a feature of "dynamic feedback". That is to say, the result of the initial inputs will be added to inputs for next round of simulation. Genetic algorithm is based on Darwin's theory of evolution. According to this theory, a species evolves in relation to its own capacity to adapt to the natural and complex environment. In Darwin's theory of evolution, the result of the initial inputs is stored in the chromsome of a species which can be passed on to next generation. Then, next generation will behave with the information saved in their chromsome in order to avoid repetitive mistakes. Genetic algorithm is applied to two fields in sociology: game theory and cultural evolution. For further illustration, Moretti (2002) cited a model from cultural evolution. Lustick (2000) apply genetic algorithm model to culture transmission, they study "how cultures emerge and transform out of vast number of micro-interactions entailing the diffusion or disappearance of cultural fragment".

**Example in political science**

In political science, examples of dynamic feedback are easy to spot. During elections, advertisements of president candidates is made in different stages. Normally, after the first round advertisement, the candidate group will collect information and feedbacks of the ads. Then, after analyzing the data, they will choose the proper content and position for the second round of advertisement. It is the same with third round and fourth round, etc. That is to say, the current choice is based on the current information, but not the starting-stage information. So the advertisement during elections exhibits dynamic feedback.

**Reference**

Moretti, Sabrina, "Computer Simulation in Sociology: What Contribution?" Social Science Computer Review, 20:1 (Spring 2002), pp. 43-57.

## 1.2 Question 2

```
In [1]: # Import initial packages
        import numpy as np
        import matplotlib.pyplot as plt
        from matplotlib.ticker import MultipleLocator
```

```
In [2]: def students_income_sim(p):

            """
            Requires a simulation profile, p, structured as a dictionary

            p = {
                'inc0'         : 80000,       #average starting income (t = 2018) for a MACSS s
                'g'            : 0.025,       #income growth rate
                'dep'          : 0.4,         #positive dependence of todays income on last per
                'st_year'      : 2018,        #starting year
                'lf_years'     : 40,          #years to work
                'num_draws'    : 10000        #simulations
                'sd'           : 0.13         #standard error
            }
            """

            #set random seed
            np.random.seed(524)

            #create an error term
            ln_errors = np.random.normal(0, p['sd'], (p['lf_years'], p['num_draws']))

            #create a matrix of dim (lf_years, num_draws)
```

```
    ln_inc_mat = np.zeros((p['lf_years'], p['num_draws']))

    #fill the matrix
    ln_inc_mat[0, :] = np.log(p['inc0']) + ln_errors[0, :]

    #loop and apply model
    for yr in np.arange(1, p['lf_years']):
        ln_inc_mat[yr, :] = (1 - p['dep'])* (np.log(p['inc0']) + p['g'] * (yr)) +\
                                             p['dep'] * ln_inc_mat[yr - 1, :] +\
                                             ln_errors[yr, :]

    inc_mat = np.exp(ln_inc_mat) #dealing with large numbers so put in terms of 10k's
    return inc_mat
```

