

Making predictions

INTRODUCTION TO REGRESSION WITH STATSMODELS IN PYTHON



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The fish dataset: bream

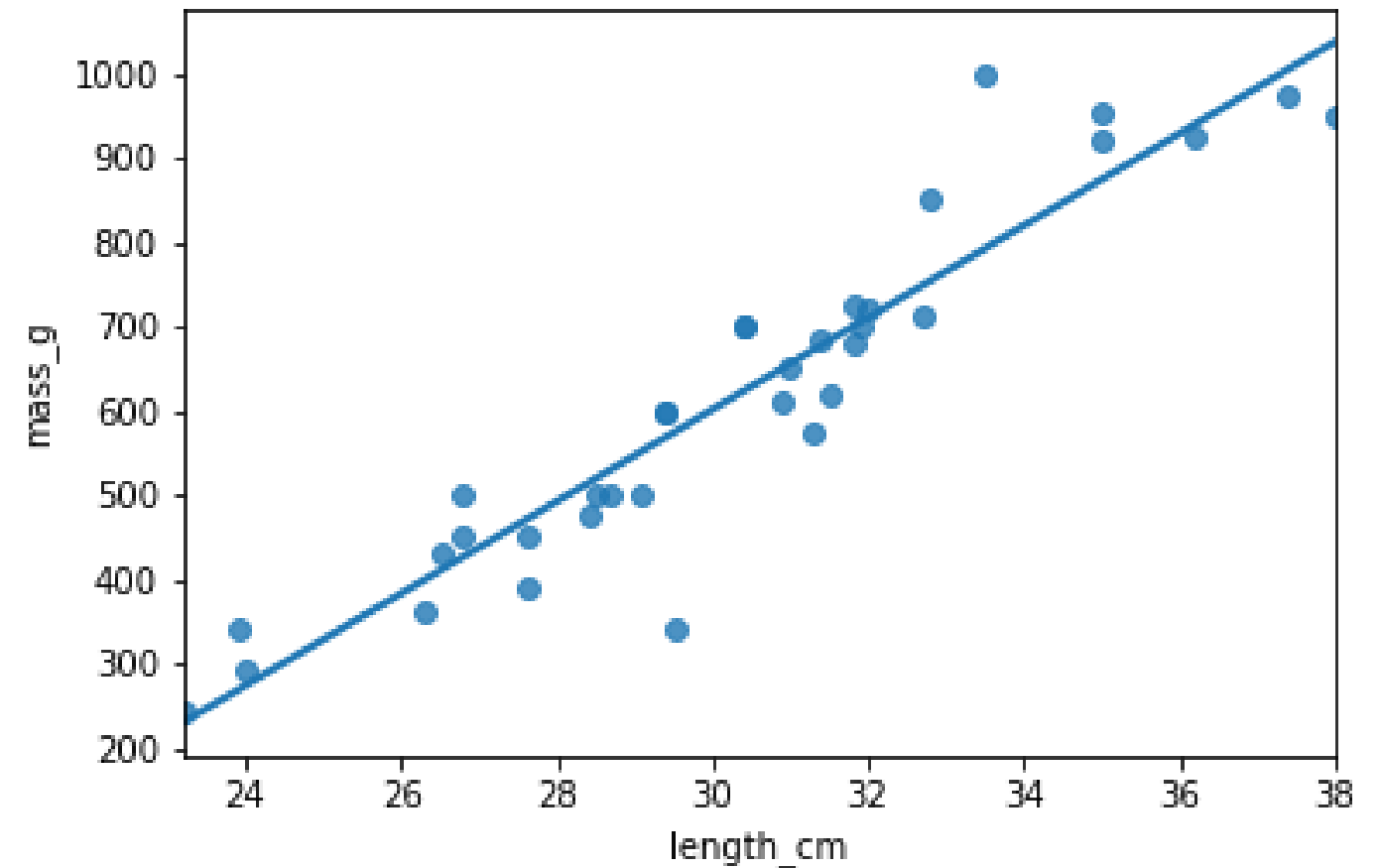
```
bream = fish[fish["species"] == "Bream"]  
print(bream.head())
```

	species	mass_g	length_cm
0	Bream	242.0	23.2
1	Bream	290.0	24.0
2	Bream	340.0	23.9
3	Bream	363.0	26.3
4	Bream	430.0	26.5



Plotting mass vs. length

```
sns.regplot(x="length_cm",  
            y="mass_g",  
            data=bream,  
            ci=None)  
  
plt.show()
```



Running the model

```
mdl_mass_vs_length = ols("mass_g ~ length_cm", data=bream).fit()  
print(mdl_mass_vs_length.params)
```

```
Intercept    -1035.347565  
length_cm      54.549981  
dtype: float64
```

Data on explanatory values to predict

If I set the explanatory variables to these values,
what value would the response variable have?

```
explanatory_data = pd.DataFrame({"length_cm": np.arange(20, 41)})
```

```
length_cm
0         20
1         21
2         22
3         23
4         24
5         25
...
```

Call predict()

```
print mdl_mass_vs_length.predict(explanatory_data))
```

```
0      55.652054
1     110.202035
2     164.752015
3     219.301996
4     273.851977
...
16     928.451749
17     983.001730
18    1037.551710
19    1092.101691
20    1146.651672
Length: 21, dtype: float64
```

