Why you need logistic regression

INTRODUCTION TO REGRESSION WITH STATSMODELS IN PYTHON

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Bank churn dataset

has_churned	time_since_first_purchase	time_since_last_purchase
0	0.3993247	-0.5158691
1	-0.4297957	0.6780654
0	3.7383122	0.4082544
0	0.6032289	-0.6990435
...	...	...
response	*length of relationship*	*recency of activity*

[1] https://www.rdocumentation.org/packages/bayesQR/topics/Churn

Churn vs. recency: a linear model

```
mdl_churn_vs_recency_lm = ols("has_churned ~ time_since_last_purchase",
                              data=churn).fit()

print(mdl_churn_vs_recency_lm.params)
```

```
Intercept                   0.490780
time_since_last_purchase    0.063783
dtype: float64
```

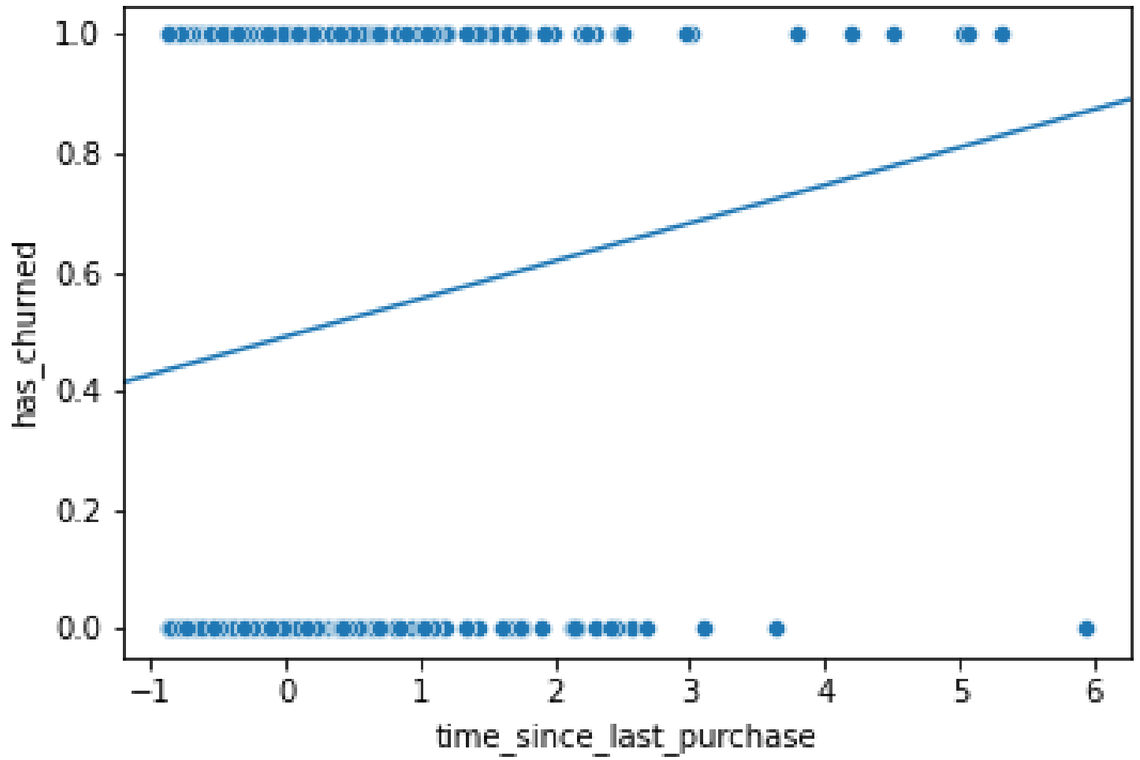
```
intercept, slope = mdl_churn_vs_recency_lm.params
```

Visualizing the linear model

```
sns.scatterplot(x="time_since_last_purchase",
                y="has_churned",
                data=churn)

plt.axline(xy1=(0, intercept),
           slope=slope)

plt.show()
```

