импорт библиотек

In [29]:
```
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
import seaborn as sns
import phik

from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split, GridSearchCV
from imblearn.over_sampling import SMOTE
from sklearn.preprocessing import StandardScaler
from sklearn.pipeline import Pipeline
from sklearn.ensemble import RandomForestClassifier
from sklearn import metrics

import xgboost as xgb
from xgboost import XGBClassifier
```

Загрузка и подготовка данных

In [30]:
```
lstm_embs = pd.read_csv('../data/ts_lstm_embeddings.csv')
lstm_embs.head()
```

Out[30]:

	student_id	emb_0	emb_1	emb_2	emb_3	emb_4	emb_5	emb_6	emb_7	emb_8	...	emb_118	eml
0	9431	0.028173	-0.059907	-0.071333	0.049000	-0.058226	-0.051722	0.041741	-0.000571	0.066269	...	0.007996	0.0
1	26090	0.025742	-0.061791	-0.073573	0.052954	-0.062950	-0.054274	0.045108	0.002962	0.069635	...	0.006690	0.0
2	36478	0.024638	-0.062649	-0.074594	0.054759	-0.065101	-0.055442	0.046645	0.004576	0.071166	...	0.006093	0.0
3	37987	0.024347	-0.062875	-0.074865	0.055237	-0.065669	-0.055751	0.047052	0.005003	0.071571	...	0.005935	0.0
4	78724	0.029430	-0.058934	-0.070180	0.046965	-0.055788	-0.050412	0.040008	-0.002387	0.064532	...	0.008667	0.0

5 rows × 129 columns

In [31]:
```
features = pd.read_csv('../data/features.csv')
features.head()
```

Out[31]:

	student_id	is_diploma	is_resume	is_refund	tu	days_to_first_dropout	first_dropout_lesson_Business/Logic	first_dropout_
0	22530050	0	0	0	0	35.0	False	
1	20483393	0	0	0	0	28.0	False	
2	21048237	0	0	0	0	56.0	True	
3	22455198	1	1	0	1	98.0	True	
4	20403558	1	1	0	1	98.0	False	

In [32]:
```
features_and_embs = pd.merge(lstm_embs, features, on='student_id')
features_and_embs.drop(columns=['student_id'], inplace=True)
features_and_embs.head()
```

Out[32]:

	emb_0	emb_1	emb_2	emb_3	emb_4	emb_5	emb_6	emb_7	emb_8	emb_9	...	first_dropout_les
0	0.028173	-0.059907	-0.071333	0.049000	-0.058226	-0.051722	0.041741	-0.000571	0.066269	0.023966	...	
1	0.025742	-0.061791	-0.073573	0.052954	-0.062950	-0.054274	0.045108	0.002962	0.069635	0.027896	...	
2	0.024638	-0.062649	-0.074594	0.054759	-0.065101	-0.055442	0.046645	0.004576	0.071166	0.029678	...	
3	0.024638	-0.062649	-0.074594	0.054759	-0.065101	-0.055442	0.046645	0.004576	0.071166	0.029678	...	
4	0.024347	-0.062875	-0.074865	0.055237	-0.065669	-0.055751	0.047052	0.005003	0.071571	0.030148	...	

5 rows × 147 columns

Эксперимент 1: объединение признаков и векторов, извлечённых lstm из временных рядов посещаемости

In [33]:
```
X = features_and_embs.drop(columns='is_refund')
y = features_and_embs['is_refund']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, shuffle=True, random_state=42)
```

```
print('Train:', X_train.shape, y_train.shape)
print('Test:', X_test.shape, y_test.shape)
```

```
Train: (2069, 146) (2069,)
Test: (518, 146) (518,)
```

In [34]:
```
sm = SMOTE(random_state=42)
X_train, y_train = sm.fit_resample(X_train, y_train)
```

In [35]:
```
print(f'Размерность тренировочной выборки после сэмплирования: {X_train.shape}')
print(f'Баланс классов после сэмплирования:\n{y_train.value_counts()}')
```

```
Размерность тренировочной выборки после сэмплирования: (3692, 146)
Баланс классов после сэмплирования:
is_refund
0    1846
1    1846
Name: count, dtype: int64
```