Predicting inside a DataFrame

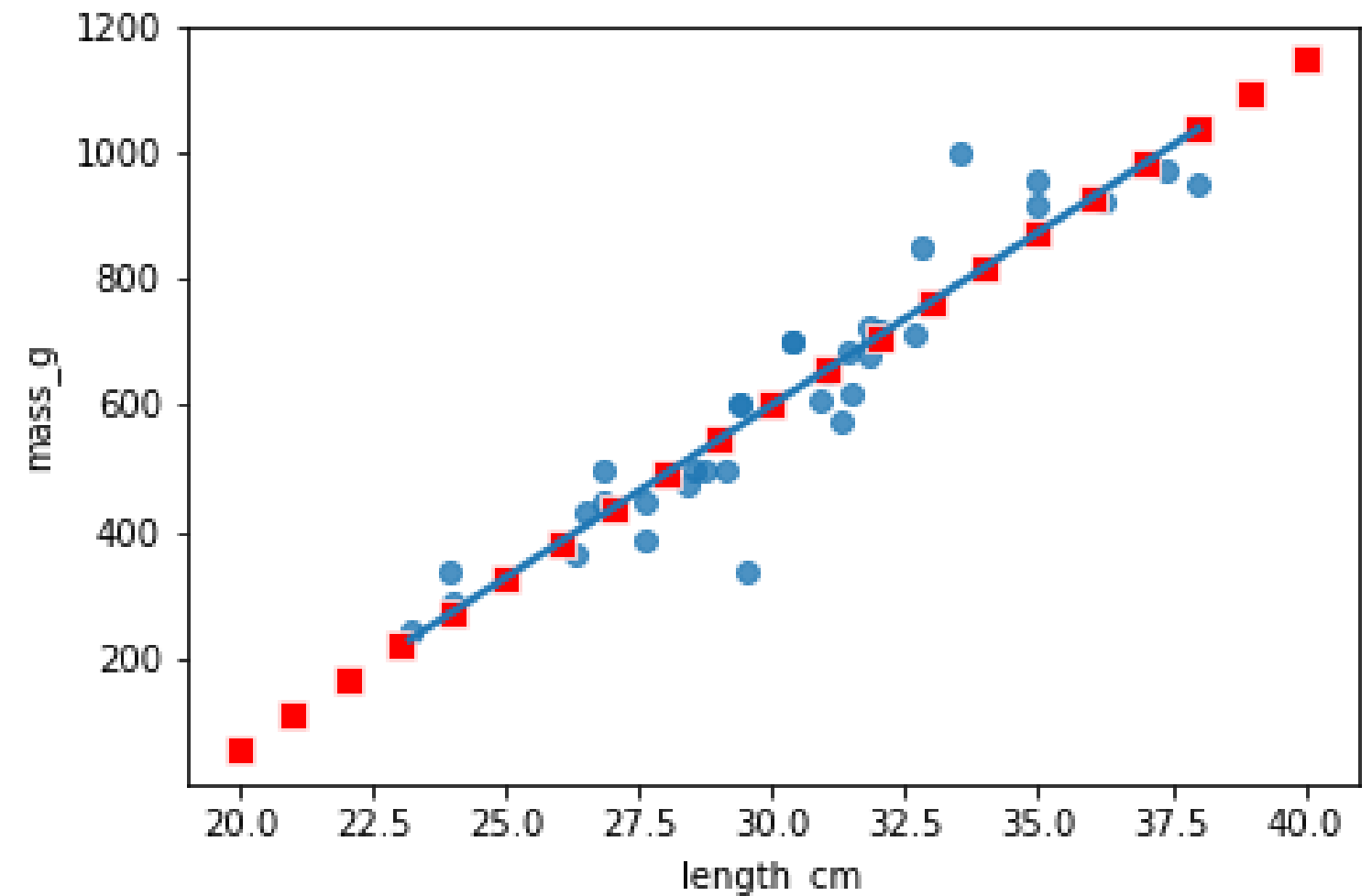
```
explanatory_data = pd.DataFrame(  
    {"length_cm": np.arange(20, 41)}  
)  
prediction_data = explanatory_data.assign(  
    mass_g=mdl_mass_vs_length.predict(explanatory_data)  
)  
print(prediction_data)
```

	length_cm	mass_g
0	20	55.652054
1	21	110.202035
2	22	164.752015
3	23	219.301996
4	24	273.851977
..
16	36	928.451749
17	37	983.001730
18	38	1037.551710
19	39	1092.101691
20	40	1146.651672

Showing predictions

```
import matplotlib.pyplot as plt
import seaborn as sns
fig = plt.figure()
sns.regplot(x="length_cm",
            y="mass_g",
            ci=None,
            data=bream,)
sns.scatterplot(x="length_cm",
               y="mass_g",
               data=prediction_data,
               color="red",
               marker="s")

plt.show()
```



Extrapolating

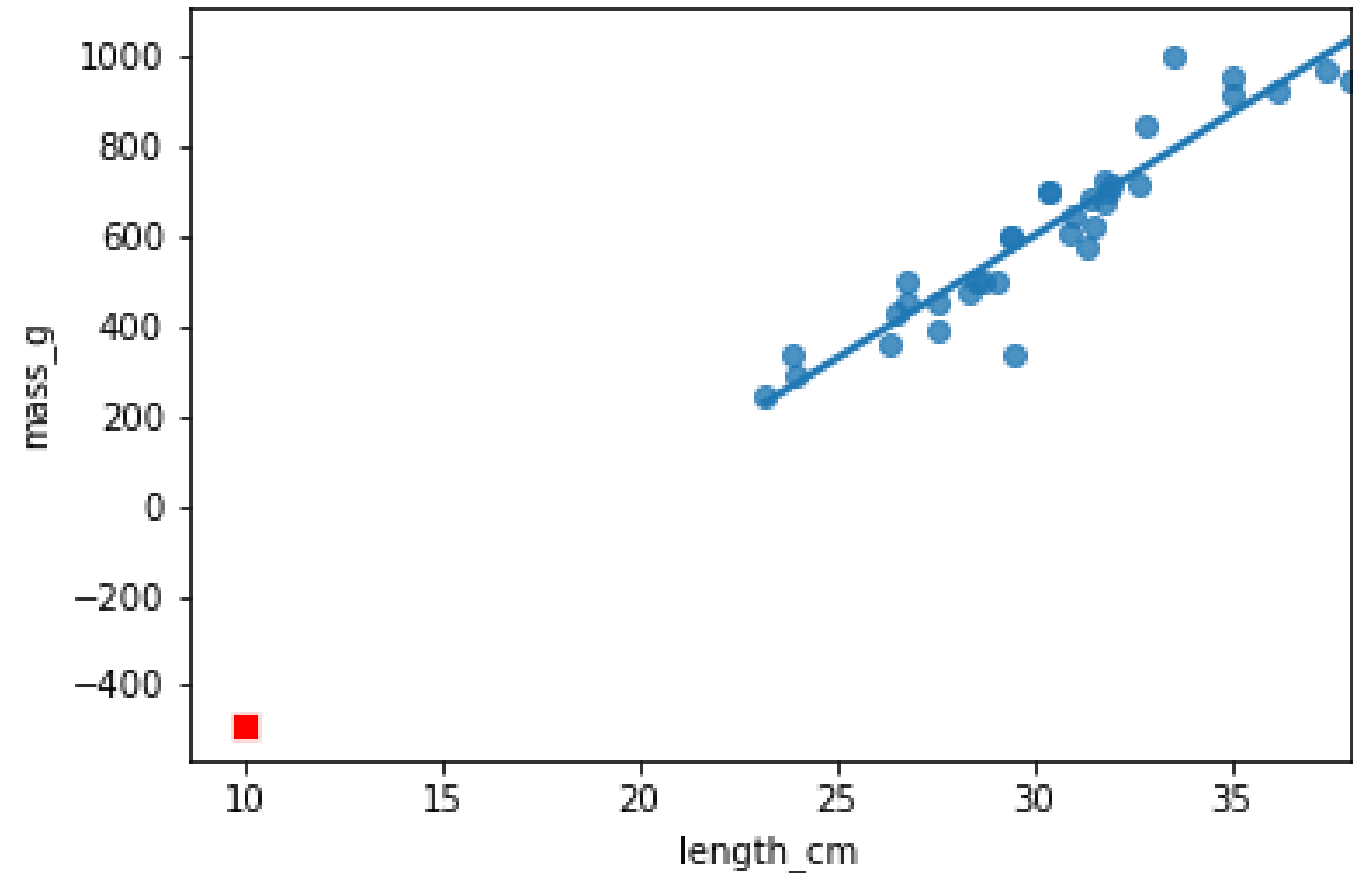
Extrapolating means making predictions outside the range of observed data.

```
little_bream = pd.DataFrame({"length_cm": [10]})

pred_little_bream = little_bream.assign(
    mass_g=mdl_mass_vs_length.predict(little_bream))

print(pred_little_bream)
```

	length_cm	mass_g
0	10	-489.847756



Let's practice!