**(a)**

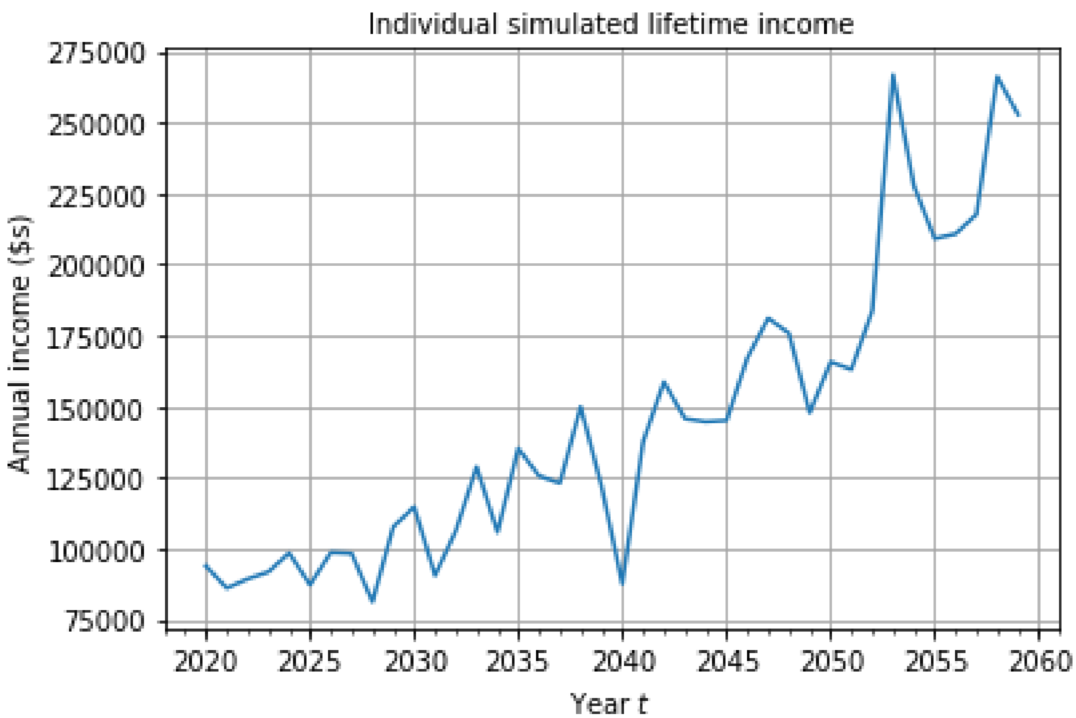
```
In [3]: simulation_profile = {
            'inc0'          : 80000,
            'g'             : 0.025,
            'dep'           : 0.4,
            'st_year'       : 2020,
            'lf_years'      : 40,
            'num_draws'     : 10000,
            'sd'            : 0.13
        }

        inc_mat = students_income_sim(simulation_profile)
        print(inc_mat)
```

```
[[ 66409.15585396  98274.13534194 101939.81109509 ...  98720.39690442
   72404.51636886  68710.32820307]
 [ 80020.53020329  67383.19350738  84557.85626308 ...  68247.7770509
   74518.33613244  80555.96068584]
 [ 75805.26636606  66134.42494243  91458.20304692 ...  67268.53350159
   90012.42673528  80645.62355527]
 ...
 [272690.56519108 217821.73027242 184724.24512469 ... 159922.45424852
  253961.68337673 209741.55004062]
 [231539.17420799 202509.15149494 197955.96626493 ... 199502.43481758
  210951.71828579 205420.27946389]
 [197895.95201384 165115.10025278 172644.86927513 ... 248654.44847819
  234237.14656466 221566.29879732]]
```

```
In [4]: %matplotlib inline
        p = simulation_profile
        year_vec = np.arange(p['st_year'], p['st_year'] + p['lf_years'])
        individual = 500
```

```
fig, ax = plt.subplots()
plt.plot(year_vec, inc_mat[:, individual])
minorLocator = MultipleLocator(1)
ax.xaxis.set_minor_locator(minorLocator)
plt.grid(b=True, which='major', color='0.65', linestyle='-')
plt.title('Individual simulated lifetime income', fontsize=10)
plt.xlabel(r'Year $t$')
plt.ylabel(r'Annual income (\$s)')
```

