FASE 1 – Comprensión del Negocio

Empresa Ficticia: ShopNow

ShopNow es una plataforma de e-commerce que opera en Guatemala, México, Colombia, Chile y Perú. Tiene más de 500,000 usuarios y maneja alrededor de 40,000 pedidos mensuales.

Problema de Negocio (churn)

La empresa ha experimentado una alta tasa de abandono de clientes durante los últimos 12 meses. Esto afecta directamente el ingreso porque los clientes que abandonan dejan de comprar, usar cupones y consumir productos premium.

Impacto económico estimado

- Valor promedio de un cliente activo: Q 420 anuales
- Abandono promedio mensual: 8%
- Clientes activos: 500,000

Pérdida anual estimada: 500,000 × 0.08 × Q420 × 12 ≈ Q201,600,000

Objetivo del proyecto

Construir un modelo de Machine Learning que prediga si un cliente abandonará la plataforma en los siguientes 30 días.

Stakeholders involucrados

Stakeholder	Necesidad
Equipo de Marketing	Campañas de retención, segmentación inteligente
Data Team	Pipeline reproducible y automatizado
Gerencia	Reducción del churn en un 15% trimestral
Equipo de Producto	Mejorar la experiencia del usuario basado en insights

Restricciones

- Tiempo máximo de desarrollo: 3 semanas
- Recursos computacionales limitados
- Modelo debe poder exponerse vía API
- El proyecto debe registrarse con MLflow

FASE 2 – Comprensión de los Datos (EDA)

In [11]:
```
import numpy as np
import pandas as pd
from datetime import datetime, timedelta

np.random.seed(42)

N = 10000

# ----------------------------
# 1. Datos básicos del cliente
# ----------------------------
customer_id = np.arange(1, N + 1)

age = np.random.randint(18, 70, N)
gender = np.random.choice(["M", "F"], N)
country = np.random.choice(
    ["Guatemala", "México", "Colombia", "Chile", "Perú"],
    N, p=[0.25, 0.25, 0.20, 0.15, 0.15]
)

# Fechas de registro entre 2019-2024
signup_date = pd.to_datetime(
    np.random.randint(
        datetime(2019, 1, 1).timestamp(),
        datetime(2024, 1, 1).timestamp(),
        N
    ),
    unit="s"
)

# -------------------------------
# 2. Comportamiento del usuario
# -------------------------------
last_login_days = np.random.exponential(scale=30, size=N).astype(int)

total_orders = np.random.poisson(lam=5, size=N)
avg_order_value = np.round(np.random.normal(50, 25, N).clip(5, 500), 2)

support_tickets = np.random.poisson(lam=0.3, size=N)
payment_issues = np.random.binomial(1, 0.1, size=N)
loyalty_points = np.random.randint(0, 5000, N)
```

```
# ------------------------------
# 3. Marketing & Engagement
# ------------------------------
email_open_rate = np.round(np.random.beta(2, 5, N), 3)
sms_click_rate = np.round(np.random.beta(1.5, 6, N), 3)
promotion_usage = np.round(np.random.beta(2, 3, N), 3)

# ------------------------------
# 4. Última compra (fecha realista)
# ------------------------------
last_purchase_date = signup_date + pd.to_timedelta(
    np.random.randint(0, 1800, N), unit="D"
)

days_since_last_purchase = (datetime.now() - last_purchase_date).days
days_since_last_purchase = np.clip(days_since_last_purchase, a_min=0, a_max=None)

# ------------------------------
# 5. Variable objetivo (churn)
#    Con reglas realistas
# ------------------------------
# Score con peso realista
score = (
    (days_since_last_purchase > 120) * 0.35 +
    (last_login_days > 60) * 0.30 +
    (total_orders == 0) * 0.20 +
    (payment_issues == 1) * 0.10 +
    (email_open_rate < 0.1) * 0.05
)

prob = np.clip(score, 0, 1)
churn = np.random.binomial(1, prob)

# Balanceamos a ~50%
churn = np.where(np.random.rand(N) < 0.5, churn, 0)

# ---------------------------
# Construir DataFrame final
# ---------------------------
df = pd.DataFrame({
    "customer_id": customer_id,
    "age": age,
    "gender": gender,
    "country": country,
    "signup_date": signup_date,
    "last_login_days": last_login_days,
    "total_orders": total_orders,
    "avg_order_value": avg_order_value,
    "support_tickets": support_tickets,
    "payment_issues": payment_issues,
    "loyalty_points": loyalty_points,
    "email_open_rate": email_open_rate,
    "sms_click_rate": sms_click_rate,
    "promotion_usage": promotion_usage,
    "last_purchase_date": last_purchase_date,
    "days_since_last_purchase": days_since_last_purchase,
```

```
    "churn": churn
})

df.head()
```

Out[11]:

	customer_id	age	gender	country	signup_date	last_login_days	total_orders	avg_or
0	1	56	M	Guatemala	2019-05-21 05:51:02	4	5	
1	2	69	F	México	2020-11-27 17:47:52	31	9	
2	3	46	F	Chile	2020-01-11 06:44:03	26	5	
3	4	32	F	México	2019-03-02 07:39:22	0	1	
4	5	60	M	México	2023-10-14 07:59:02	10	4	

2.1 Estructura del dataset

In [12]:
```
df.info()
df.describe(include="all")
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 17 columns):
 #   Column                    Non-Null Count  Dtype
---  ------                    --------------  -----
 0   customer_id               10000 non-null  int64
 1   age                       10000 non-null  int64
 2   gender                    10000 non-null  object
 3   country                   10000 non-null  object
 4   signup_date               10000 non-null  datetime64[ns]
 5   last_login_days           10000 non-null  int64
 6   total_orders              10000 non-null  int64
 7   avg_order_value           10000 non-null  float64
 8   support_tickets           10000 non-null  int64
 9   payment_issues            10000 non-null  int64
 10  loyalty_points            10000 non-null  int64
 11  email_open_rate           10000 non-null  float64
 12  sms_click_rate            10000 non-null  float64
 13  promotion_usage           10000 non-null  float64
 14  last_purchase_date        10000 non-null  datetime64[ns]
 15  days_since_last_purchase  10000 non-null  int64
 16  churn                     10000 non-null  int64
dtypes: datetime64[ns](2), float64(4), int64(9), object(2)
memory usage: 1.3+ MB
```

Out[12]:

	customer_id	age	gender	country	signup_date	last_login_days	
count	10000.00000	10000.000000	10000	10000	10000	10000.000000	1
unique	NaN	NaN	2	5	NaN	NaN	
top	NaN	NaN	F	México	NaN	NaN	
freq	NaN	NaN	5022	2490	NaN	NaN	
mean	5000.50000	43.539400	NaN	NaN	2021-07-06 02:59:16.616100096	29.292500	
min	1.00000	18.000000	NaN	NaN	2019-01-01 00:10:17	0.000000	
25%	2500.75000	31.000000	NaN	NaN	2020-04-10 07:22:26	8.000000	
50%	5000.50000	43.000000	NaN	NaN	2021-07-04 16:12:07	20.000000	
75%	7500.25000	56.000000	NaN	NaN	2022-10-04 11:46:38.249999872	40.000000	
max	10000.00000	69.000000	NaN	NaN	2023-12-31 23:19:43	276.000000	
std	2886.89568	14.911636	NaN	NaN	NaN	30.201224	