INTRODUCTION TO REGRESSION WITH STATSMODELS IN PYTHON

Working with model objects

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.params attribute

```
from statsmodels.formula.api import ols
mdl_mass_vs_length = ols("mass_g ~ length_cm", data = bream).fit()
print(mdl_mass_vs_length.params)
```

```
Intercept    -1035.347565
length_cm      54.549981
dtype: float64
```

.fittedvalues attribute

Fitted values: predictions on the original dataset

```
print mdl_mass_vs_length.fittedvalues
```

or equivalently

```
explanatory_data = bream["length_cm"]  
  
print(mdl_mass_vs_length.predict(explanatory_data))
```

```
0      230.211993  
1      273.851977  
2      268.396979  
3      399.316934  
4      410.226930  
  
...  
30     873.901768  
31     873.901768  
32     939.361745  
33    1004.821722  
34    1037.551710  
Length: 35, dtype: float64
```

.resid attribute

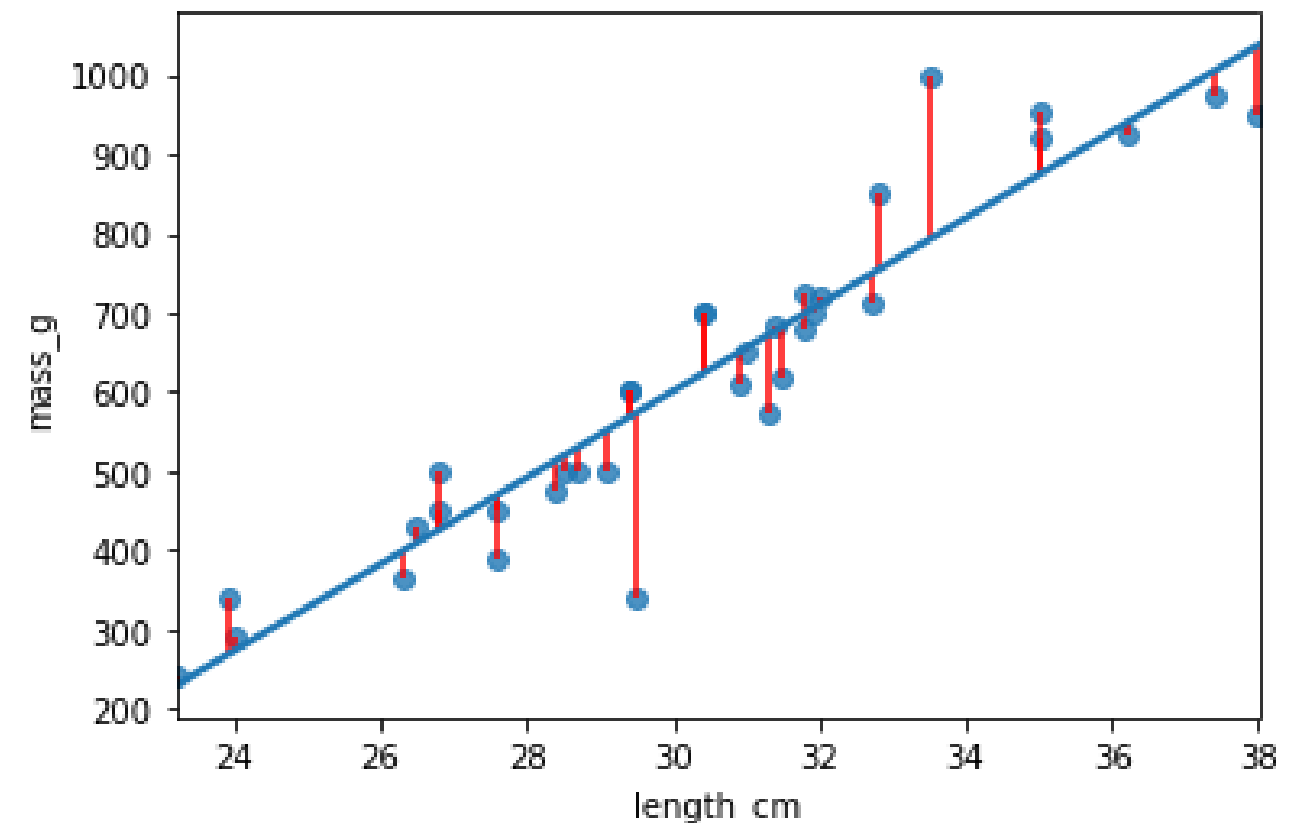
Residuals: actual response values minus predicted response values

```
print mdl_mass_vs_length.resid
```

or equivalently

```
print(bream["mass_g"] - mdl_mass_vs_length.fittedvalues)
```

```
0    11.788007
1    16.148023
2    71.603021
3   -36.316934
4    19.773070
...
```



.summary()

```
mdl_mass_vs_length.summary()
```

```

                    OLS Regression Results
=====
Dep. Variable:      mass_g      R-squared:      0.878
Model:              OLS        Adj. R-squared:   0.874
Method:             Least Squares    F-statistic: 237.6
Date:               Thu, 29 Oct 2020    Prob (F-statistic): 1.22e-16
Time:               13:23:21    Log-Likelihood: -199.35
No. Observations:   35    AIC:      402.7
Df Residuals:       33    BIC:      405.8
Df Model:            1
Covariance Type:    nonrobust
=====
                    coef    std err          t      P>|t|      [0.025     0.975]
-----
Intercept  -1035.3476    107.973     -9.589     0.000   -1255.020    -815.676
length_cm    54.5500      3.539     15.415     0.000     47.350     61.750
=====
Omnibus:         7.314    Durbin-Watson:      1.478
Prob(Omnibus):   0.026    Jarque-Bera (JB):    10.857
Skew:            -0.252    Prob(JB):            0.00439
Kurtosis:        5.682    Cond. No.            263.
```

OLS Regression Results

```
=====
Dep. Variable:          mass_g    R-squared:                0.878
Model:                  OLS       Adj. R-squared:           0.874
Method:                 Least Squares    F-statistic:           237.6
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No. Observations:       35          AIC:                   402.7
Df Residuals:           33          BIC:                   405.8
Df Model:                1
Covariance Type:        nonrobust
```

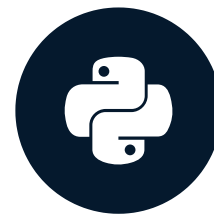

	coef	std err	t	P> t	[0.025	0.975]
<-----						
Intercept	-1035.3476	107.973	-9.589	0.000	-1255.020	-815.676
length_cm	54.5500	3.539	15.415	0.000	47.350	61.750
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Omnibus:		7.314	Durbin-Watson:			1.478
Prob(Omnibus):		0.026	Jarque-Bera (JB):			10.857
Skew:		-0.252	Prob(JB):			0.00439
Kurtosis:		5.682	Cond. No.			263.

Let's practice!

INTRODUCTION TO REGRESSION WITH STATSMODELS IN PYTHON

Regression to the mean

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The concept

- Response value = fitted value + residual
- "The stuff you explained" + "the stuff you couldn't explain"
- Residuals exist due to problems in the model *and* fundamental randomness
- Extreme cases are often due to randomness
- *Regression to the mean* means extreme cases don't persist over time

Pearson's father son dataset

- 1078 father/son pairs
- Do tall fathers have tall sons?

father_height_cm	son_height_cm
165.2	151.8
160.7	160.6
165.0	160.9
167.0	159.5
155.3	163.3
...	...