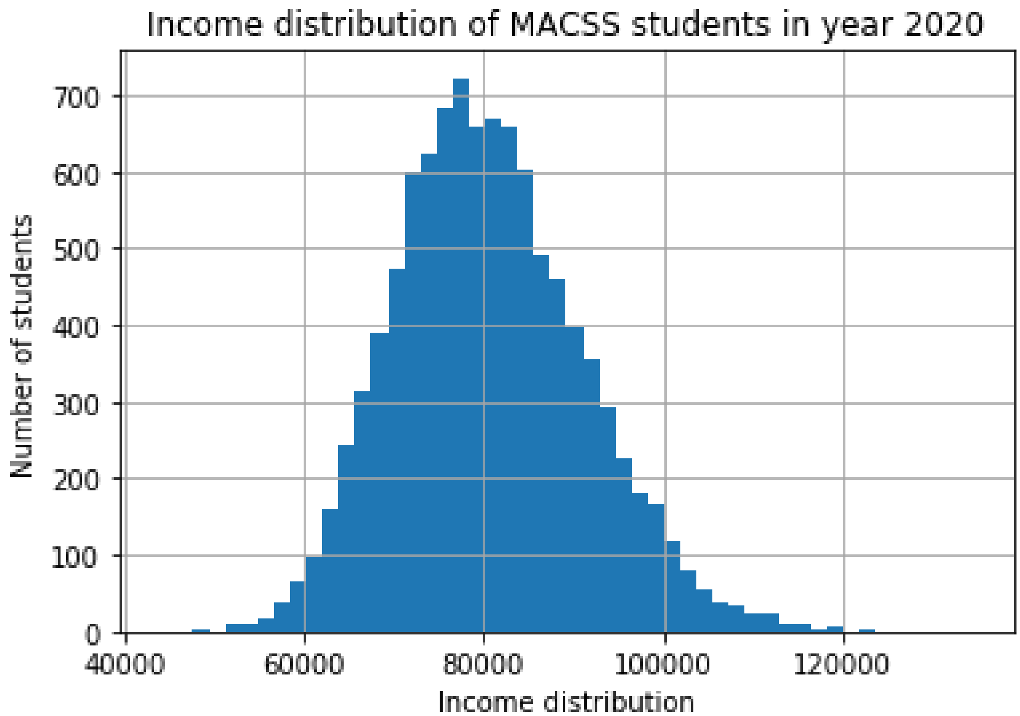
Out[4]: Text(0,0.5,'Annual income (\\$s)')




**(b)**

```
In [5]: plt.hist(inc_mat[0,:], bins=50)
        plt.grid(b=True, which='major', color='0.65', linestyle='-')
        plt.xlabel("Income distribution")
        plt.ylabel("Number of students")
        plt.title("Income distribution of MACSS students in year 2020")
```

Out[5]: Text(0.5,1,'Income distribution of MACSS students in year 2020')




```
In [6]: #Transform Numpy Arrays Into Useful Dataframe
        import pandas as pd

        years = np.arange(p['st_year'], p['st_year'] + p['lf_years']).tolist()
        df = pd.DataFrame(inc_mat).T
        df.columns = years
        df = df.T
        df['year'] = df.index
        df = pd.melt(df, id_vars='year', var_name='id')
        df.head()
```

Out[6]:

| | year | id | value |
|---|---|---|---|
| 0 | 2020 | 0 | 66409.155854 |
| 1 | 2021 | 0 | 80020.530203 |
| 2 | 2022 | 0 | 75805.266366 |
| 3 | 2023 | 0 | 88075.026534 |
| 4 | 2024 | 0 | 106861.634158 |

```
In [7]: df_year = df.loc[df['year'] == 2020]
        df_year['value'].describe()
```

```
Out[7]: count    10000.000000
        mean     80653.274318
        std      10541.874277
```

```
min       43891.472511
25%       73182.442566
50%       79865.114586
75%       87363.900030
max      134596.691453
Name: value, dtype: float64
```

```
In [8]: #Calculate percentile of given earnings
        from scipy import stats
        percentile_more_than_100000 = 100 - stats.percentileofscore(df_year['value'], 100001,
        print(percentile_more_than_100000)
```

```
4.170000000000002
```

The percent of my class will earn more than $100,000 in the first year out of the program is 4.17%.

```
In [9]: percentile_less_than_70000 = stats.percentileofscore(df_year['value'], 70001, 'strict')
        print(percentile_less_than_70000)
```

```
15.120000000000001
```

The percent of my class will earn less than $70,000 in the first year out of the program is 15.1%.

```
In [10]: # Check if the distribution normally distributed
         stats.normaltest(df_year['value'])

Out[10]: NormaltestResult(statistic=290.481782626689, pvalue=8.369169350300544e-64)
```

From the normal test with such a small p-value, we believe that the income of MACSS student is normal. It is symmetric and bell-curved.