2.2 Distribución del Target

In [48]:
```
from sklearn.utils import resample

df_majority = df[df.churn == 0]
df_minority = df[df.churn == 1]

df_minority_up = resample(
    df_minority,
    replace=True,
    n_samples=len(df_majority),
    random_state=42
)

df_balanced = pd.concat([df_majority, df_minority_up])
df_balanced = df_balanced.sample(frac=1, random_state=42).reset_index(drop=True)
```

In [49]:
```
df_balanced["churn"].value_counts(normalize=True)
```

Out[49]:

churn	proportion
0	0.5
1	0.5

dtype: float64

In [38]:
```
import os

output_dir = "data"
if not os.path.exists(output_dir):
    os.makedirs(output_dir)

df.to_csv(os.path.join(output_dir, "dataset_churn_sintetico.csv"), index=False)
print(f"Dataset guardado en {output_dir}/")
```

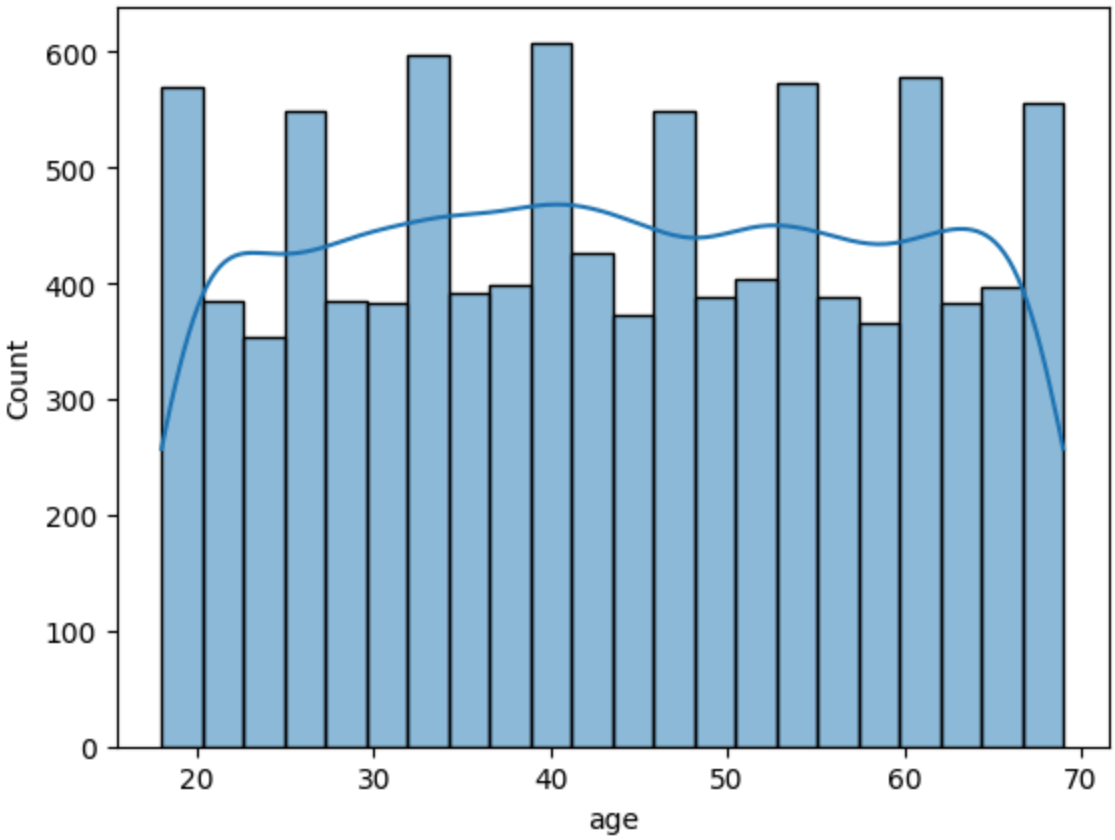
```
Dataset guardado en data/
```

2.3 Gráficos

Distribución de edad

In [39]:
```
import seaborn as sns
sns.histplot(df["age"], kde=True)
```

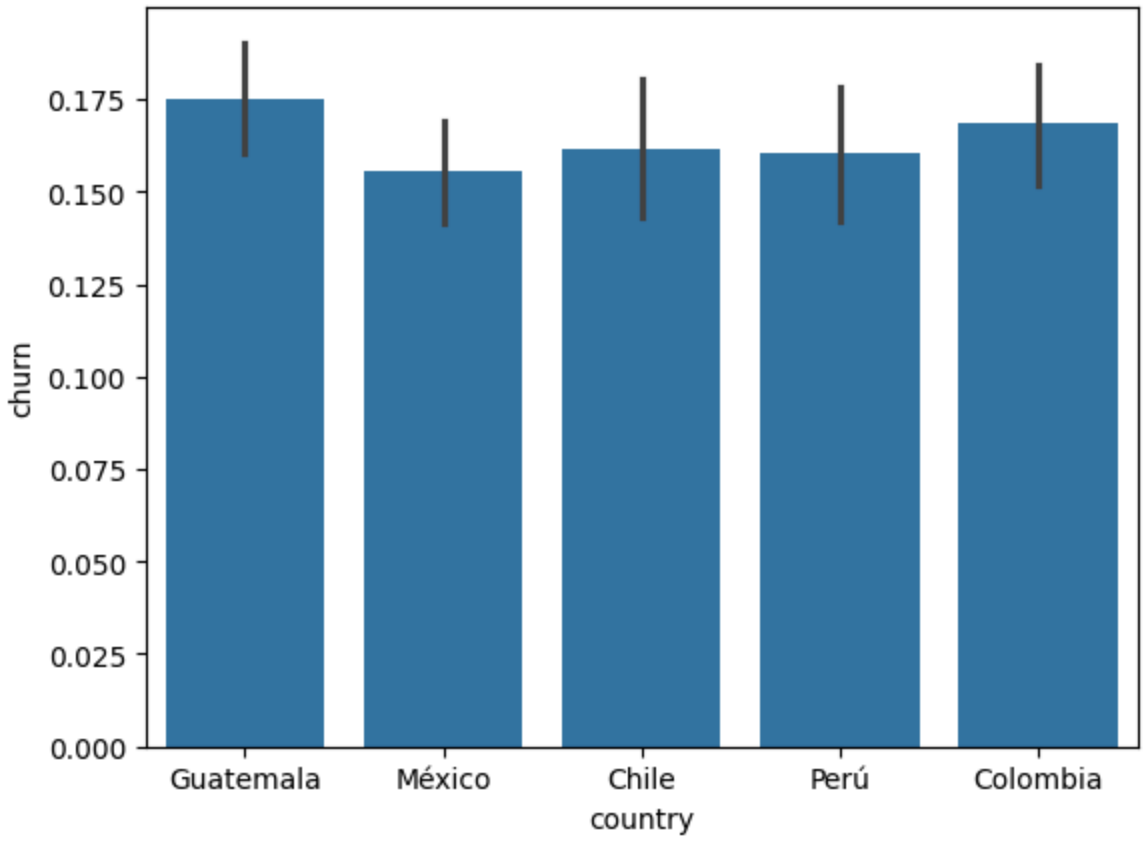
Out[39]:
```
<Axes: xlabel='age', ylabel='Count'>
```