¹ Adapted from <https://www.rdocumentation.org/packages/UsingR/topics/father.son>

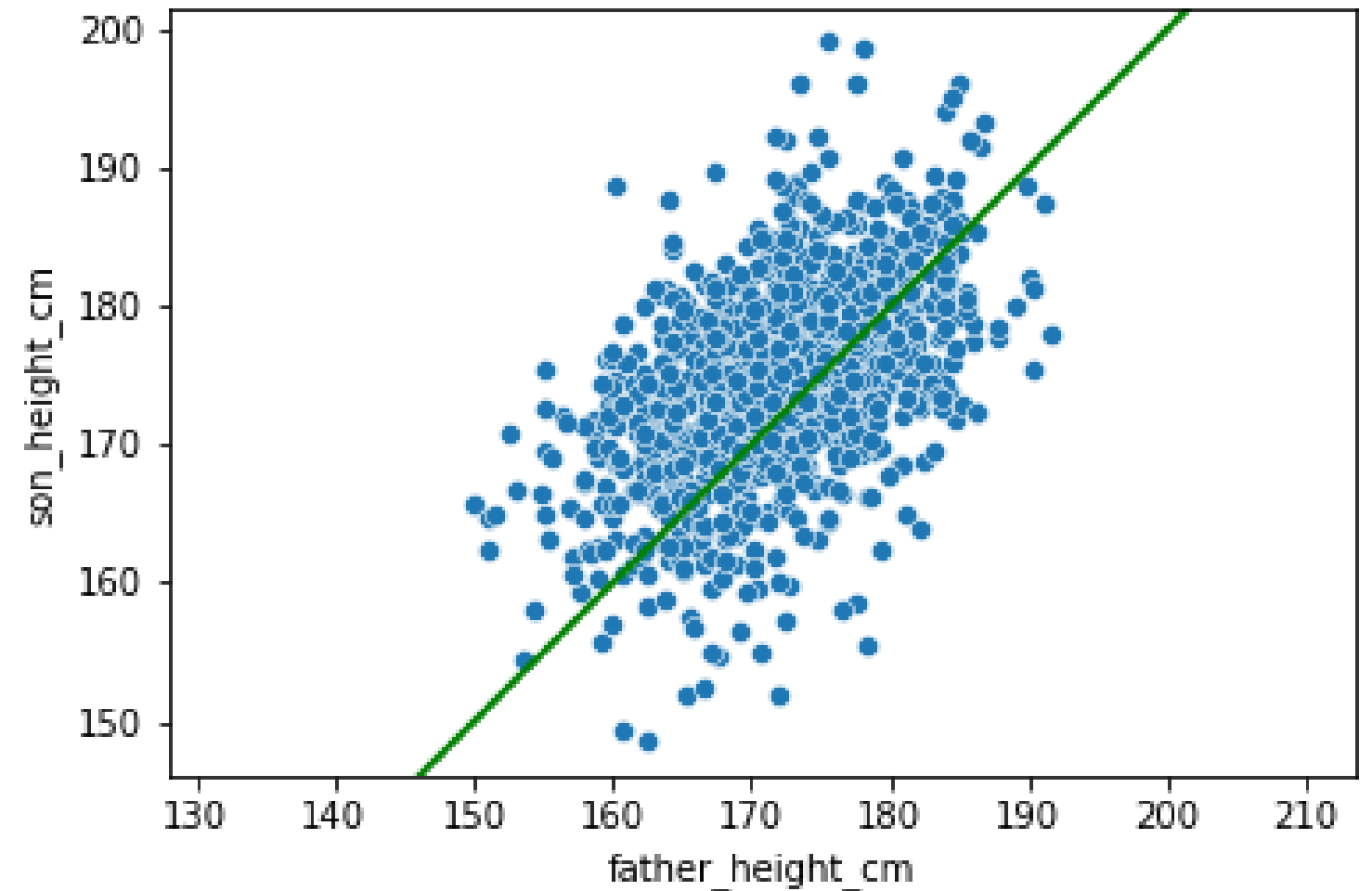
Scatter plot

```
fig = plt.figure()
```

```
sns.scatterplot(x="father_height_cm",  
                y="son_height_cm",  
                data=father_son)
```

```
plt.axline(xy1=(150, 150),  
           slope=1,  
           linewidth=2,  
           color="green")
```

```
plt.axis("equal")  
plt.show()
```



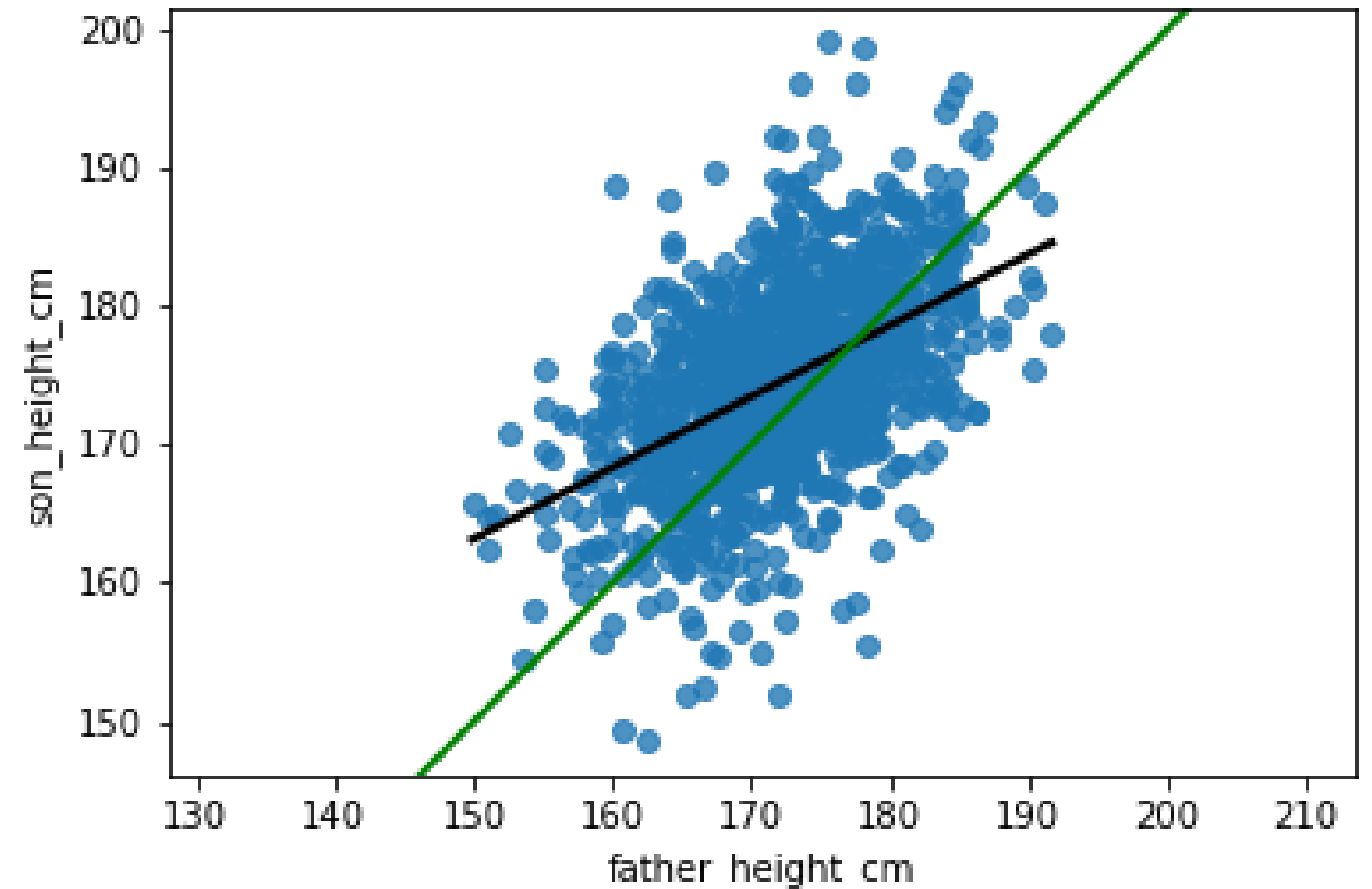
Adding a regression line

```
fig = plt.figure()

sns.regplot(x="father_height_cm",
            y="son_height_cm",
            data=father_son,
            ci = None,
            line_kws={"color": "black"})

plt.axline(xy1 = (150, 150),
            slope=1,
            linewidth=2,
            color="green")

plt.axis("equal")
plt.show()
```