**(c)**

```
In [11]: # Calculate the year of paying off the loan
         inc_mat_loan = 0.1 * inc_mat
         inc_mat_loan_count = inc_mat_loan.cumsum(axis=0)
         df_count = pd.DataFrame(inc_mat_loan_count).T
         df_count['payoff_year'] = df_count.apply(lambda x: (x<95000).sum() + 2020, axis=1)
         df_count.head()

Out[11]:              0             1             2             3             4  \
         0   6640.915585  14642.968606  22223.495242  31030.997896  41717.161311
         1   9827.413534  16565.732885  23179.175379  31525.852192  41258.618848
         2  10193.981110  18649.766736  27795.587041  36777.439151  45797.855445
         3  10233.704639  18946.540346  27524.243572  37661.664339  47253.827953
         4  10124.798322  17686.536303  25482.631147  33616.286403  40848.363562
```

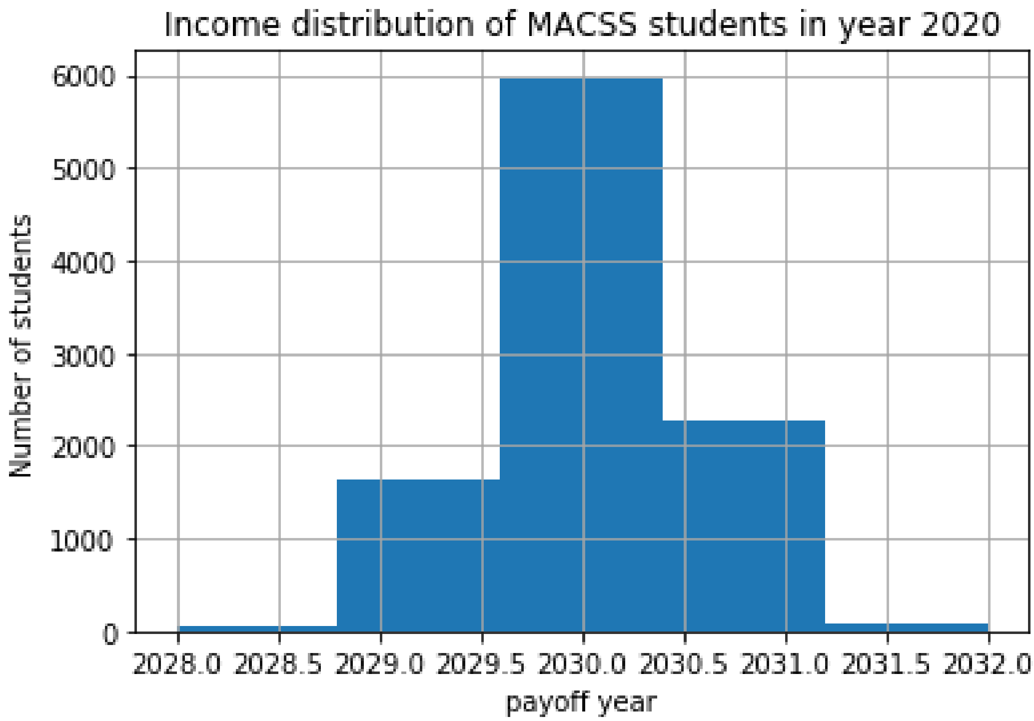
```
              5              6              7              8              9  \
0  52676.693530   61802.183208   72777.802094   81851.561040   90545.655033
1  48916.052326   58145.237557   68716.189449   79366.460690   89201.898695
2  55903.458803   66055.526545   76675.919178   87577.596683   97206.692550
3  57876.950873   68924.709523   79103.893255   88773.587840   97722.872590
4  47363.138501   54752.099691   63622.606918   71769.940539   82510.675309

     ...             31              32              33              34  \
0    ...  401320.070822   416826.041658   431634.560790   448494.207843
1    ...  370901.093848   385737.661666   404338.083038   428022.431760
2    ...  384172.593397   403016.624248   421111.319671   443370.331011
3    ...  373251.374256   391183.734099   411393.734102   431922.235539
4    ...  398451.017414   420788.974503   438703.481476   458197.910693

              35              36              37              38              39  \
0  470080.410935   489583.886535   516852.943054   540006.860475   559796.455676
1  448057.333219   470661.887333   492444.060360   512694.975510   529206.485535
2  468386.636542   490570.416678   509042.841190   528838.437817   546102.924744
3  454122.307209   474466.476564   495085.866389   513470.490072   532248.706033
4  477064.734821   490432.584758   509769.914805   530601.811995   547182.885692

   payoff_year
0         2030
1         2030
2         2029
3         2029
4         2030

[5 rows x 41 columns]
```