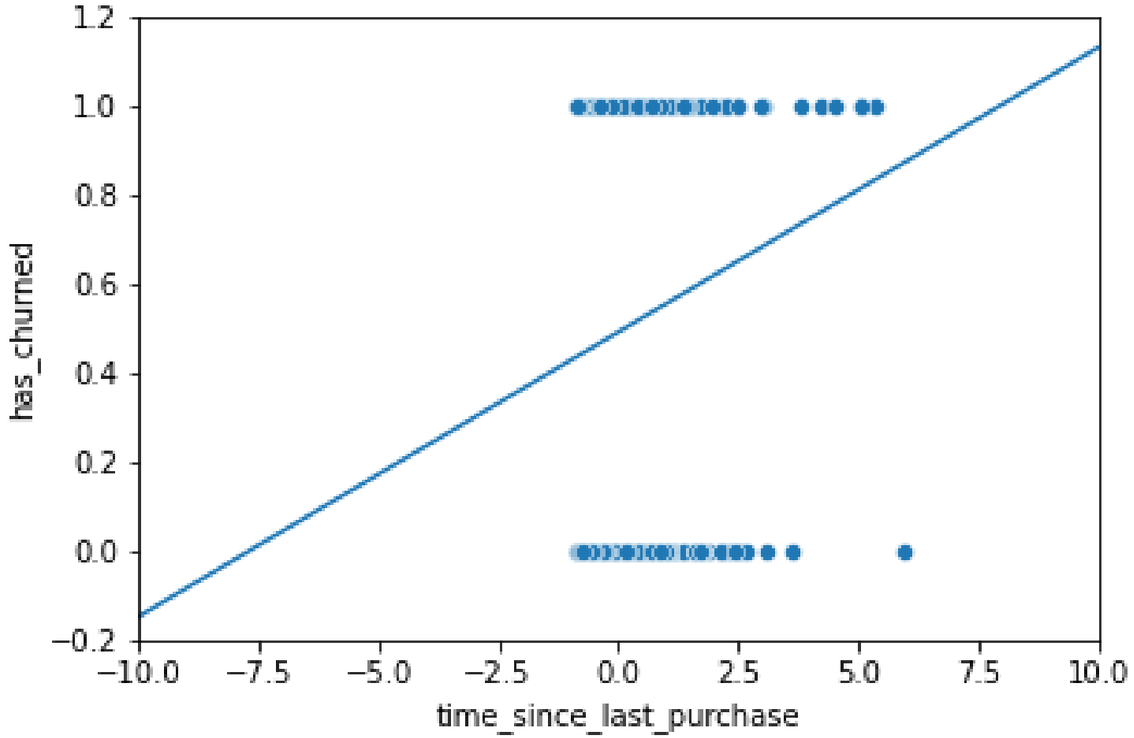


Zooming out

```
sns.scatterplot(x="time_since_last_purchase",
                y="has_churned",
                data=churn)

plt.axline(xy1=(0,intercept),
           slope=slope)

plt.xlim(-10, 10)
plt.ylim(-0.2, 1.2)
plt.show()
```



What is logistic regression?

- Another type of generalized linear model.
- Used when the response variable is logical.
- The responses follow logistic (S-shaped) curve.

Logistic regression using logit()

```
from statsmodels.formula.api import logit
mdl_churn_vs_recency_logit = logit("has_churned ~ time_since_last_purchase",
                                   data=churn).fit()
print(mdl_churn_vs_recency_logit.params)
```

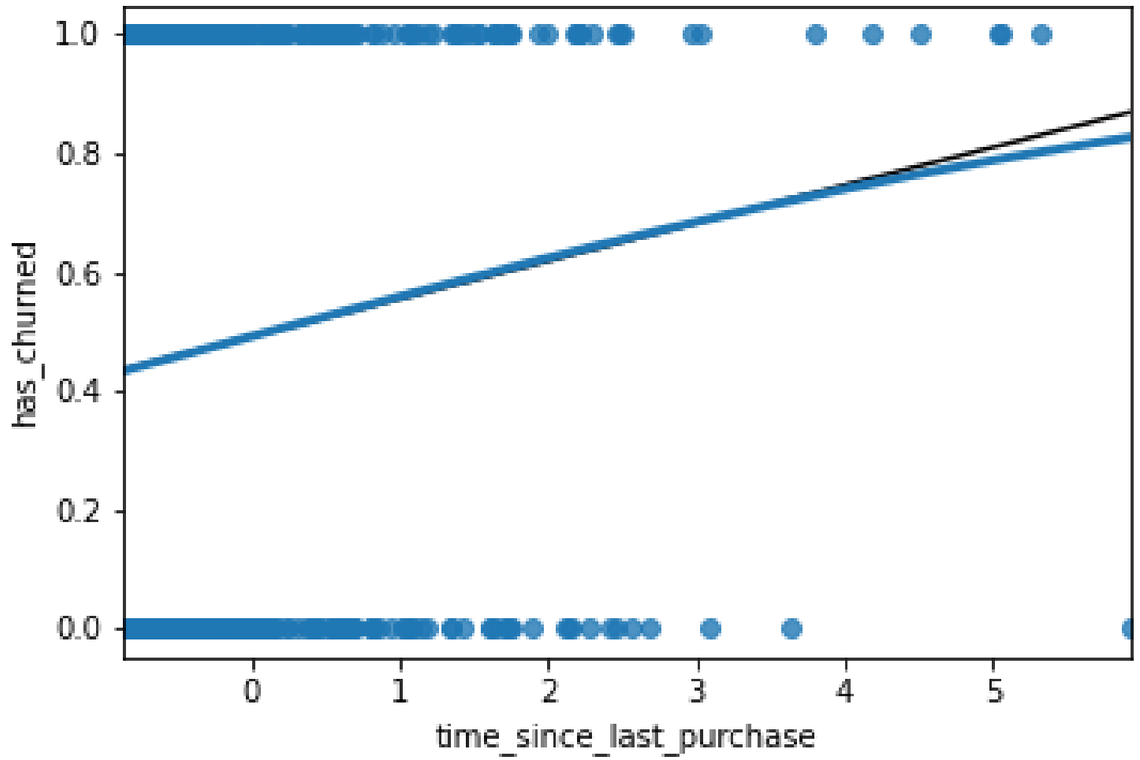
```
Intercept                 -0.035019
time_since_last_purchase   0.269215
dtype: float64
```