Churn por país

In [40]:
```
sns.barplot(x="country", y="churn", data=df)
```

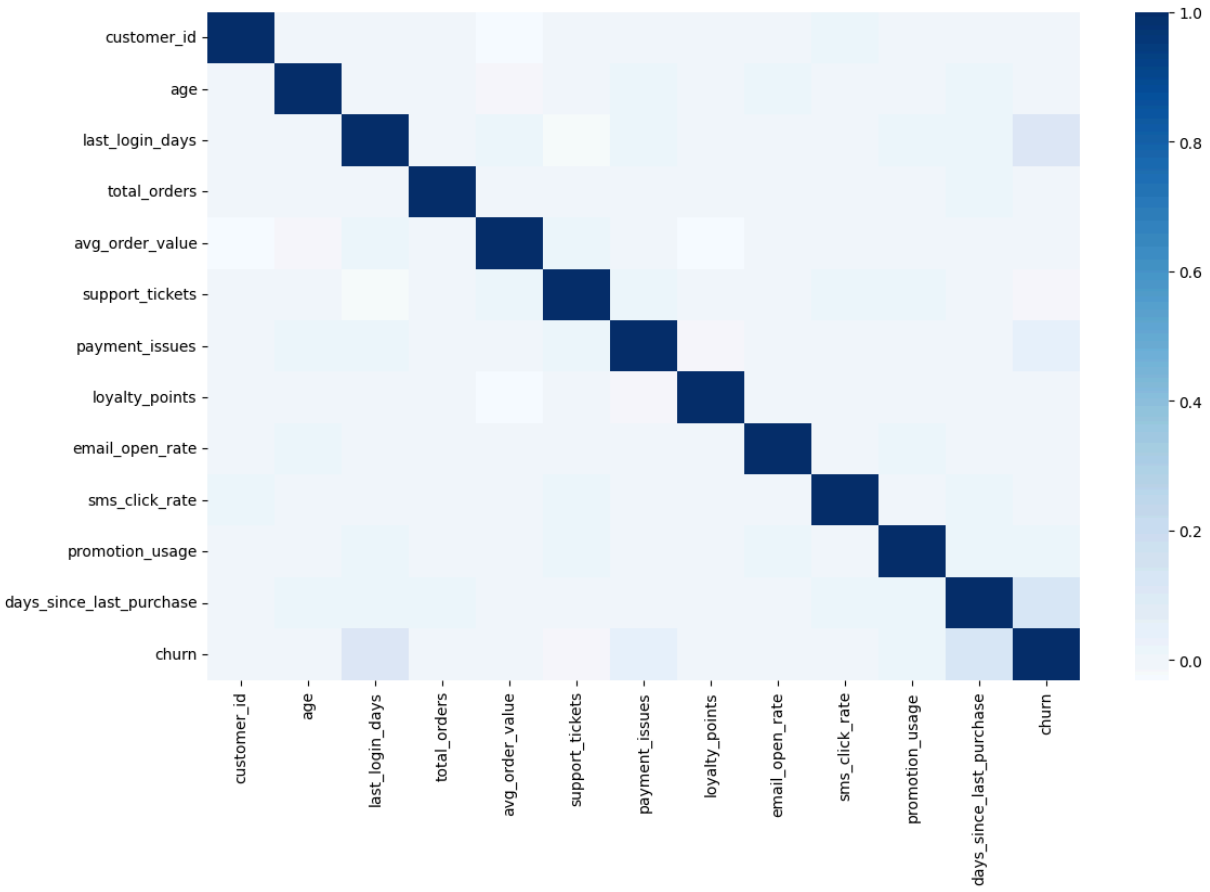
Out[40]:
```
<Axes: xlabel='country', ylabel='churn'>
```



Correlación

In [41]:
```
import matplotlib.pyplot as plt
import seaborn as sns

plt.figure(figsize=(13,8))
sns.heatmap(df.corr(numeric_only=True), annot=False, cmap="Blues")
```

Out[41]: <Axes: >



FASE 3 – Preparación de los Datos

In [42]:
```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline

def data_pipeline(df):

    df = df.copy()

    # Eliminar duplicados
    df.drop_duplicates(inplace=True)

    # Manejo de valores faltantes
    df.fillna({
        "email_open_rate": df["email_open_rate"].median(),
        "sms_click_rate": df["sms_click_rate"].median()
    }, inplace=True)

    # Feature Engineering
    df["orders_per_year"] = df["total_orders"] / ((2024 - pd.to_datetime(df["signup_d

    # Seleccionar variables
    X = df.drop(columns=["churn", "customer_id", "signup_date", "last_purchase_date"]
    y = df["churn"]
```

```
    # Columnas numéricas y categóricas
    numeric_features = X.select_dtypes(include=["int64", "float64"]).columns
    categorical_features = X.select_dtypes(include=["object"]).columns

    # Transformaciones
    preprocessor = ColumnTransformer(
        transformers=[
            ("num", StandardScaler(), numeric_features),
            ("cat", OneHotEncoder(handle_unknown="ignore"), categorical_features)
        ]
    )

    # División temporal (simulada)
    X_train, X_test, y_train, y_test = train_test_split(
        X, y, test_size=0.2, shuffle=False
    )

    return X_train, X_test, y_train, y_test, preprocessor
```