In [12]:
```
# Calculate number of bins by calculate number of unique years
len(df_count['payoff_year'].unique())
```

Out[12]:
```
5
```

In [13]:
```
# Plot the histogram of how many years it takes to pay off the loan
plt.hist(df_count['payoff_year'], bins=5)
plt.grid(b=True, which='major', color='0.65', linestyle='-')
plt.xlabel("payoff year")
plt.ylabel("Number of students")
plt.title("Income distribution of MACSS students in year 2020")
```

Out[13]:
```
Text(0.5,1,'Income distribution of MACSS students in year 2020')
```




```
In [14]: percentile_10yr = stats.percentileofscore(df_count['payoff_year'], 2030, 'strict')
         print(percentile_10yr)
```

```
16.78
```

16.8% percent of the simulations are able to pay off the loan in 10 years.

**(d)**

```
In [15]: # New simulation
         simulation_profile1 = {
             'inc0'          : 90000,
             'g'             : 0.025,
             'dep'           : 0.4,
             'st_year'       : 2020,
             'lf_years'      : 40,
             'num_draws'     : 10000,
             'sd'            : 0.17
         }

         inc_mat1 = students_income_sim(simulation_profile1)
         print(inc_mat1)
```

```
[[ 70550.46142451 117783.33011091 123561.20729139 ... 118483.24080508
   78992.81966812  73764.25171169]
 [ 89615.63768821  71575.56495871  96317.75493523 ...  72778.88084775
   81644.3347736   90400.57899801]
 [ 82955.30101689  69396.06916251 106035.55593099 ...  70956.3661129
  103848.93176006  89949.09077038]
 ...
 [338309.11761165 252187.52025149 203293.03644369 ... 168361.21927259
  308250.29858492 240024.49205936]
 [271061.07048342 227502.32436192 220836.5697397  ... 223095.32811759
  239983.96514044 231788.44418303]
 [219057.46748997 172865.33333479 183245.71710131 ... 295275.8618388
  273090.00167035 253934.86273481]]
```

In [16]:
```
# Calculate the year of paying off the loan
inc_mat_loan1 = 0.1 * inc_mat1
inc_mat_loan1_count = inc_mat_loan1.cumsum(axis=0)
df_count1 = pd.DataFrame(inc_mat_loan1_count).T
df_count1['payoff_year'] = df_count1.apply(lambda x: (x<95000).sum()+2020, axis=1)
df_count1.head()
```

Out[16]:
```
             0             1             2             3             4  \
0   7055.046142  16016.609911  24312.140013  34333.296161  47140.911566
1  11778.333011  18935.889507  25875.496423  35216.582126  46550.888080
2  12356.120729  21987.896223  32591.451816  42872.807107  53134.720879
3  12419.122357  22435.567638  32186.140501  44230.528342  55351.190956
4  12246.576993  20568.831331  29174.187992  38204.750454  45891.409034

             5             6             7              8              9  \
0  60278.250807  70538.832110  83501.014229   93530.289712  102941.709379
1  54771.198811  65184.514942  77525.312299   89891.909093  100950.693669
2  64949.829434  76745.318015  89161.647500  101911.366268  112667.740724
3  67963.700504  81138.195166  92884.345976  103783.561489  113557.846084
4  52545.816626  60331.417932  70143.066774   78854.839154   91263.186075

       ...               31             32             33             34  \
0      ...       461907.029993  478710.884413  494412.014189  512873.278455
1      ...       415136.337440  430997.912532  452152.620044  480946.075180
2      ...       435560.458455  457244.366269  477650.088915  504198.845312
3      ...       418926.251938  439248.634289  462828.475331  486711.019972
4      ...       457203.348438  484288.814926  504429.220114  526750.916183

              35             36             37             38             39  \
0  538182.129208  560176.382415  594007.294176  621113.401225  643019.147974
1  503903.201069  530578.622378  555797.374404  578547.606840  595834.140173
2  534890.908317  560918.860780  581248.164425  603331.821399  621656.393109
3  512965.151441  536207.314368  559680.244528  579728.470866  600181.868244
```