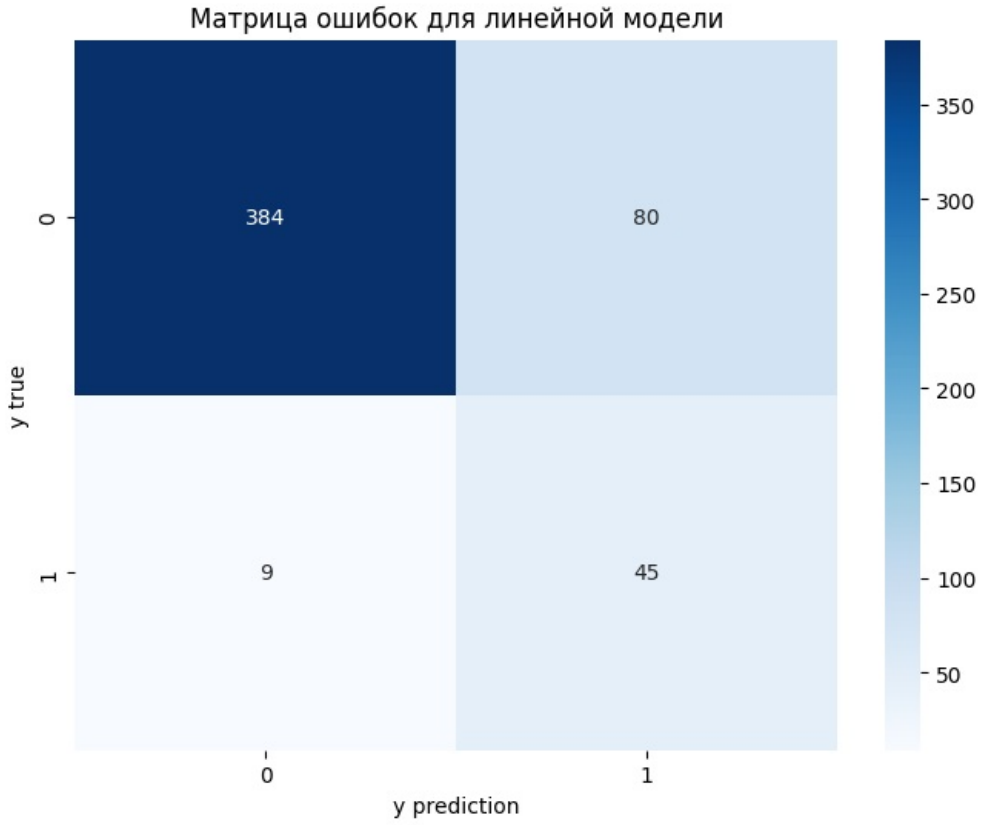
In [36]:
```
num_features = []
for col in features_and_embs.columns:
    if 'emb' in col or 'days' in col:
        num_features.append(col)

scaler = StandardScaler()

X_train[num_features] = scaler.fit_transform(X_train[num_features])
X_test[num_features] = scaler.transform(X_test[num_features])
```

Модель логистической регрессии

In [37]:
```
logistic_regression = LogisticRegression(C=1)
logistic_regression.fit(X_train, y_train)
y_pred_train_lr = logistic_regression.predict(X_train)
y_pred_test_lr = logistic_regression.predict(X_test)
print(f'Метрики train\n{metrics.classification_report(y_train, y_pred_train_lr)}')
print(f'Метрики test\n{metrics.classification_report(y_test, y_pred_test_lr)}')
```

```
Метрики train
              precision    recall  f1-score   support

           0       0.96      0.81      0.88      1846
           1       0.84      0.96      0.90      1846

    accuracy                           0.89      3692
   macro avg       0.90      0.89      0.89      3692
weighted avg       0.90      0.89      0.89      3692

Метрики test
              precision    recall  f1-score   support

           0       0.98      0.83      0.90       464
           1       0.36      0.83      0.50        54

    accuracy                           0.83       518
   macro avg       0.67      0.83      0.70       518
weighted avg       0.91      0.83      0.86       518
```

In [38]:
```
confusion_matrix1 = metrics.confusion_matrix(y_test, y_pred_test_lr)

plt.figure(figsize=(8, 6))
sns.heatmap(confusion_matrix1, annot=True, fmt='', cmap='Blues')
plt.title('Матрица ошибок для линейной модели')
plt.xlabel('y prediction')
plt.ylabel('y true')
plt.show()
```