Visualizing the logistic model

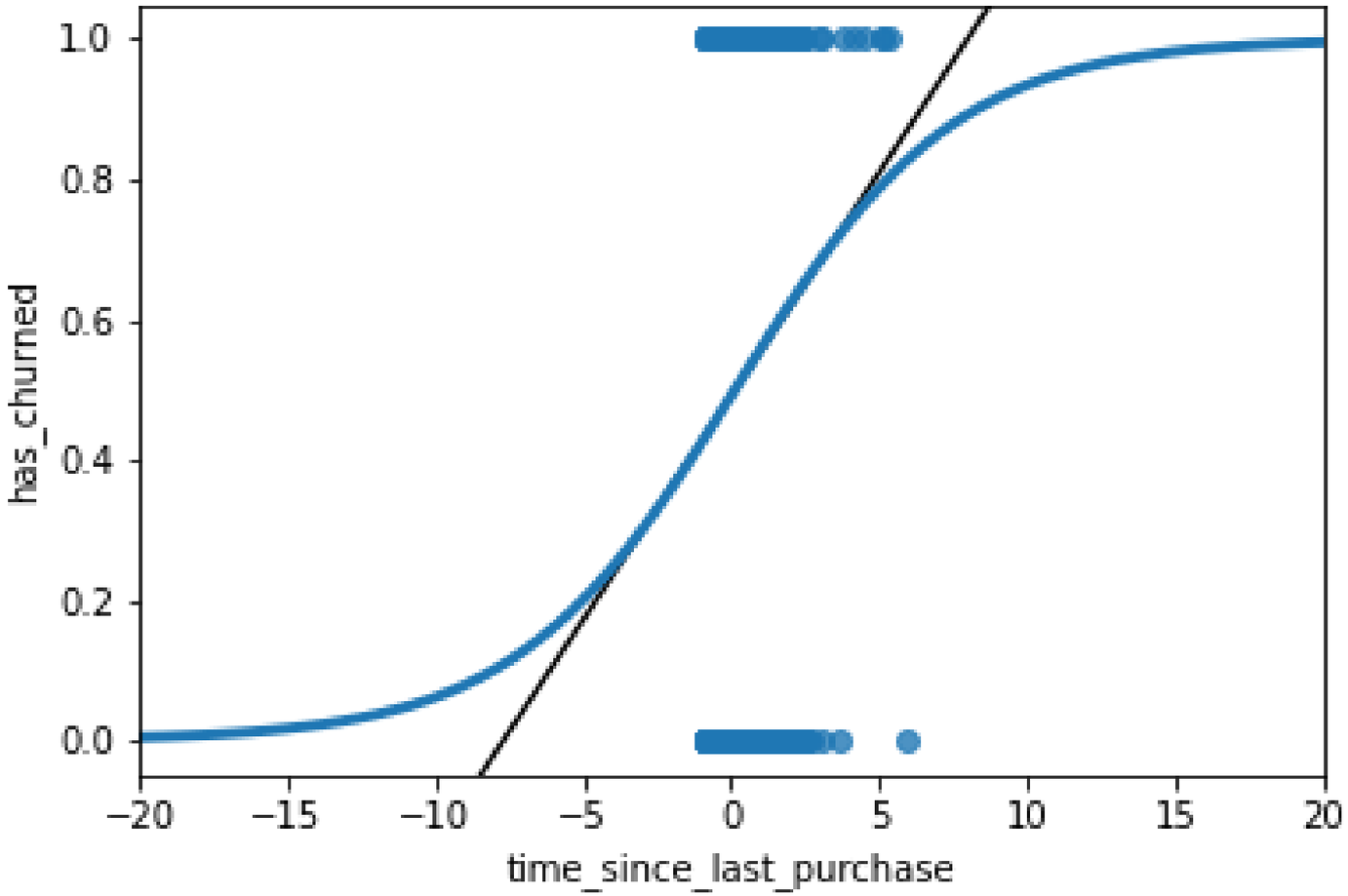
```
sns.regplot(x="time_since_last_purchase",
            y="has_churned",
            data=churn,
            ci=None,
            logistic=True)
```

```
plt.axline(xy1=(0,intercept),
           slope=slope,
           color="black")

plt.show()
```



Zooming out


1.0
0.8
0.6
0.4
0.2
0.0
has_churned
−20
−15
−10
−5
0
5
10
15
20
time_since_last_purchase

Let's practice!