FASE 4 – MLflow + Modelado

4.1 Iniciar servidor MLflow

In [53]:
```
!pip install mlflow
!mlflow server --host 0.0.0.0 --port 5000
```

```
Requirement already satisfied: mlflow in /usr/local/lib/python3.12/dist-packages (3.6.
0)
Requirement already satisfied: mlflow-skinny==3.6.0 in /usr/local/lib/python3.12/dist-
packages (from mlflow) (3.6.0)
Requirement already satisfied: mlflow-tracing==3.6.0 in /usr/local/lib/python3.12/dist
-packages (from mlflow) (3.6.0)
Requirement already satisfied: Flask-CORS<7 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (6.0.1)
Requirement already satisfied: Flask<4 in /usr/local/lib/python3.12/dist-packages (fro
m mlflow) (3.1.2)
Requirement already satisfied: alembic!=1.10.0,<2 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow) (1.17.1)
Requirement already satisfied: cryptography<47,>=43.0.0 in /usr/local/lib/python3.12/d
ist-packages (from mlflow) (43.0.3)
Requirement already satisfied: docker<8,>=4.0.0 in /usr/local/lib/python3.12/dist-pack
ages (from mlflow) (7.1.0)
Requirement already satisfied: graphene<4 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (3.4.3)
Requirement already satisfied: gunicorn<24 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (23.0.0)
Requirement already satisfied: huey<3,>=2.5.0 in /usr/local/lib/python3.12/dist-packag
es (from mlflow) (2.5.4)
Requirement already satisfied: matplotlib<4 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (3.10.0)
Requirement already satisfied: numpy<3 in /usr/local/lib/python3.12/dist-packages (fro
m mlflow) (2.0.2)
Requirement already satisfied: pandas<3 in /usr/local/lib/python3.12/dist-packages (fr
om mlflow) (2.2.2)
Requirement already satisfied: pyarrow<23,>=4.0.0 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow) (18.1.0)
Requirement already satisfied: scikit-learn<2 in /usr/local/lib/python3.12/dist-packag
es (from mlflow) (1.6.1)
Requirement already satisfied: scipy<2 in /usr/local/lib/python3.12/dist-packages (fro
m mlflow) (1.16.3)
Requirement already satisfied: sqlalchemy<3,>=1.4.0 in /usr/local/lib/python3.12/dist-
packages (from mlflow) (2.0.44)
Requirement already satisfied: cachetools<7,>=5.0.0 in /usr/local/lib/python3.12/dist-
packages (from mlflow-skinny==3.6.0->mlflow) (5.5.2)
Requirement already satisfied: click<9,>=7.0 in /usr/local/lib/python3.12/dist-package
s (from mlflow-skinny==3.6.0->mlflow) (8.3.0)
Requirement already satisfied: cloudpickle<4 in /usr/local/lib/python3.12/dist-package
s (from mlflow-skinny==3.6.0->mlflow) (3.1.2)
Requirement already satisfied: databricks-sdk<1,>=0.20.0 in /usr/local/lib/python3.12/
dist-packages (from mlflow-skinny==3.6.0->mlflow) (0.73.0)
Requirement already satisfied: fastapi<1 in /usr/local/lib/python3.12/dist-packages (f
rom mlflow-skinny==3.6.0->mlflow) (0.121.1)
Requirement already satisfied: gitpython<4,>=3.1.9 in /usr/local/lib/python3.12/dist-p
ackages (from mlflow-skinny==3.6.0->mlflow) (3.1.45)
Requirement already satisfied: importlib_metadata!=4.7.0,<9,>=3.7.0 in /usr/local/lib/
python3.12/dist-packages (from mlflow-skinny==3.6.0->mlflow) (8.7.0)
Requirement already satisfied: opentelemetry-api<3,>=1.9.0 in /usr/local/lib/python3.1
2/dist-packages (from mlflow-skinny==3.6.0->mlflow) (1.37.0)
Requirement already satisfied: opentelemetry-proto<3,>=1.9.0 in /usr/local/lib/python
3.12/dist-packages (from mlflow-skinny==3.6.0->mlflow) (1.37.0)
Requirement already satisfied: opentelemetry-sdk<3,>=1.9.0 in /usr/local/lib/python3.1
2/dist-packages (from mlflow-skinny==3.6.0->mlflow) (1.37.0)
```

```
Requirement already satisfied: packaging<26 in /usr/local/lib/python3.12/dist-packages
(from mlflow-skinny==3.6.0->mlflow) (25.0)
Requirement already satisfied: protobuf<7,>=3.12.0 in /usr/local/lib/python3.12/dist-p
ackages (from mlflow-skinny==3.6.0->mlflow) (5.29.5)
Requirement already satisfied: pydantic<3,>=2.0.0 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow-skinny==3.6.0->mlflow) (2.11.10)
Requirement already satisfied: python-dotenv<2,>=0.19.0 in /usr/local/lib/python3.12/d
ist-packages (from mlflow-skinny==3.6.0->mlflow) (1.2.1)
Requirement already satisfied: pyyaml<7,>=5.1 in /usr/local/lib/python3.12/dist-packag
es (from mlflow-skinny==3.6.0->mlflow) (6.0.3)
Requirement already satisfied: requests<3,>=2.17.3 in /usr/local/lib/python3.12/dist-p
ackages (from mlflow-skinny==3.6.0->mlflow) (2.32.4)
Requirement already satisfied: sqlparse<1,>=0.4.0 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow-skinny==3.6.0->mlflow) (0.5.3)
Requirement already satisfied: typing-extensions<5,>=4.0.0 in /usr/local/lib/python3.1
2/dist-packages (from mlflow-skinny==3.6.0->mlflow) (4.15.0)
Requirement already satisfied: uvicorn<1 in /usr/local/lib/python3.12/dist-packages (f
rom mlflow-skinny==3.6.0->mlflow) (0.38.0)
Requirement already satisfied: Mako in /usr/local/lib/python3.12/dist-packages (from a
lembic!=1.10.0,<2->mlflow) (1.3.10)
Requirement already satisfied: cffi>=1.12 in /usr/local/lib/python3.12/dist-packages
(from cryptography<47,>=43.0.0->mlflow) (2.0.0)
Requirement already satisfied: urllib3>=1.26.0 in /usr/local/lib/python3.12/dist-packa
ges (from docker<8,>=4.0.0->mlflow) (2.5.0)
Requirement already satisfied: blinker>=1.9.0 in /usr/local/lib/python3.12/dist-packag
es (from Flask<4->mlflow) (1.9.0)
Requirement already satisfied: itsdangerous>=2.2.0 in /usr/local/lib/python3.12/dist-p
ackages (from Flask<4->mlflow) (2.2.0)
Requirement already satisfied: jinja2>=3.1.2 in /usr/local/lib/python3.12/dist-package
s (from Flask<4->mlflow) (3.1.6)
Requirement already satisfied: markupsafe>=2.1.1 in /usr/local/lib/python3.12/dist-pac
kages (from Flask<4->mlflow) (3.0.3)
Requirement already satisfied: werkzeug>=3.1.0 in /usr/local/lib/python3.12/dist-packa
ges (from Flask<4->mlflow) (3.1.3)
Requirement already satisfied: graphql-core<3.3,>=3.1 in /usr/local/lib/python3.12/dis