XGboost

In [39]:
```
param_grid = {
    'n_estimators': [10, 25, 50],
    'max_depth': [1, 2, 3],
    'learning_rate': [0.0001, 0.001, 0.01, 0.1]
}

grid_search = GridSearchCV(estimator=XGBClassifier(), param_grid=param_grid, cv=5, scoring='f1')
grid_search.fit(X_train, y_train)
print(f"Best parameters: {grid_search.best_params_}")
```

```
Best parameters: {'learning_rate': 0.1, 'max_depth': 3, 'n_estimators': 50}
```

In [40]:
```
best_model_xgb = grid_search.best_estimator_
print("Best Parameters:", grid_search.best_params_)
print("Лучшая метрика f1 на обучающем наборе данных:", grid_search.best_score_)
```

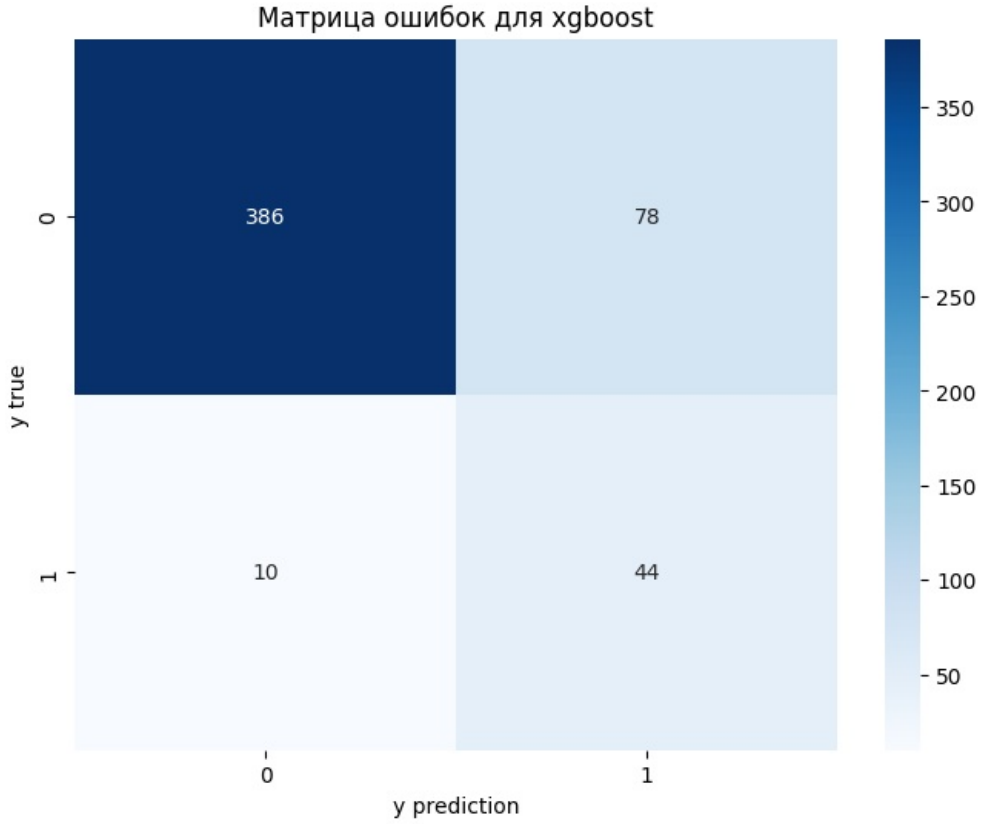
```
Best Parameters: {'learning_rate': 0.1, 'max_depth': 3, 'n_estimators': 50}
Лучшая метрика f1 на обучающем наборе данных: 0.8867427921343172
```

In [41]:
```
y_pred_train_xgb = best_model_xgb.predict(X_train)
y_pred_test_xgb = best_model_xgb.predict(X_test)
print(f'Метрики train\n{metrics.classification_report(y_train, y_pred_train_xgb)}')
print(f'Метрики test\n{metrics.classification_report(y_test, y_pred_test_xgb)}')
```

```
Метрики train
              precision    recall  f1-score   support

           0       0.95      0.83      0.89      1846
           1       0.85      0.96      0.90      1846

    accuracy                           0.89      3692
   macro avg       0.90      0.89      0.89      3692
weighted avg       0.90      0.89      0.89      3692

Метрики test
              precision    recall  f1-score   support

           0       0.97      0.83      0.90       464
           1       0.36      0.81      0.50        54

    accuracy                           0.83       518
   macro avg       0.67      0.82      0.70       518
weighted avg       0.91      0.83      0.86       518
```