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Predictions and odds ratios

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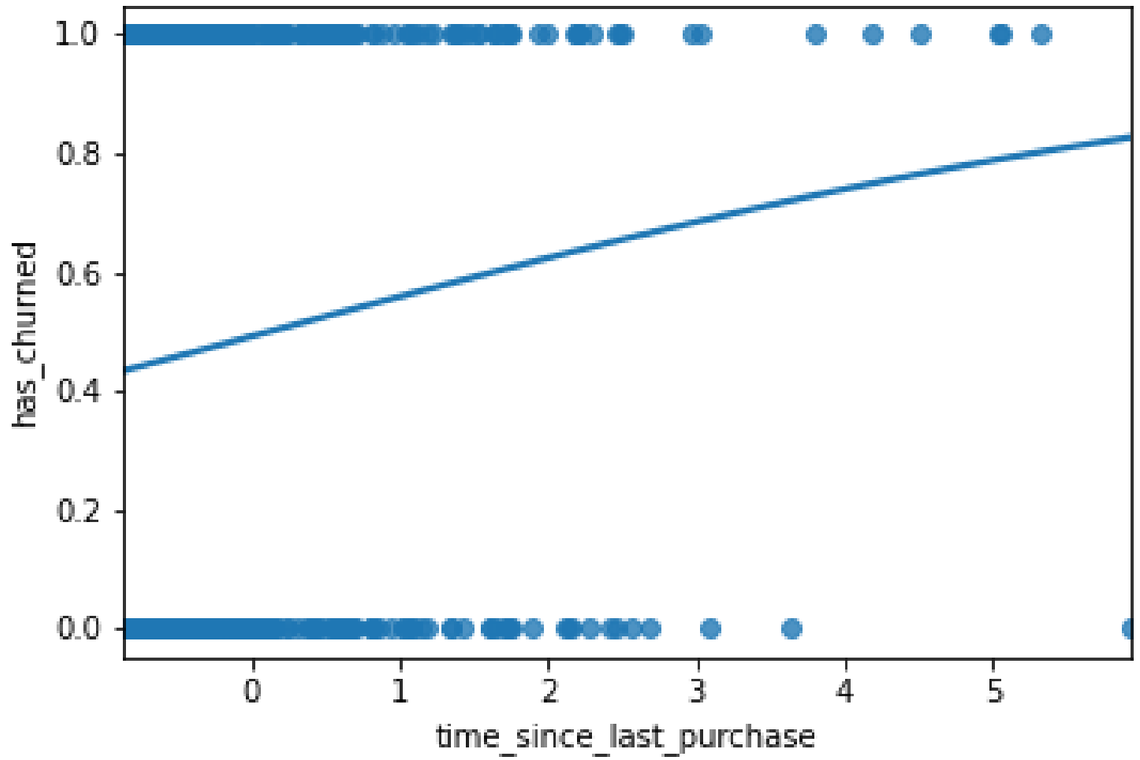
The regplot() predictions

```
sns.regplot(x="time_since_last_purchase",
            y="has_churned",
            data=churn,
            ci=None,
            logistic=True)

plt.show()
```

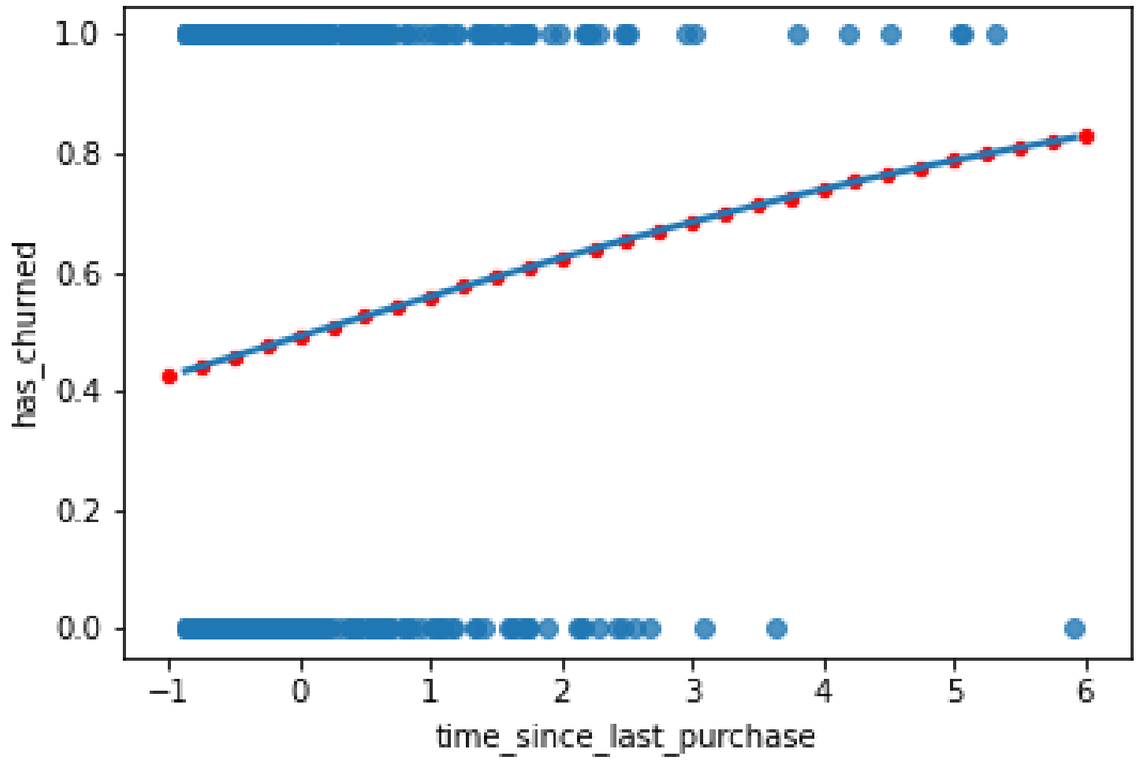


Making predictions

```
mdl_recency = logit("has_churned ~ time_since_last_purchase",
                    data = churn).fit()

explanatory_data = pd.DataFrame(
  {"time_since_last_purchase": np.arange(-1, 6.25, 0.25)})

prediction_data = explanatory_data.assign(
    has_churned = mdl_recency.predict(explanatory_data))
```