Running a regression

```
mdl_son_vs_father = ols("son_height_cm ~ father_height_cm",  
                        data = father_son).fit()  
  
print(mdl_son_vs_father.params)
```

```
Intercept          86.071975  
father_height_cm    0.514093  
dtype: float64
```


Making predictions

```
really_tall_father = pd.DataFrame(  
    {"father_height_cm": [190]})
```

```
mdl_son_vs_father.predict(  
    really_tall_father)
```

183.7

```
really_short_father = pd.DataFrame(  
    {"father_height_cm": [150]})
```

```
mdl_son_vs_father.predict(  
    really_short_father)
```

163.2

Let's practice!

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Transforming variables

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Perch dataset

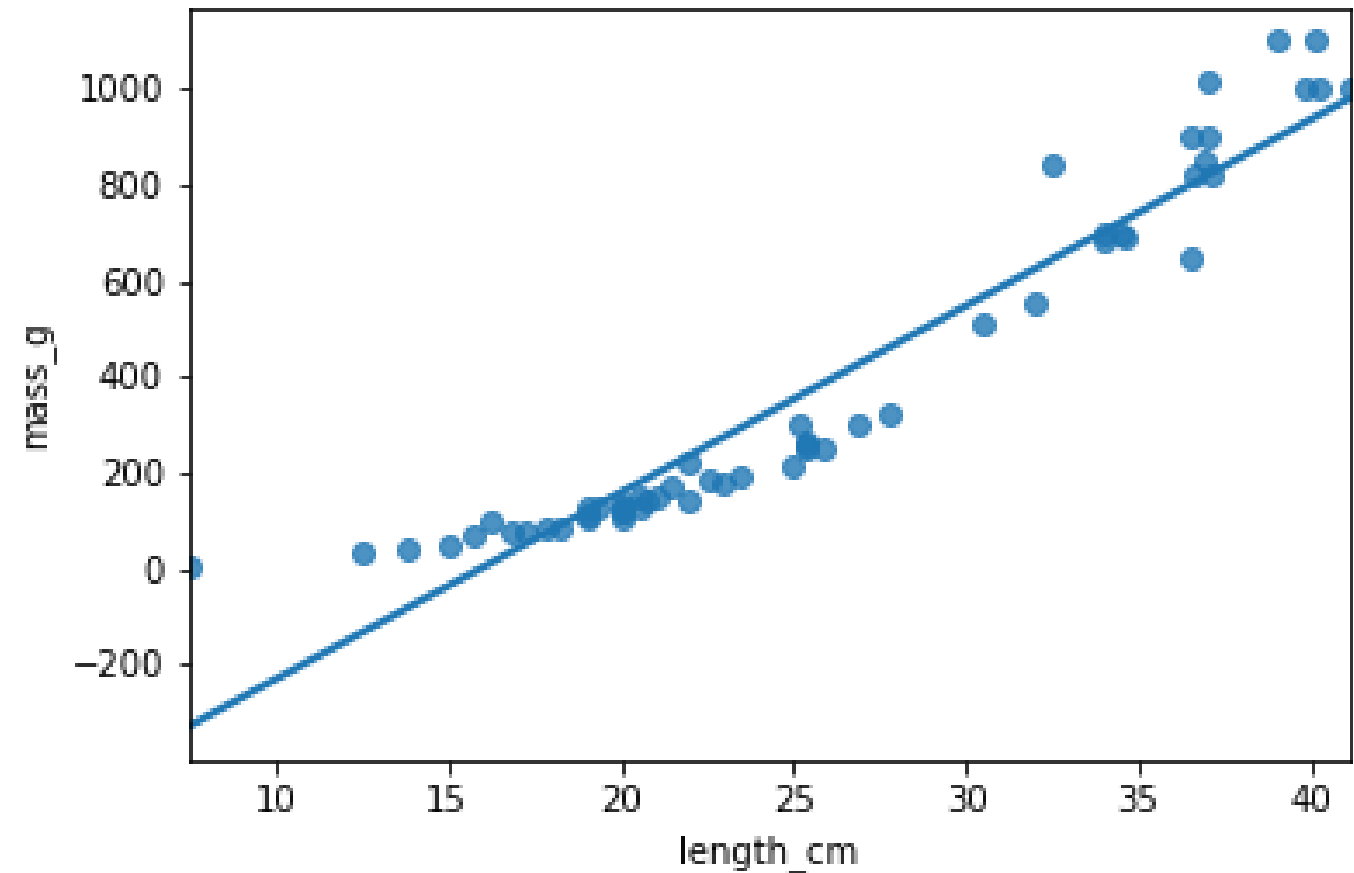
```
perch = fish[fish["species"] == "Perch"]  
print(perch.head())
```

	species	mass_g	length_cm
55	Perch	5.9	7.5
56	Perch	32.0	12.5
57	Perch	40.0	13.8
58	Perch	51.5	15.0
59	Perch	70.0	15.7



It's not a linear relationship

```
sns.regplot(x="length_cm",  
            y="mass_g",  
            data=perch,  
            ci=None)  
  
plt.show()
```