In [42]:
```
confusion_matrix2 = metrics.confusion_matrix(y_test, y_pred_test_xgb)

plt.figure(figsize=(8, 6))
sns.heatmap(confusion_matrix2, annot=True, fmt='', cmap='Blues')
plt.title('Матрица ошибок для xgboost')
```

```
plt.xlabel('y prediction')
plt.ylabel('y true')
plt.show()
```



Эксперимент 2: объединение признаков и добавление нового: вероятность оттока, полученная из lstm временных рядов

In [43]:
```
lstm_probs = pd.read_csv('../data/ts_lstm_refund_prob.csv')
features_and_probs = pd.merge(lstm_probs, features, on='student_id')
features_and_probs.drop(columns=['student_id'], inplace=True)
features_and_probs.head()
```

Out[43]:

	refund_prob	is_diploma	is_resume	is_refund	tu	days_to_first_dropout	first_dropout_lesson_Business/Logic	first_dropou
0	0.114276	1	0	0	1	70.0	False	
1	0.231850	0	0	0	0	11.0	False	
2	0.307584	0	0	1	0	7.0	False	
3	0.307584	0	0	1	0	21.0	True	
4	0.329730	0	0	0	0	11.0	False	

In [44]:
```
X = features_and_probs.drop(columns='is_refund')
y = features_and_probs['is_refund']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, shuffle=True, random_state=42)

print('Train:', X_train.shape, y_train.shape)
print('Test:', X_test.shape, y_test.shape)
```

```
Train: (2069, 19) (2069,)
Test: (518, 19) (518,)
```

In [45]:
```
sm = SMOTE(random_state=42)
X_train, y_train = sm.fit_resample(X_train, y_train)
```

In [46]:
```
print(f'Размерность тренировочной выборки после сэмплирования: {X_train.shape}')
print(f'Баланс классов после сэмплирования:\n{y_train.value_counts()}')
```

```
Размерность тренировочной выборки после сэмплирования: (3692, 19)
Баланс классов после сэмплирования:
is_refund
0    1846
1    1846
Name: count, dtype: int64
```

In [47]:
```
num_features = []
```

```
for col in features_and_probs.columns:
    if 'emb' in col or 'days' in col:
        num_features.append(col)

scaler = StandardScaler()

X_train[num_features] = scaler.fit_transform(X_train[num_features])
X_test[num_features] = scaler.transform(X_test[num_features])
```