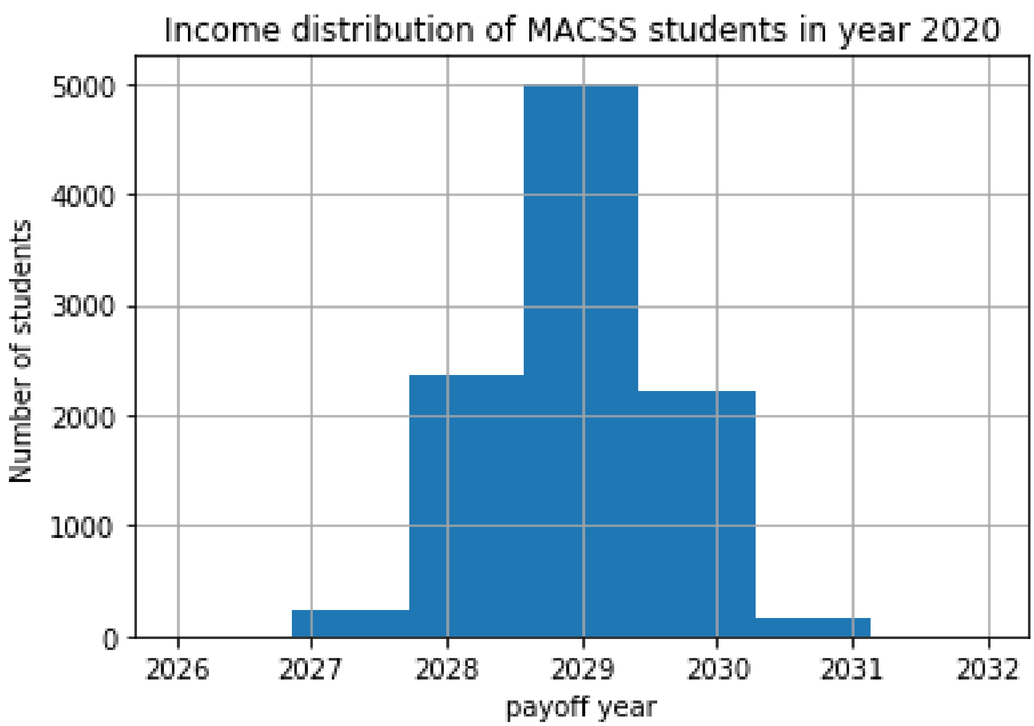
```
4  547973.678153  561394.580288  582977.478421  606584.965040  623966.797805

   payoff_year
0         2029
1         2029
2         2028
3         2028
4         2030

[5 rows x 41 columns]
```

In [17]:
```python
# Calculate number of bins by calculate number of unique years
len(df_count1['payoff_year'].unique())
```

Out[17]: 7

In [18]:
```python
# Plot the histogram of how many years it takes to pay off the loan
plt.hist(df_count1['payoff_year'], bins=7)
plt.grid(b=True, which='major', color='0.65', linestyle='-')
plt.xlabel("payoff year")
plt.ylabel("Number of students")
plt.title("Income distribution of MACSS students in year 2020")
```

Out[18]: Text(0.5,1,'Income distribution of MACSS students in year 2020')



```
In [19]: percentile_10yr1 = stats.percentileofscore(df_count1['payoff_year'], 2030, 'strict')
         print(percentile_10yr1)
```

```
76.02
```

76.0%percent of the simulations are able to pay off the loan in 10 years.