Adding point predictions

```
sns.regplot(x="time_since_last_purchase",
            y="has_churned",
            data=churn,
            ci=None,
            logistic=True)

sns.scatterplot(x="time_since_last_purchase",
                y="has_churned",
                data=prediction_data,
                color="red")

plt.show()
```

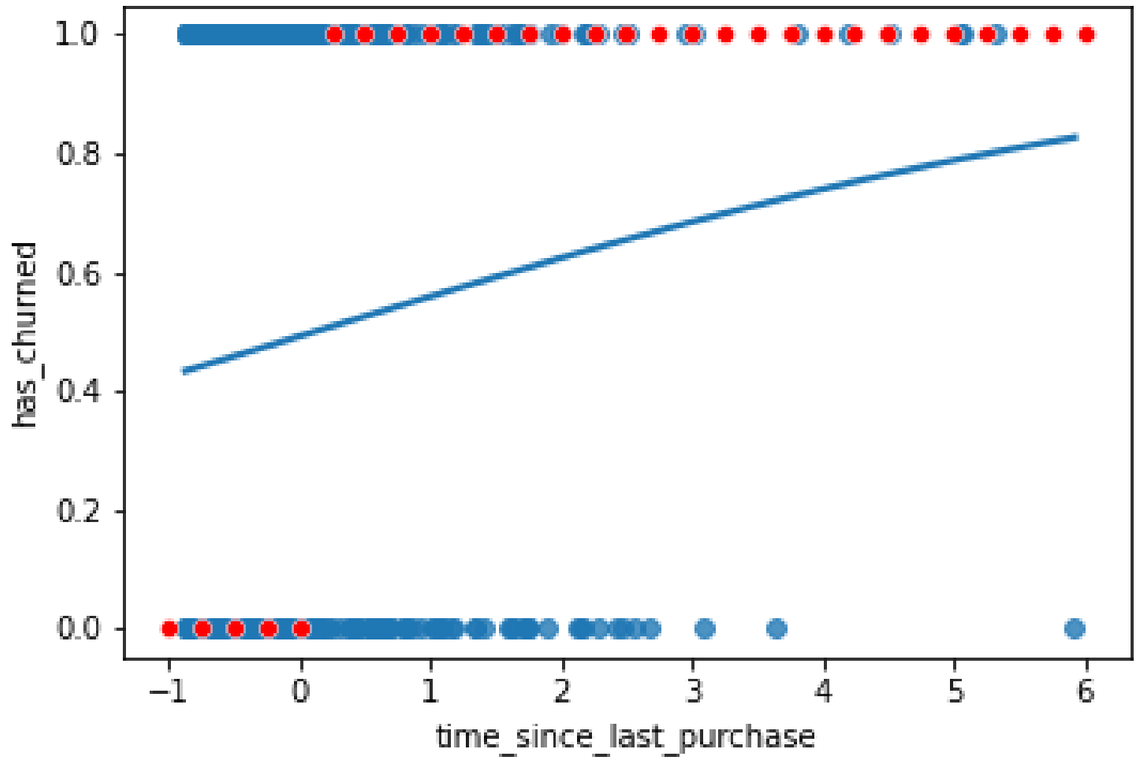


Getting the most likely outcome

```
prediction_data = explanatory_data.assign(
    has_churned = mdl_recency.predict(explanatory_data))
prediction_data["most_likely_outcome"] = np.round(prediction_data["has_churned"])
```

Visualizing most likely outcome

```
sns.regplot(x="time_since_last_purchase",
            y="has_churned",
            data=churn,
            ci=None,
            logistic=True)

sns.scatterplot(x="time_since_last_purchase",
                y="most_likely_outcome",
                data=prediction_data,
                color="red")

plt.show()
```