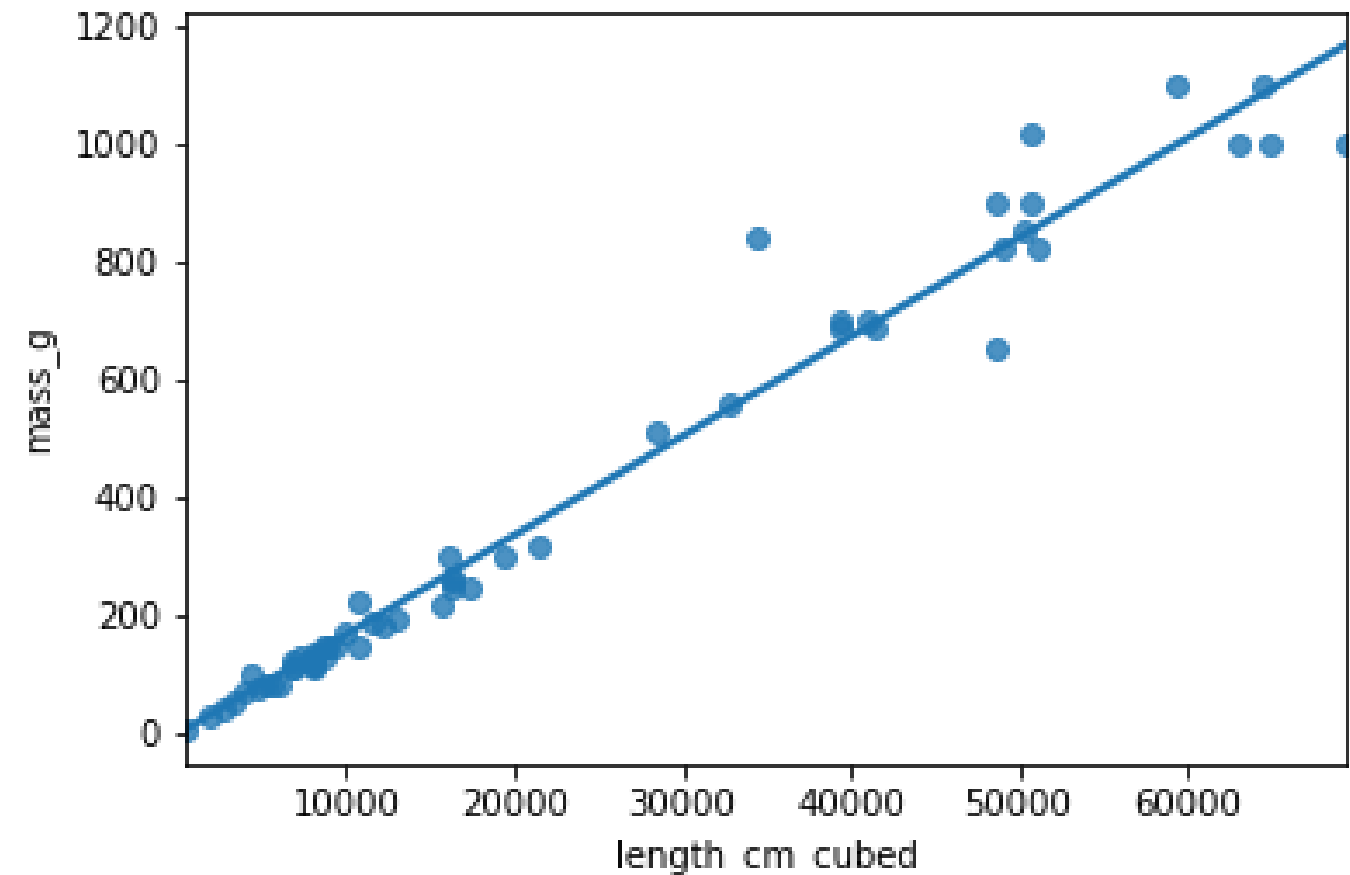
Bream vs. perch



Plotting mass vs. length cubed

```
perch["length_cm_cubed"] = perch["length_cm"] ** 3
```

```
sns.regplot(x="length_cm_cubed",  
            y="mass_g",  
            data=perch,  
            ci=None)  
  
plt.show()
```



Modeling mass vs. length cubed

```
perch["length_cm_cubed"] = perch["length_cm"] ** 3

mdl_perch = ols("mass_g ~ length_cm_cubed", data=perch).fit()
mdl_perch.params
```

```
Intercept      -0.117478
length_cm_cubed  0.016796
dtype: float64
```


Predicting mass vs. length cubed

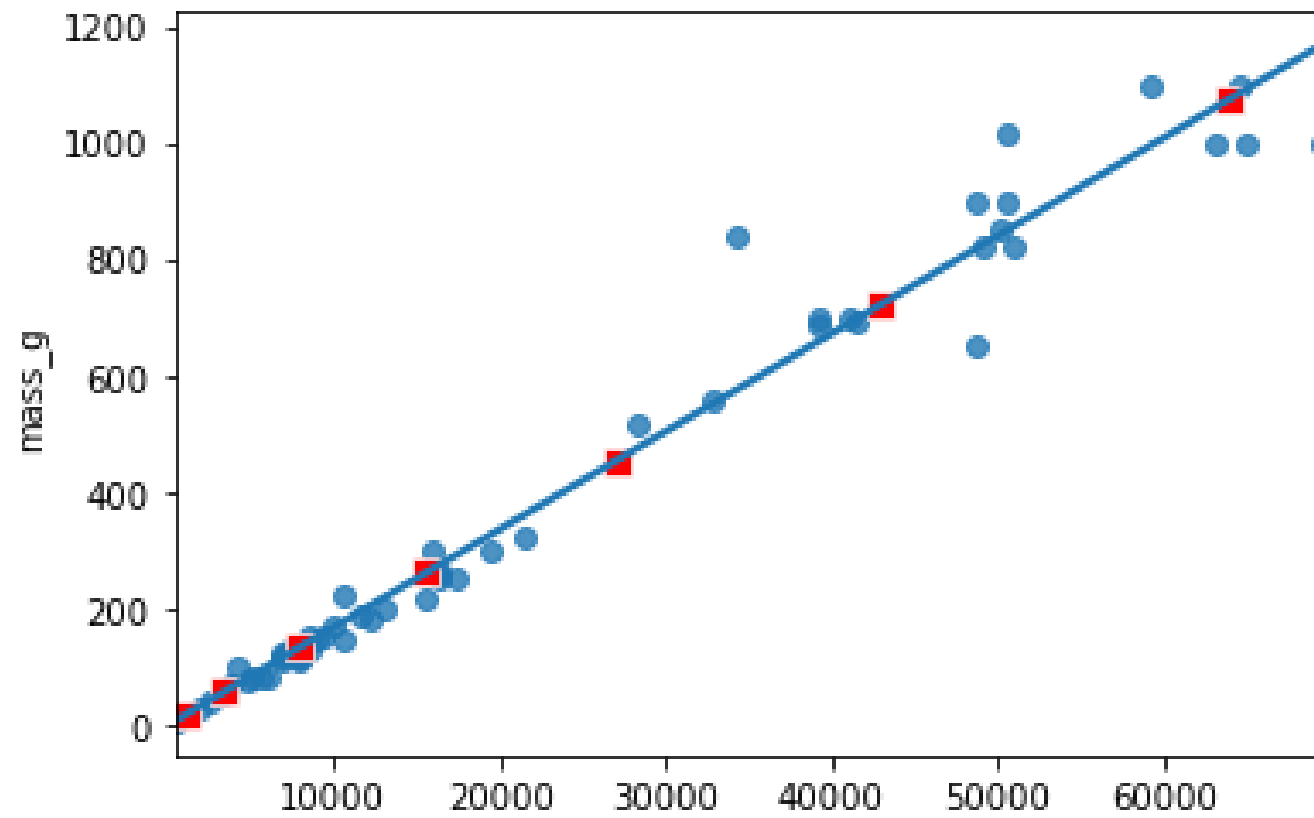
```
explanatory_data = pd.DataFrame({"length_cm_cubed": np.arange(10, 41, 5) ** 3,  
                                "length_cm": np.arange(10, 41, 5)})
```

```
prediction_data = explanatory_data.assign(  
    mass_g=mdl_perch.predict(explanatory_data))  
print(prediction_data)
```