t-packages (from graphene<4->mlflow) (3.2.7)
Requirement already satisfied: graphql-relay<3.3,>=3.1 in /usr/local/lib/python3.12/di
st-packages (from graphene<4->mlflow) (3.2.0)
Requirement already satisfied: python-dateutil<3,>=2.7.0 in /usr/local/lib/python3.12/
dist-packages (from graphene<4->mlflow) (2.9.0.post0)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.12/dist-pack
ages (from matplotlib<4->mlflow) (1.3.3)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.12/dist-packages
(from matplotlib<4->mlflow) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.12/dist-pac
kages (from matplotlib<4->mlflow) (4.60.1)
Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.12/dist-pac
kages (from matplotlib<4->mlflow) (1.4.9)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.12/dist-packages (f
rom matplotlib<4->mlflow) (11.3.0)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.12/dist-pack
ages (from matplotlib<4->mlflow) (3.2.5)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.12/dist-packages
(from pandas<3->mlflow) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.12/dist-packag
es (from pandas<3->mlflow) (2025.2)
```

```
Requirement already satisfied: joblib>=1.2.0 in /usr/local/lib/python3.12/dist-package
s (from scikit-learn<2->mlflow) (1.5.2)
Requirement already satisfied: threadpoolctl>=3.1.0 in /usr/local/lib/python3.12/dist-
packages (from scikit-learn<2->mlflow) (3.6.0)
Requirement already satisfied: greenlet>=1 in /usr/local/lib/python3.12/dist-packages
(from sqlalchemy<3,>=1.4.0->mlflow) (3.2.4)
Requirement already satisfied: pycparser in /usr/local/lib/python3.12/dist-packages (f
rom cffi>=1.12->cryptography<47,>=43.0.0->mlflow) (2.23)
Requirement already satisfied: google-auth~=2.0 in /usr/local/lib/python3.12/dist-pack
ages (from databricks-sdk<1,>=0.20.0->mlflow-skinny==3.6.0->mlflow) (2.38.0)
Requirement already satisfied: starlette<0.50.0,>=0.40.0 in /usr/local/lib/python3.12/
dist-packages (from fastapi<1->mlflow-skinny==3.6.0->mlflow) (0.49.3)
Requirement already satisfied: annotated-doc>=0.0.2 in /usr/local/lib/python3.12/dist-
packages (from fastapi<1->mlflow-skinny==3.6.0->mlflow) (0.0.4)
Requirement already satisfied: gitdb<5,>=4.0.1 in /usr/local/lib/python3.12/dist-packa
ges (from gitpython<4,>=3.1.9->mlflow-skinny==3.6.0->mlflow) (4.0.12)
Requirement already satisfied: zipp>=3.20 in /usr/local/lib/python3.12/dist-packages
(from importlib_metadata!=4.7.0,<9,>=3.7.0->mlflow-skinny==3.6.0->mlflow) (3.23.0)
Requirement already satisfied: opentelemetry-semantic-conventions==0.58b0 in /usr/loca
l/lib/python3.12/dist-packages (from opentelemetry-sdk<3,>=1.9.0->mlflow-skinny==3.6.0
->mlflow) (0.58b0)
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python3.12/dis
t-packages (from pydantic<3,>=2.0.0->mlflow-skinny==3.6.0->mlflow) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.2 in /usr/local/lib/python3.12/dist
-packages (from pydantic<3,>=2.0.0->mlflow-skinny==3.6.0->mlflow) (2.33.2)
Requirement already satisfied: typing-inspection>=0.4.0 in /usr/local/lib/python3.12/d
ist-packages (from pydantic<3,>=2.0.0->mlflow-skinny==3.6.0->mlflow) (0.4.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.12/dist-packages (fr
om python-dateutil<3,>=2.7.0->graphene<4->mlflow) (1.17.0)
Requirement already satisfied: charset_normalizer<4,>=2 in /usr/local/lib/python3.12/d
ist-packages (from requests<3,>=2.17.3->mlflow-skinny==3.6.0->mlflow) (3.4.4)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.12/dist-packages
(from requests<3,>=2.17.3->mlflow-skinny==3.6.0->mlflow) (3.11)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.12/dist-pa
ckages (from requests<3,>=2.17.3->mlflow-skinny==3.6.0->mlflow) (2025.10.5)
Requirement already satisfied: h11>=0.8 in /usr/local/lib/python3.12/dist-packages (fr
om uvicorn<1->mlflow-skinny==3.6.0->mlflow) (0.16.0)
Requirement already satisfied: smmap<6,>=3.0.1 in /usr/local/lib/python3.12/dist-packa
ges (from gitdb<5,>=4.0.1->gitpython<4,>=3.1.9->mlflow-skinny==3.6.0->mlflow) (5.0.2)
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python3.12/dist
-packages (from google-auth~=2.0->databricks-sdk<1,>=0.20.0->mlflow-skinny==3.6.0->mlf
low) (0.4.2)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.12/dist-package
s (from google-auth~=2.0->databricks-sdk<1,>=0.20.0->mlflow-skinny==3.6.0->mlflow) (4.
9.1)
Requirement already satisfied: anyio<5,>=3.6.2 in /usr/local/lib/python3.12/dist-packa
ges (from starlette<0.50.0,>=0.40.0->fastapi<1->mlflow-skinny==3.6.0->mlflow) (4.11.0)
Requirement already satisfied: sniffio>=1.1 in /usr/local/lib/python3.12/dist-packages
(from anyio<5,>=3.6.2->starlette<0.50.0,>=0.40.0->fastapi<1->mlflow-skinny==3.6.0->mlf
low) (1.3.1)
Requirement already satisfied: pyasn1<0.7.0,>=0.6.1 in /usr/local/lib/python3.12/dist-
packages (from pyasn1-modules>=0.2.1->google-auth~=2.0->databricks-sdk<1,>=0.20.0->mlf
low-skinny==3.6.0->mlflow) (0.6.1)
/usr/local/lib/python3.12/dist-packages/mlflow/server/handlers.py:256: FutureWarning:
Filesystem tracking backend (e.g., './mlruns') is deprecated. Please switch to a datab
ase backend (e.g., 'sqlite:///mlflow.db'). For feedback, see: https://github.com/mlflo
```

```
w/mlflow/issues/18534
  return FileStore(store_uri, artifact_uri)
/usr/local/lib/python3.12/dist-packages/mlflow/server/handlers.py:285: FutureWarning:
Filesystem model registry backend (e.g., './mlruns') is deprecated. Please switch to a
database backend (e.g., 'sqlite:///mlflow.db'). For feedback, see: https://github.com/
mlflow/mlflow/issues/18534
  return FileStore(store_uri)
[MLflow] Security middleware enabled with default settings (localhost-only). To allow
connections from other hosts, use --host 0.0.0.0 and configure --allowed-hosts and --c
ors-allowed-origins.
ERROR:    [Errno 98] Address already in use
```