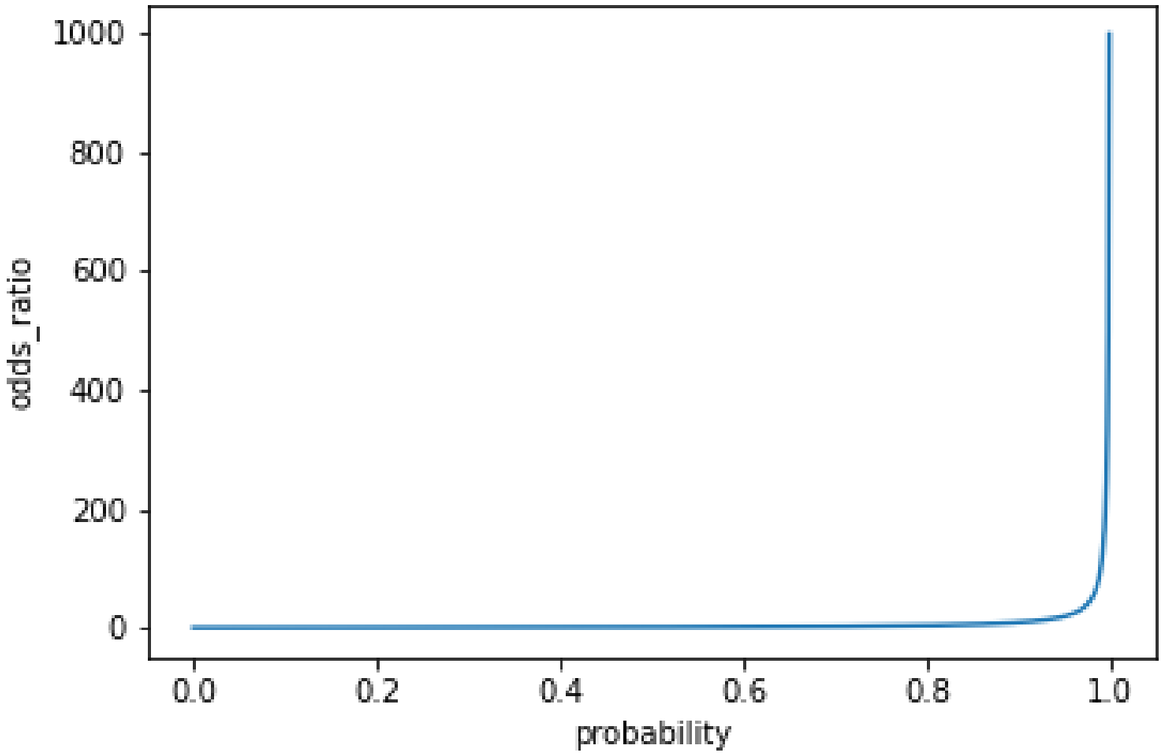


Odds ratios

Odds ratio is the probability of something happening divided by the probability that it doesn't.

$$\text{odds\_ratio} = \frac{\text{probability}}{(1 - \text{probability})}$$

$$\text{odds\_ratio} = \frac{0.25}{(1 - 0.25)} = \frac{1}{3}$$

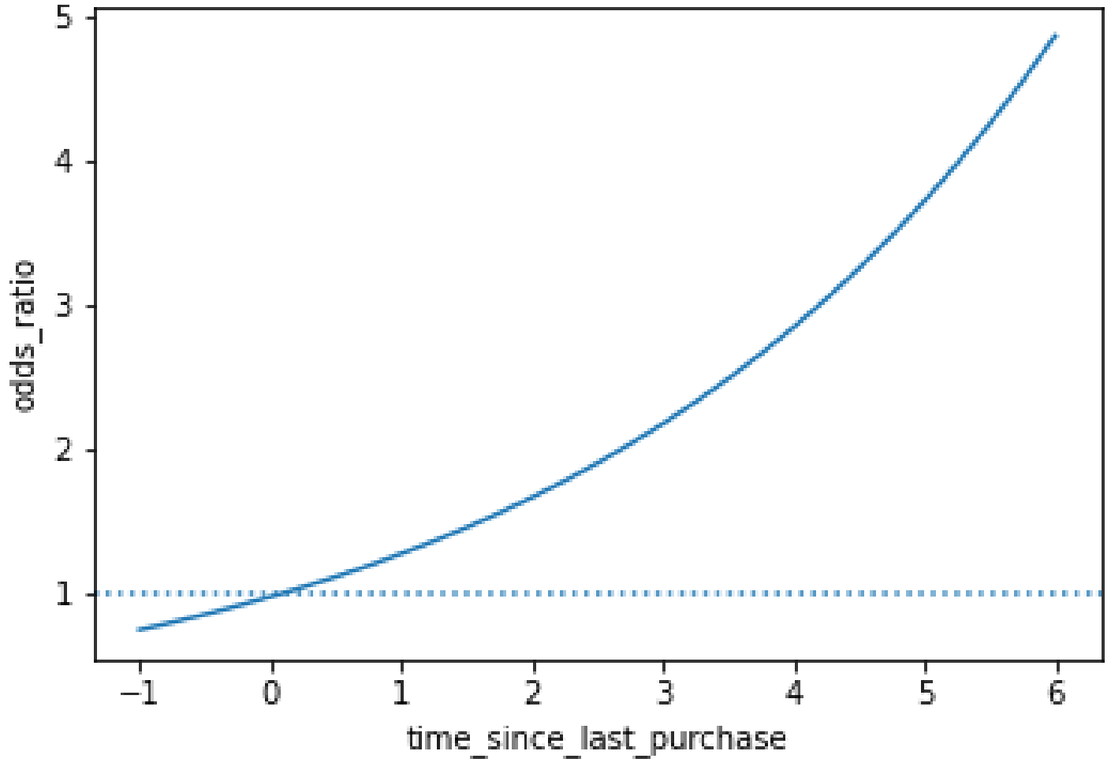


Calculating odds ratio

```
prediction_data["odds_ratio"] = prediction_data["has_churned"] /
                                (1 - prediction_data["has_churned"])
```