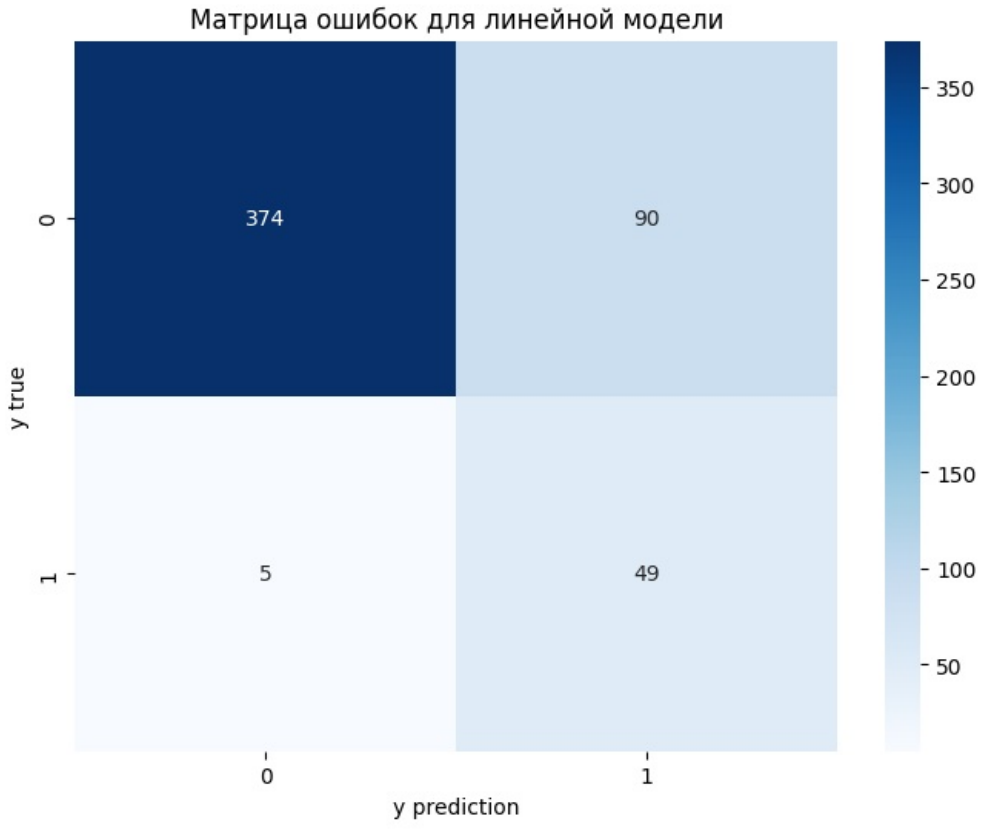
In [48]:

```
logistic_regression = LogisticRegression(C=1)
logistic_regression.fit(X_train, y_train)
y_pred_train_lr = logistic_regression.predict(X_train)
y_pred_test_lr = logistic_regression.predict(X_test)
print(f'Метрики train\n{metrics.classification_report(y_train, y_pred_train_lr)}')
print(f'Метрики test\n{metrics.classification_report(y_test, y_pred_test_lr)}')
```

```
Метрики train
              precision    recall  f1-score   support

           0       0.95      0.78      0.85      1846
           1       0.81      0.96      0.88      1846

    accuracy                           0.87      3692
   macro avg       0.88      0.87      0.87      3692
weighted avg       0.88      0.87      0.87      3692

Метрики test
              precision    recall  f1-score   support

           0       0.99      0.81      0.89       464
           1       0.35      0.91      0.51        54

    accuracy                           0.82       518
   macro avg       0.67      0.86      0.70       518
weighted avg       0.92      0.82      0.85       518
```

In [49]:

```
confusion_matrix3 = metrics.confusion_matrix(y_test, y_pred_test_lr)

plt.figure(figsize=(8, 6))
sns.heatmap(confusion_matrix3, annot=True, fmt='', cmap='Blues')
plt.title('Матрица ошибок для линейной модели')
plt.xlabel('y prediction')
plt.ylabel('y true')
plt.show()
```



In [50]:

```
param_grid = {
    'n_estimators': [10, 25, 50],
    'max_depth': [1, 2, 3],
    'learning_rate': [0.0001, 0.001, 0.01, 0.1]
}

grid_search = GridSearchCV(estimator=XGBClassifier(), param_grid=param_grid, cv=5, scoring='f1')
```

```
grid_search.fit(X_train, y_train)
print(f"Best parameters: {grid_search.best_params_}")
```

```
Best parameters: {'learning_rate': 0.1, 'max_depth': 3, 'n_estimators': 50}
```