In [54]:
```
!pip install mlflow pyngrok

from pyngrok import ngrok

ngrok.set_auth_token("35V8MAVVVJMveDjf5Y1YlMge7he_6wdF3Yvqseha4yx1kf3e")
```

```
Requirement already satisfied: mlflow in /usr/local/lib/python3.12/dist-packages (3.6.
0)
Requirement already satisfied: pyngrok in /usr/local/lib/python3.12/dist-packages (7.
4.1)
Requirement already satisfied: mlflow-skinny==3.6.0 in /usr/local/lib/python3.12/dist-
packages (from mlflow) (3.6.0)
Requirement already satisfied: mlflow-tracing==3.6.0 in /usr/local/lib/python3.12/dist
-packages (from mlflow) (3.6.0)
Requirement already satisfied: Flask-CORS<7 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (6.0.1)
Requirement already satisfied: Flask<4 in /usr/local/lib/python3.12/dist-packages (fro
m mlflow) (3.1.2)
Requirement already satisfied: alembic!=1.10.0,<2 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow) (1.17.1)
Requirement already satisfied: cryptography<47,>=43.0.0 in /usr/local/lib/python3.12/d
ist-packages (from mlflow) (43.0.3)
Requirement already satisfied: docker<8,>=4.0.0 in /usr/local/lib/python3.12/dist-pack
ages (from mlflow) (7.1.0)
Requirement already satisfied: graphene<4 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (3.4.3)
Requirement already satisfied: gunicorn<24 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (23.0.0)
Requirement already satisfied: huey<3,>=2.5.0 in /usr/local/lib/python3.12/dist-packag
es (from mlflow) (2.5.4)
Requirement already satisfied: matplotlib<4 in /usr/local/lib/python3.12/dist-packages
(from mlflow) (3.10.0)
Requirement already satisfied: numpy<3 in /usr/local/lib/python3.12/dist-packages (fro
m mlflow) (2.0.2)
Requirement already satisfied: pandas<3 in /usr/local/lib/python3.12/dist-packages (fr
om mlflow) (2.2.2)
Requirement already satisfied: pyarrow<23,>=4.0.0 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow) (18.1.0)
Requirement already satisfied: scikit-learn<2 in /usr/local/lib/python3.12/dist-packag
es (from mlflow) (1.6.1)
Requirement already satisfied: scipy<2 in /usr/local/lib/python3.12/dist-packages (fro
m mlflow) (1.16.3)
Requirement already satisfied: sqlalchemy<3,>=1.4.0 in /usr/local/lib/python3.12/dist-
packages (from mlflow) (2.0.44)
Requirement already satisfied: cachetools<7,>=5.0.0 in /usr/local/lib/python3.12/dist-
packages (from mlflow-skinny==3.6.0->mlflow) (5.5.2)
Requirement already satisfied: click<9,>=7.0 in /usr/local/lib/python3.12/dist-package
s (from mlflow-skinny==3.6.0->mlflow) (8.3.0)
Requirement already satisfied: cloudpickle<4 in /usr/local/lib/python3.12/dist-package
s (from mlflow-skinny==3.6.0->mlflow) (3.1.2)
Requirement already satisfied: databricks-sdk<1,>=0.20.0 in /usr/local/lib/python3.12/
dist-packages (from mlflow-skinny==3.6.0->mlflow) (0.73.0)
Requirement already satisfied: fastapi<1 in /usr/local/lib/python3.12/dist-packages (f
rom mlflow-skinny==3.6.0->mlflow) (0.121.1)
Requirement already satisfied: gitpython<4,>=3.1.9 in /usr/local/lib/python3.12/dist-p
ackages (from mlflow-skinny==3.6.0->mlflow) (3.1.45)
Requirement already satisfied: importlib_metadata!=4.7.0,<9,>=3.7.0 in /usr/local/lib/
python3.12/dist-packages (from mlflow-skinny==3.6.0->mlflow) (8.7.0)
Requirement already satisfied: opentelemetry-api<3,>=1.9.0 in /usr/local/lib/python3.1
2/dist-packages (from mlflow-skinny==3.6.0->mlflow) (1.37.0)
Requirement already satisfied: opentelemetry-proto<3,>=1.9.0 in /usr/local/lib/python
3.12/dist-packages (from mlflow-skinny==3.6.0->mlflow) (1.37.0)
```

```
Requirement already satisfied: opentelemetry-sdk<3,>=1.9.0 in /usr/local/lib/python3.1
2/dist-packages (from mlflow-skinny==3.6.0->mlflow) (1.37.0)
Requirement already satisfied: packaging<26 in /usr/local/lib/python3.12/dist-packages
(from mlflow-skinny==3.6.0->mlflow) (25.0)
Requirement already satisfied: protobuf<7,>=3.12.0 in /usr/local/lib/python3.12/dist-p
ackages (from mlflow-skinny==3.6.0->mlflow) (5.29.5)
Requirement already satisfied: pydantic<3,>=2.0.0 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow-skinny==3.6.0->mlflow) (2.11.10)
Requirement already satisfied: python-dotenv<2,>=0.19.0 in /usr/local/lib/python3.12/d
ist-packages (from mlflow-skinny==3.6.0->mlflow) (1.2.1)
Requirement already satisfied: pyyaml<7,>=5.1 in /usr/local/lib/python3.12/dist-packag
es (from mlflow-skinny==3.6.0->mlflow) (6.0.3)
Requirement already satisfied: requests<3,>=2.17.3 in /usr/local/lib/python3.12/dist-p
ackages (from mlflow-skinny==3.6.0->mlflow) (2.32.4)
Requirement already satisfied: sqlparse<1,>=0.4.0 in /usr/local/lib/python3.12/dist-pa
ckages (from mlflow-skinny==3.6.0->mlflow) (0.5.3)
Requirement already satisfied: typing-extensions<5,>=4.0.0 in /usr/local/lib/python3.1
2/dist-packages (from mlflow-skinny==3.6.0->mlflow) (4.15.0)
Requirement already satisfied: uvicorn<1 in /usr/local/lib/python3.12/dist-packages (f
rom mlflow-skinny==3.6.0->mlflow) (0.38.0)
Requirement already satisfied: Mako in /usr/local/lib/python3.12/dist-packages (from a
lembic!=1.10.0,<2->mlflow) (1.3.10)
Requirement already satisfied: cffi>=1.12 in /usr/local/lib/python3.12/dist-packages
(from cryptography<47,>=43.0.0->mlflow) (2.0.0)
Requirement already satisfied: urllib3>=1.26.0 in /usr/local/lib/python3.12/dist-packa
ges (from docker<8,>=4.0.0->mlflow) (2.5.0)
Requirement already satisfied: blinker>=1.9.0 in /usr/local/lib/python3.12/dist-packag
es (from Flask<4->mlflow) (1.9.0)
Requirement already satisfied: itsdangerous>=2.2.0 in /usr/local/lib/python3.12/dist-p
ackages (from Flask<4->mlflow) (2.2.0)
Requirement already satisfied: jinja2>=3.1.2 in /usr/local/lib/python3.12/dist-package
s (from Flask<4->mlflow) (3.1.6)
Requirement already satisfied: markupsafe>=2.1.1 in /usr/local/lib/python3.12/dist-pac
kages (from Flask<4->mlflow) (3.0.3)
Requirement already satisfied: werkzeug>=3.1.0 in /usr/local/lib/python3.12/dist-packa
ges (from Flask<4->mlflow) (3.1.3)
Requirement already satisfied: graphql-core<3.3,>=3.1 in /usr/local/lib/python3.12/dis
t-packages (from graphene<4->mlflow) (3.2.7)
Requirement already satisfied: graphql-relay<3.3,>=3.1 in /usr/local/lib/python3.12/di
st-packages (from graphene<4->mlflow) (3.2.0)
Requirement already satisfied: python-dateutil<3,>=2.7.0 in /usr/local/lib/python3.12/
dist-packages (from graphene<4->mlflow) (2.9.0.post0)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.12/dist-pack
ages (from matplotlib<4->mlflow) (1.3.3)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.12/dist-packages
(from matplotlib<4->mlflow) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.12/dist-pac
kages (from matplotlib<4->mlflow) (4.60.1)
Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.12/dist-pac
kages (from matplotlib<4->mlflow) (1.4.9)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.12/dist-packages (f
rom matplotlib<4->mlflow) (11.3.0)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.12/dist-pack
ages (from matplotlib<4->mlflow) (3.2.5)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.12/dist-packages
(from pandas<3->mlflow) (2025.2)
```

```
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.12/dist-packag
es (from pandas<3->mlflow) (2025.2)
Requirement already satisfied: joblib>=1.2.0 in /usr/local/lib/python3.12/dist-package
s (from scikit-learn<2->mlflow) (1.5.2)
Requirement already satisfied: threadpoolctl>=3.1.0 in /usr/local/lib/python3.12/dist-
packages (from scikit-learn<2->mlflow) (3.6.0)
Requirement already satisfied: greenlet>=1 in /usr/local/lib/python3.12/dist-packages
(from sqlalchemy<3,>=1.4.0->mlflow) (3.2.4)
Requirement already satisfied: pycparser in /usr/local/lib/python3.12/dist-packages (f
rom cffi>=1.12->cryptography<47,>=43.0.0->mlflow) (2.23)
Requirement already satisfied: google-auth~=2.0 in /usr/local/lib/python3.12/dist-pack
ages (from databricks-sdk<1,>=0.20.0->mlflow-skinny==3.6.0->mlflow) (2.38.0)
Requirement already satisfied: starlette<0.50.0,>=0.40.0 in /usr/local/lib/python3.12/
dist-packages (from fastapi<1->mlflow-skinny==3.6.0->mlflow) (0.49.3)
Requirement already satisfied: annotated-doc>=0.0.2 in /usr/local/lib/python3.12/dist-
packages (from fastapi<1->mlflow-skinny==3.6.0->mlflow) (0.0.4)
Requirement already satisfied: gitdb<5,>=4.0.1 in /usr/local/lib/python3.12/dist-packa
ges (from gitpython<4,>=3.1.9->mlflow-skinny==3.6.0->mlflow) (4.0.12)
Requirement already satisfied: zipp>=3.20 in /usr/local/lib/python3.12/dist-packages
(from importlib_metadata!=4.7.0,<9,>=3.7.0->mlflow-skinny==3.6.0->mlflow) (3.23.0)
Requirement already satisfied: opentelemetry-semantic-conventions==0.58b0 in /usr/loca
l/lib/python3.12/dist-packages (from opentelemetry-sdk<3,>=1.9.0->mlflow-skinny==3.6.0
->mlflow) (0.58b0)
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python3.12/dis
t-packages (from pydantic<3,>=2.0.0->mlflow-skinny==3.6.0->mlflow) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.2 in /usr/local/lib/python3.12/dist
-packages (from pydantic<3,>=2.0.0->mlflow-skinny==3.6.0->mlflow) (2.33.2)
Requirement already satisfied: typing-inspection>=0.4.0 in /usr/local/lib/python3.12/d
ist-packages (from pydantic<3,>=2.0.0->mlflow-skinny==3.6.0->mlflow) (0.4.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.12/dist-packages (fr
om python-dateutil<3,>=2.7.0->graphene<4->mlflow) (1.17.0)
Requirement already satisfied: charset_normalizer<4,>=2 in /usr/local/lib/python3.12/d
ist-packages (from requests<3,>=2.17.3->mlflow-skinny==3.6.0->mlflow) (3.4.4)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.12/dist-packages
(from requests<3,>=2.17.3->mlflow-skinny==3.6.0->mlflow) (3.11)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.12/dist-pa
ckages (from requests<3,>=2.17.3->mlflow-skinny==3.6.0->mlflow) (2025.10.5)
Requirement already satisfied: h11>=0.8 in /usr/local/lib/python3.12/dist-packages (fr
om uvicorn<1->mlflow-skinny==3.6.0->mlflow) (0.16.0)
Requirement already satisfied: smmap<6,>=3.0.1 in /usr/local/lib/python3.12/dist-packa
ges (from gitdb<5,>=4.0.1->gitpython<4,>=3.1.9->mlflow-skinny==3.6.0->mlflow) (5.0.2)
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python3.12/dist
-packages (from google-auth~=2.0->databricks-sdk<1,>=0.20.0->mlflow-skinny==3.6.0->mlf
low) (0.4.2)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.12/dist-package
s (from google-auth~=2.0->databricks-sdk<1,>=0.20.0->mlflow-skinny==3.6.0->mlflow) (4.
9.1)
Requirement already satisfied: anyio<5,>=3.6.2 in /usr/local/lib/python3.12/dist-packa
ges (from starlette<0.50.0,>=0.40.0->fastapi<1->mlflow-skinny==3.6.0->mlflow) (4.11.0)
Requirement already satisfied: sniffio>=1.1 in /usr/local/lib/python3.12/dist-packages
(from anyio<5,>=3.6.2->starlette<0.50.0,>=0.40.0->fastapi<1->mlflow-skinny==3.6.0->mlf
low) (1.3.1)
Requirement already satisfied: pyasn1<0.7.0,>=0.6.1 in /usr/local/lib/python3.12/dist-
packages (from pyasn1-modules>=0.2.1->google-auth~=2.0->databricks-sdk<1,>=0.20.0->mlf
low-skinny==3.6.0->mlflow) (0.6.1)
```