Visualizing odds ratio

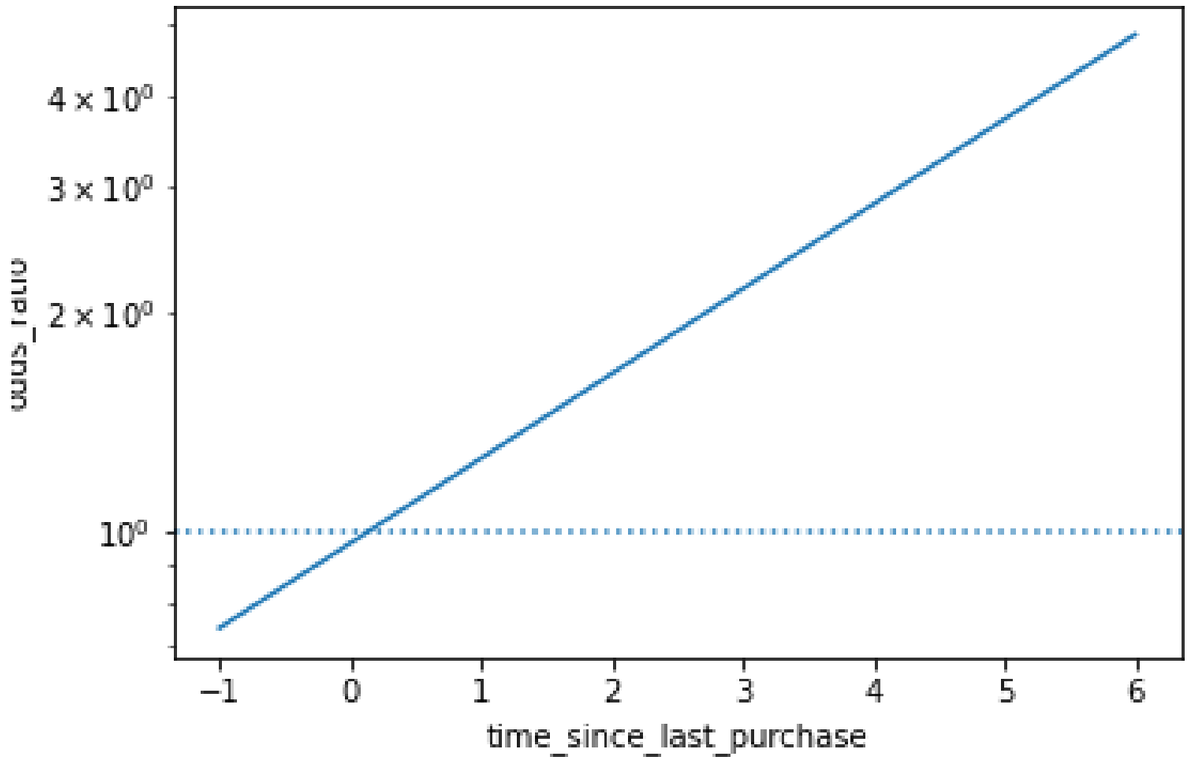
```
sns.lineplot(x="time_since_last_purchase",
             y="odds_ratio",
             data=prediction_data)

plt.axhline(y=1,
            linestyle="dotted")

plt.show()
```



Visualizing log odds ratio

```
sns.lineplot(x="time_since_last_purchase",
             y="odds_ratio",
             data=prediction_data)

plt.axhline(y=1,
            linestyle="dotted")
```

```
plt.yscale("log")

plt.show()
```



Calculating log odds ratio

```
prediction_data["log_odds_ratio"] = np.log(prediction_data["odds_ratio"])
```

All predictions together

time_since_last_prchs	has_churned	most_likely_rspns	odds_ratio	log_odds_ratio
0	0.491	0	0.966	-0.035
2	0.623	1	1.654	0.503
4	0.739	1	2.834	1.042
6	0.829	1	4.856	1.580
...	...	...	...	...

Comparing scales

Scale	Are values easy to interpret?	Are changes easy to interpret?	Is precise?
Probability	✔	✘	✔
Most likely outcome	✔✔	✔	✘
Odds ratio	✔	✘	✔
Log odds ratio	✘	✔	✔

Let's practice!