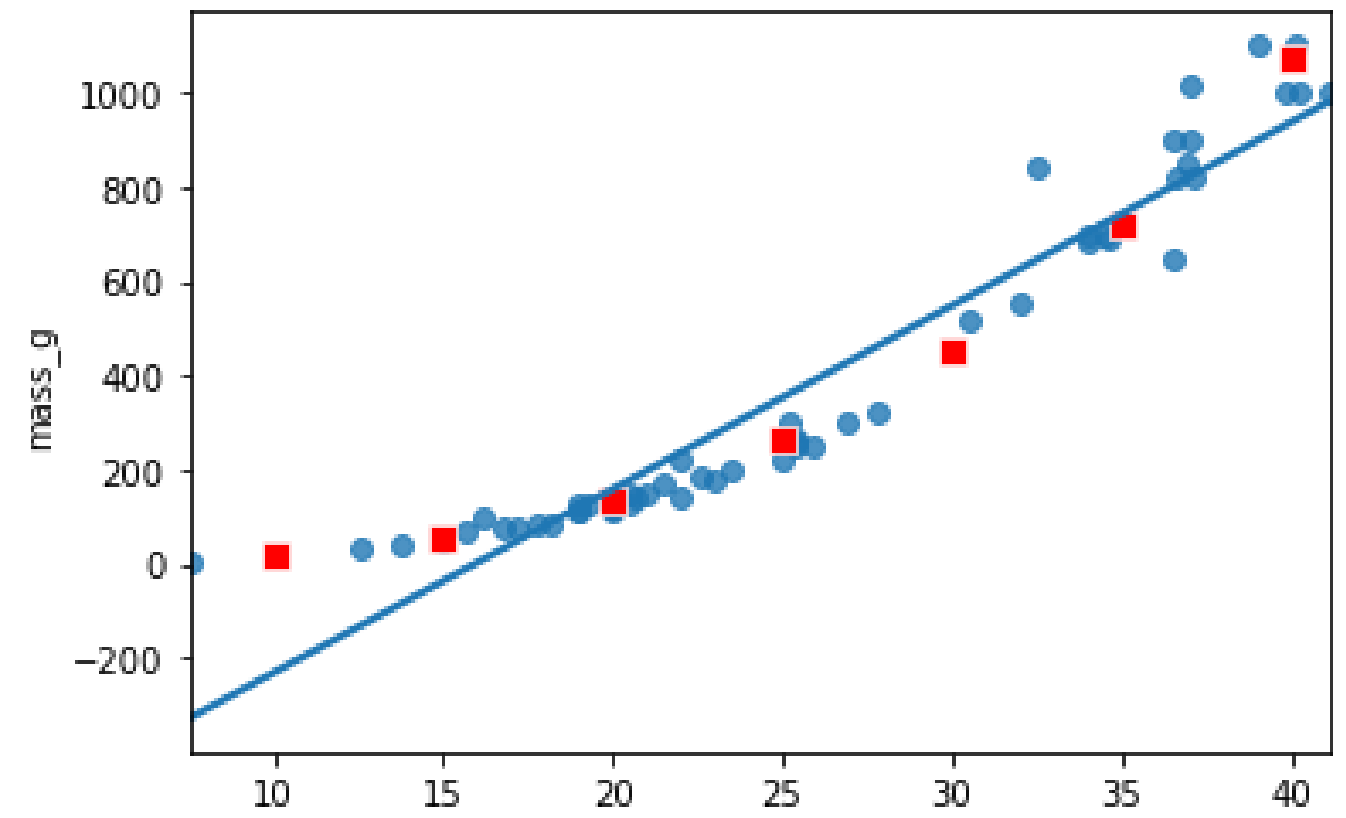
	length_cm_cubed	length_cm	mass_g
0	1000	10	16.678135
1	3375	15	56.567717
2	8000	20	134.247429
3	15625	25	262.313982
4	27000	30	453.364084
5	42875	35	719.994447
6	64000	40	1074.801781

Plotting mass vs. length cubed

```
fig = plt.figure()
sns.regplot(x="length_cm_cubed", y="mass_g",
            data=perch, ci=None)
sns.scatterplot(data=prediction_data,
                x="length_cm_cubed", y="mass_g",
                color="red", marker="s")
```



```
fig = plt.figure()
sns.regplot(x="length_cm", y="mass_g",
            data=perch, ci=None)
sns.scatterplot(data=prediction_data,
                x="length_cm", y="mass_g",
                color="red", marker="s")
```



Facebook advertising dataset

How advertising works

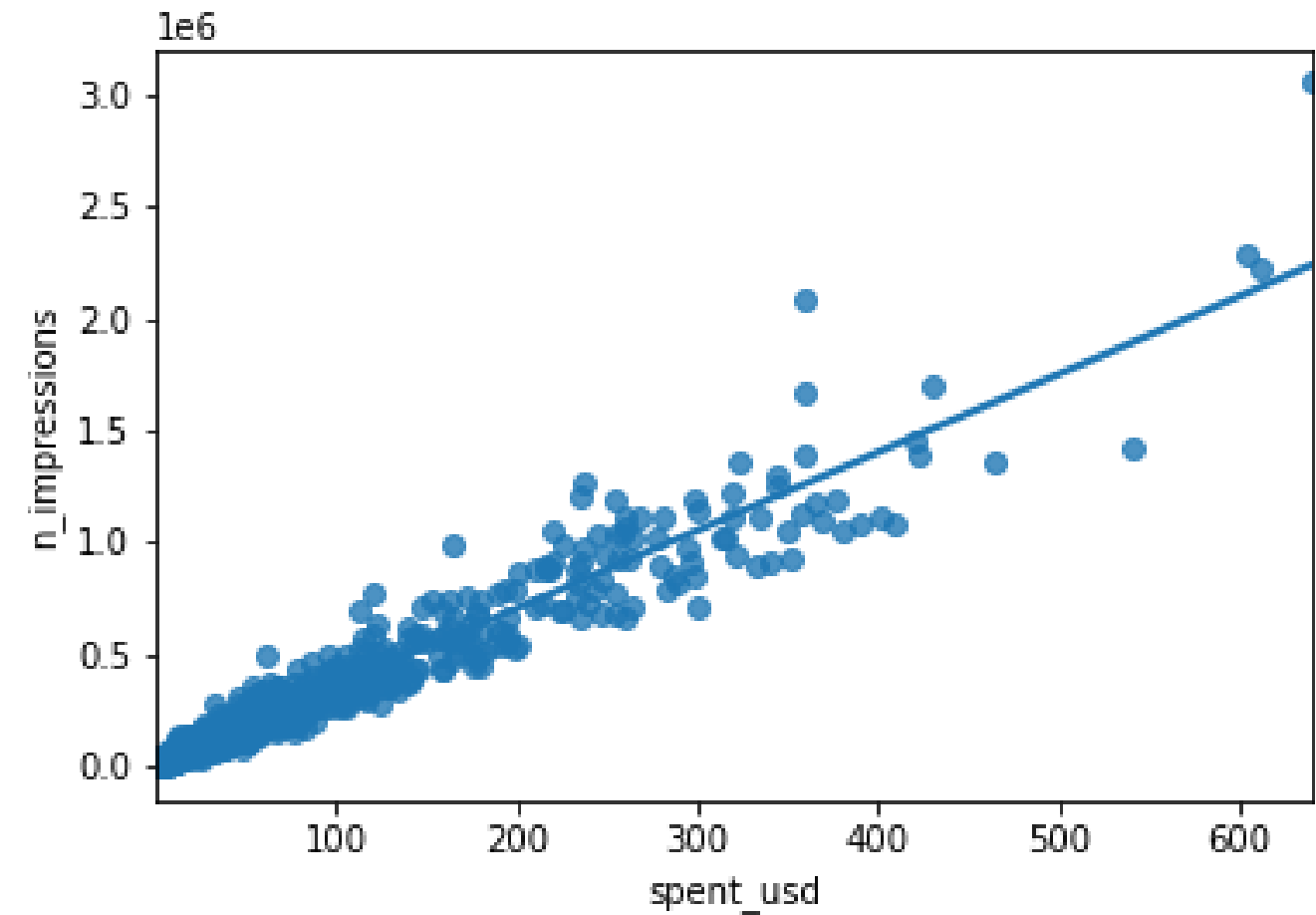
1. Pay Facebook to shows ads.
2. People see the ads ("impressions").
3. Some people who see it, click it.