In [55]:
```
# iniciar servidor MLflow
get_ipython().system_raw("mlflow server --host 0.0.0.0 --port 5000 &")

# abrir túnel
public_url = ngrok.connect(5000)
public_url
```

Out[55]:
```
<NgrokTunnel: "https://overglaze-couthily-lily.ngrok-free.dev" -> "http://localhost:
5000">
```

4.2 Entrenamiento con MLflow

In [56]:
```
import mlflow
import mlflow.sklearn
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from lightgbm import LGBMClassifier

def train_and_log(model, model_name, X_train, y_train, X_test, y_test, preprocessor):

    from sklearn.pipeline import Pipeline
    from sklearn.metrics import f1_score, accuracy_score, roc_auc_score

    pipe = Pipeline([
        ("prep", preprocessor),
        ("model", model)
    ])

    mlflow.set_experiment("proyecto-final")

    with mlflow.start_run():

        pipe.fit(X_train, y_train)
        preds = pipe.predict(X_test)
        proba = pipe.predict_proba(X_test)[:,1]

        mlflow.log_param("model", model_name)
        mlflow.log_metric("accuracy", accuracy_score(y_test, preds))
        mlflow.log_metric("f1", f1_score(y_test, preds))
        mlflow.log_metric("auc", roc_auc_score(y_test, proba))

        mlflow.sklearn.log_model(pipe, model_name)

# Execute the data pipeline and train a model to make variables available
X_train, X_test, y_train, y_test, preprocessor = data_pipeline(df)

# Example: Train a RandomForestClassifier and get predictions
model_rf = RandomForestClassifier(random_state=42)
model_name_rf = "RandomForest"

# Create a pipeline and train it to get preds and proba for ConfusionMatrixDisplay ar
from sklearn.pipeline import Pipeline
pipe_rf = Pipeline([
```

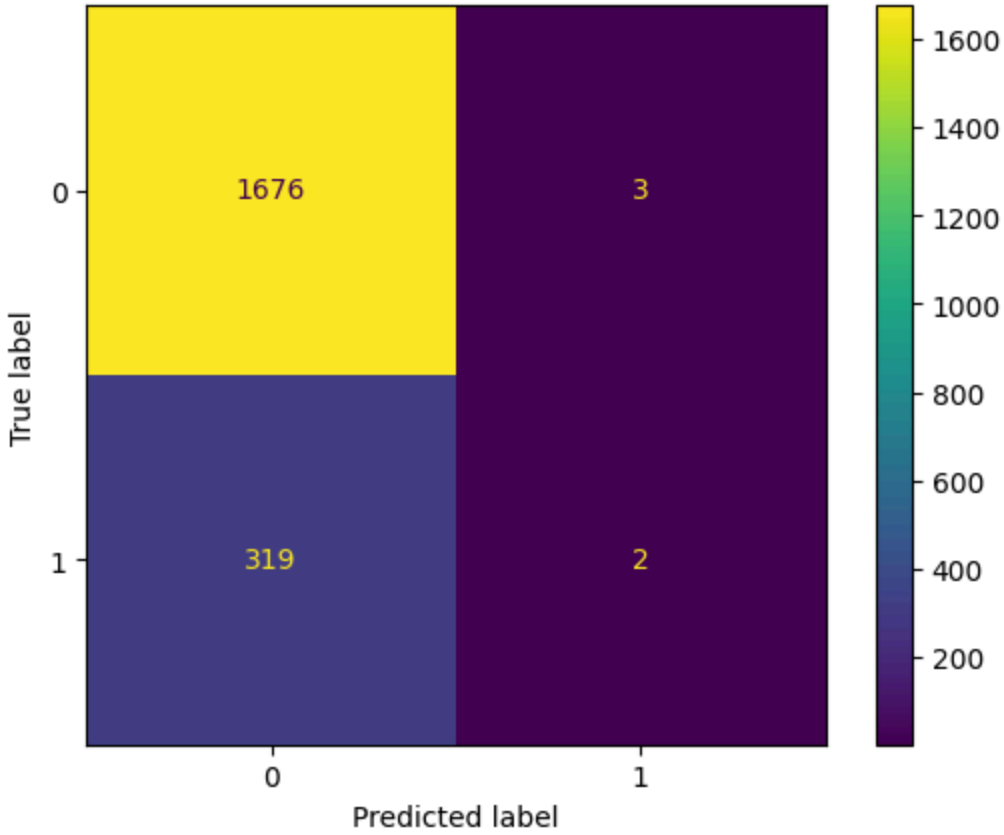
```
    ("prep", preprocessor),
    ("model", model_rf)
])

pipe_rf.fit(X_train, y_train)
preds = pipe_rf.predict(X_test)
proba = pipe_rf.predict_proba(X_test)[:,1] # Make proba globally available

# Call train_and_log for MLflow tracking (optional, but good practice)
train_and_log(model_rf, model_name_rf, X_train, y_train, X_test, y_test, preprocessor
```

```
2025/11/15 05:38:35 WARNING mlflow.models.model: `artifact_path` is deprecated. Please
use `name` instead.
2025/11/15 05:38:51 WARNING mlflow.models.model: Model logged without a signature and
input example. Please set `input_example` parameter when logging the model to auto inf
er the model signature.
```