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Quantifying logistic regression fit

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The four outcomes

	predicted false	predicted true
actual false	correct	false positive
actual true	false negative	correct

Confusion matrix: counts of outcomes

```
actual_response = churn["has_churned"]
```

```
predicted_response = np.round(mdl_recency.predict())
```

```
outcomes = pd.DataFrame({"actual_response": actual_response,
                         "predicted_response": predicted_response})
```

```
print(outcomes.value_counts(sort=False))
```

```
actual_response  predicted_response
0                0.0                 141
                 1.0                  59
1                0.0                 111
                 1.0                  89
```

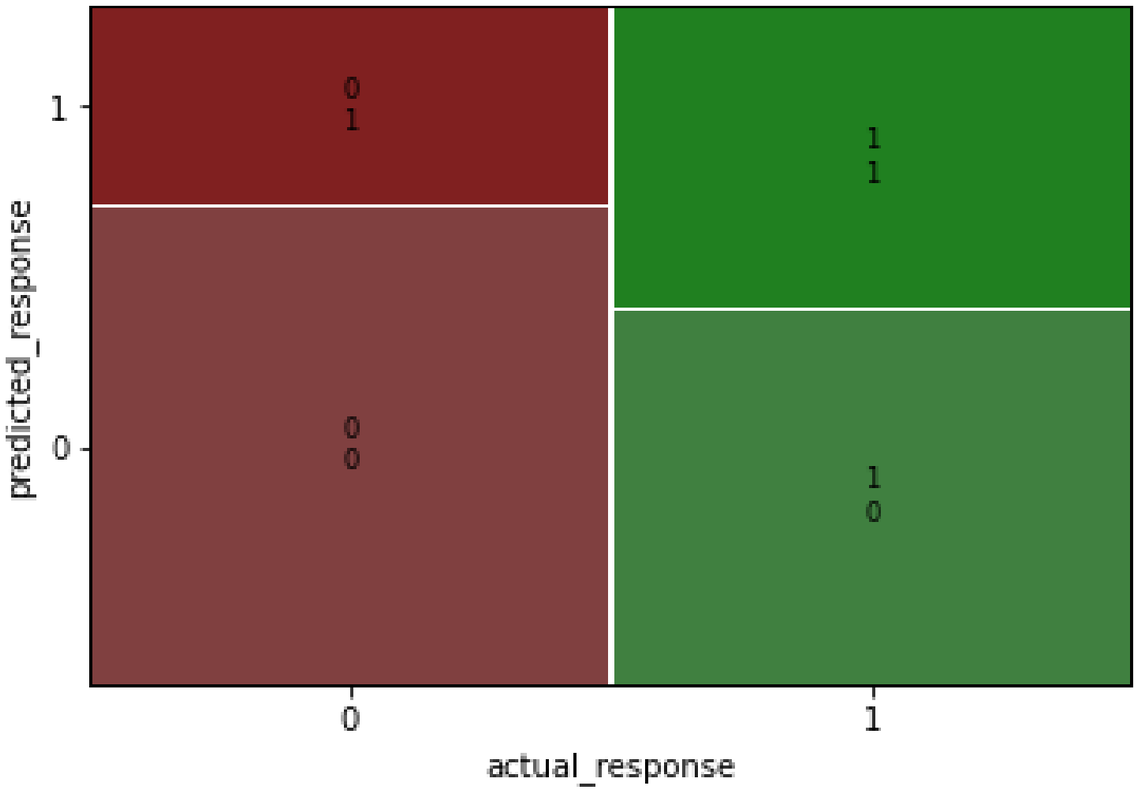
Visualizing the confusion matrix

```
conf_matrix = mdl_recency.pred_table()

print(conf_matrix)
```

```
[[141.                59.]
 [111.                89.]]
```

true negative	false positive
false negative	true positive

```
from statsmodels.graphics.mosaicplot
import mosaic

mosaic(conf_matrix)
```



Accuracy

Accuracy is the proportion of correct predictions.

$$\text{accuracy} = \frac{TN + TP}{TN + FN + FP + TP}$$

```
[[141.,  59.],
 [111.,  89.]]
```

```
TN = conf_matrix[0,0]
TP = conf_matrix[1,1]
FN = conf_matrix[1,0]
FP = conf_matrix[0,1]
```

```
acc = (TN + TP) / (TN + TP + FN + FP)
print(acc)
```

```
0.575
```

Sensitivity

Sensitivity is the proportion of true positives.

$$\text{sensitivity} = \frac{TP}{FN + TP}$$

```
[[141.,  59.],
 [111.,  89.]]
```

```
TN = conf_matrix[0,0]
TP = conf_matrix[1,1]
FN = conf_matrix[1,0]
FP = conf_matrix[0,1]
```

```
sens = TP / (FN + TP)
print(sens)
```

```
0.445
```

Specificity

Specificity is the proportion of true negatives.

$$\text{specificity} = \frac{TN}{TN + FP}$$

```
[[141.,  59.],
 [111.,  89.]]
```

```
TN = conf_matrix[0,0]
TP = conf_matrix[1,1]
FN = conf_matrix[1,0]
FP = conf_matrix[0,1]
```

```
spec = TN / (TN + FP)
print(spec)
```

```
0.705
```

Let's practice!

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Congratulations

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You learned things

Chapter 1

- Fit a simple linear regression
- Interpret coefficients

Chapter 2

- Make predictions
- Regression to the mean
- Transforming variables

Chapter 3

- Quantifying model fit
- Outlier, leverage, and influence

Chapter 4

- Fit a simple logistic regression
- Make predictions
- Get performance from confusion matrix

Multiple explanatory variables

Intermediate Regression with statsmodels in Python

Unlocking advanced skills

- Generalized Linear Models in Python
- Introduction to Predictive Analytics in Python
- Linear Classifiers in Python

Happy learning!

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