- 936 rows
- Each row represents 1 advert

spent_usd	n_impressions	n_clicks
1.43	7350	1
1.82	17861	2
1.25	4259	1
1.29	4133	1
4.77	15615	3
...

Plot is cramped

```
sns.regplot(x="spent_usd",  
            y="n_impressions",  
            data=ad_conversion,  
            ci=None)
```

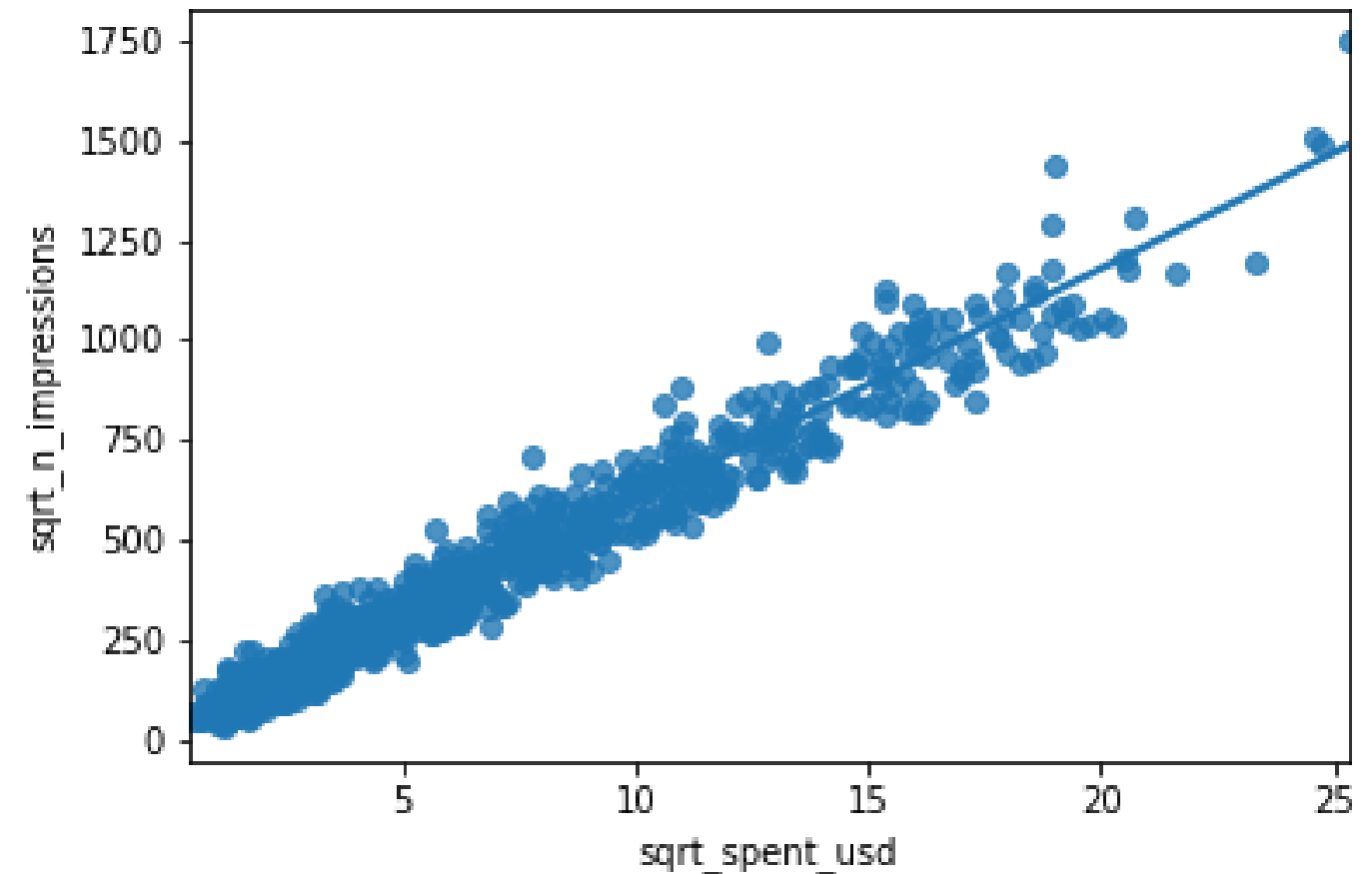


Square root vs square root

```
ad_conversion["sqrt_spent_usd"] = np.sqrt(
    ad_conversion["spent_usd"])

ad_conversion["sqrt_n_impressions"] = np.sqrt(
    ad_conversion["n_impressions"])

sns.regplot(x="sqrt_spent_usd",
            y="sqrt_n_impressions",
            data=ad_conversion,
            ci=None)
```



Modeling and predicting

```
mdl_ad = ols("sqrt_n_impressions ~ sqrt_spent_usd", data=ad_conversion).fit()
```

```
explanatory_data = pd.DataFrame({"sqrt_spent_usd": np.sqrt(np.arange(0, 601, 100)),  
                                "spent_usd": np.arange(0, 601, 100)})
```

```
prediction_data = explanatory_data.assign(sqrt_n_impressions=mdl_ad.predict(explanatory_data),  
                                         n_impressions=mdl_ad.predict(explanatory_data) ** 2)  
print(prediction_data)
```

	sqrt_spent_usd	spent_usd	sqrt_n_impressions	n_impressions
0	0.000000	0	15.319713	2.346936e+02
1	10.000000	100	597.736582	3.572890e+05
2	14.142136	200	838.981547	7.038900e+05
3	17.320508	300	1024.095320	1.048771e+06
4	20.000000	400	1180.153450	1.392762e+06
5	22.360680	500	1317.643422	1.736184e+06
6	24.494897	600	1441.943858	2.079202e+06

Let's practice!

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