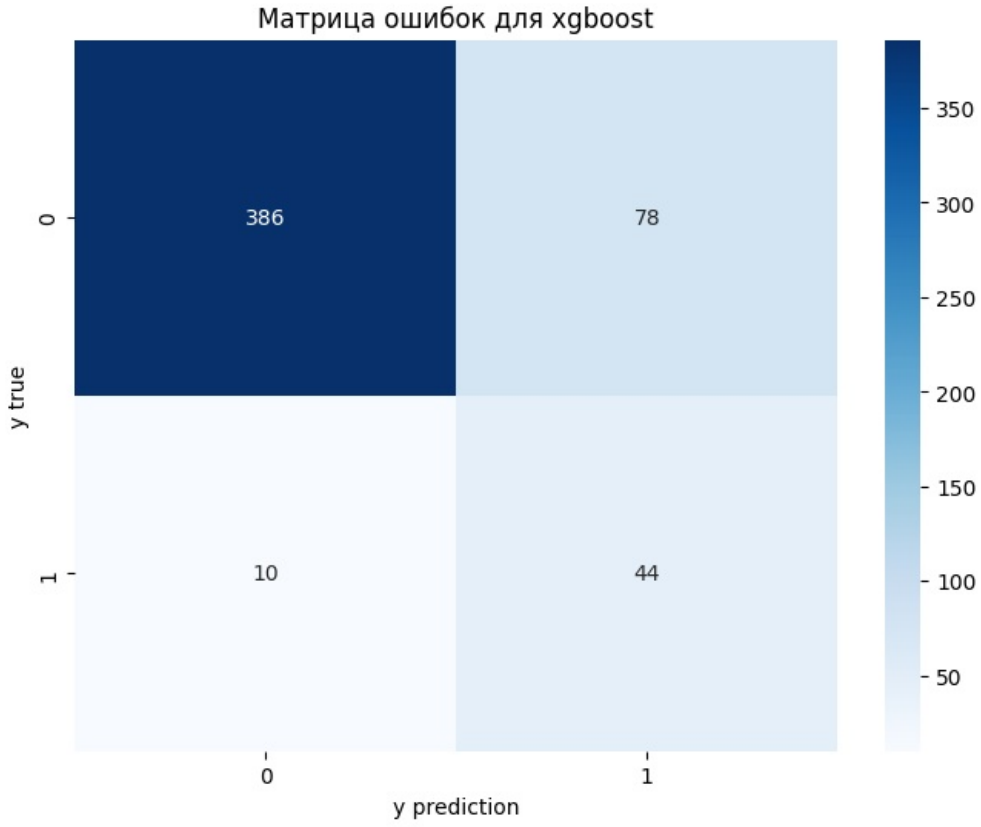
In [51]:
```
best_model_xgb = grid_search.best_estimator_
print("Best Parameters:", grid_search.best_params_)
print("Лучшая метрика f1 на обучающем наборе данных:", grid_search.best_score_)
```

```
Best Parameters: {'learning_rate': 0.1, 'max_depth': 3, 'n_estimators': 50}
Лучшая метрика f1 на обучающем наборе данных: 0.8829256773370331
```

In [52]:
```
y_pred_train_xgb = best_model_xgb.predict(X_train)
y_pred_test_xgb = best_model_xgb.predict(X_test)
print(f'Метрики train\n{metrics.classification_report(y_train, y_pred_train_xgb)}')
print(f'Метрики test\n{metrics.classification_report(y_test, y_pred_test_xgb)}')
```

```
Метрики train
              precision    recall  f1-score   support

           0       0.95      0.82      0.88      1846
           1       0.85      0.96      0.90      1846

    accuracy                           0.89      3692
   macro avg       0.90      0.89      0.89      3692
weighted avg       0.90      0.89      0.89      3692

Метрики test
              precision    recall  f1-score   support

           0       0.97      0.83      0.90       464
           1       0.36      0.81      0.50        54

    accuracy                           0.83       518
   macro avg       0.67      0.82      0.70       518
weighted avg       0.91      0.83      0.86       518
```

In [53]:
```
confusion_matrix4 = metrics.confusion_matrix(y_test, y_pred_test_xgb)

plt.figure(figsize=(8, 6))
sns.heatmap(confusion_matrix4, annot=True, fmt='', cmap='Blues')
plt.title('Матрица ошибок для xgboost')
plt.xlabel('y prediction')
plt.ylabel('y true')
plt.show()
```



Результаты

In [58]:
```
results = pd.DataFrame(columns=['experiment', 'model', 'accuracy', 'precision', 'recall', 'f1'])
lr_1 = {'experiment': 1, 'model': 'log reg', 'accuracy': 0.83, 'precision': 0.67, 'recall': 0.83, 'f1': 0.70}
results.loc[len(results)] = lr_1
```

```
xgb_1 = {'experiment': 1, 'model': 'xgb', 'accuracy': 0.83, 'precision': 0.67, 'recall': 0.82, 'f1': 0.70}
results.loc[len(results)] = xgb_1
lr_2 = {'experiment': 2, 'model': 'log reg', 'accuracy': 0.82, 'precision': 0.67, 'recall': 0.86, 'f1': 0.70}
results.loc[len(results)] = lr_2
xgb_2 = {'experiment': 2, 'model': 'xgb', 'accuracy': 0.83, 'precision': 0.67, 'recall': 0.82, 'f1': 0.70}
results.loc[len(results)] = xgb_2

results
```

Out[58]:

	experiment	model	accuracy	precision	recall	f1
0	1	log reg	0.83	0.67	0.83	0.7
1	1	xgb	0.83	0.67	0.82	0.7
2	2	log reg	0.82	0.67	0.86	0.7
3	2	xgb	0.83	0.67	0.82	0.7