FASE 5 – Evaluación del Modelo

Matriz de Confusión

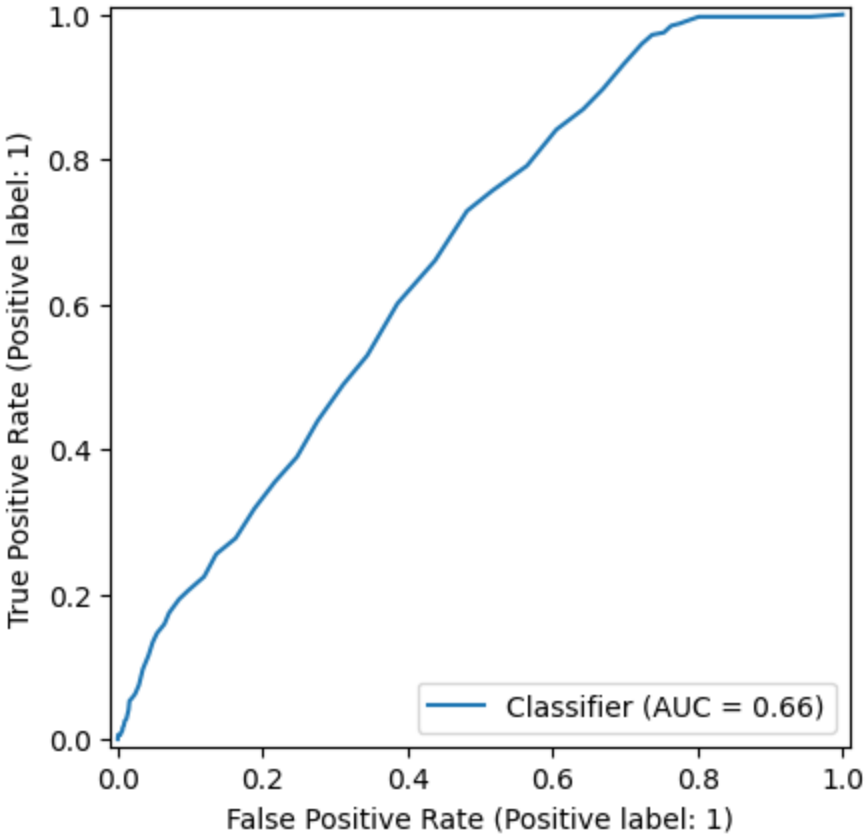
In [32]:
```
from sklearn.metrics import ConfusionMatrixDisplay
import matplotlib.pyplot as plt

# y_test and preds are now available from the previous cell

# Matriz de confusión
disp = ConfusionMatrixDisplay.from_predictions(y_test, preds)
plt.show()
```



Curva ROC

In [45]:
```
from sklearn.metrics import RocCurveDisplay
RocCurveDisplay.from_predictions(y_test, proba)
```

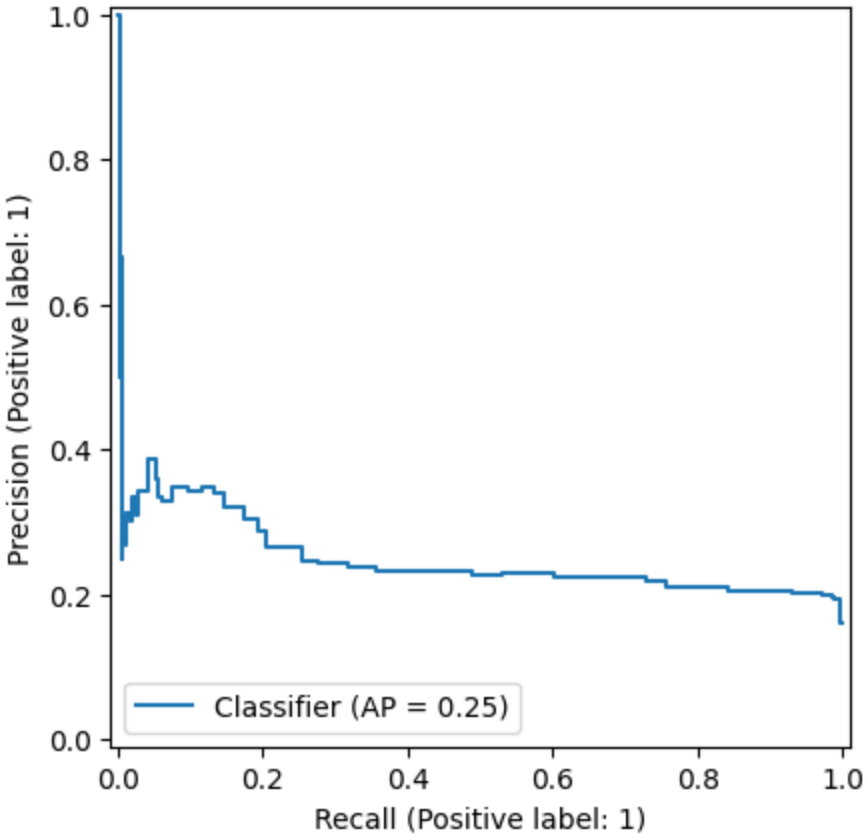
Out[45]:
```
<sklearn.metrics._plot.roc_curve.RocCurveDisplay at 0x7ac3d6d373b0>
```



Precision-Recall

In [46]:
```
from sklearn.metrics import PrecisionRecallDisplay
PrecisionRecallDisplay.from_predictions(y_test, proba)
```

Out[46]:
```
<sklearn.metrics._plot.precision_recall_curve.PrecisionRecallDisplay at 0x7ac3d51578
c0>
```



Feature Importance

In [47]:
```
display(pipe_rf['model'].feature_importances_)
```

```
array([0.08054367, 0.09989498, 0.04579272, 0.09244087, 0.01642624,
       0.00887444, 0.09727504, 0.09646846, 0.09567762, 0.09950319,
       0.13053074, 0.06437287, 0.01126817, 0.0107283 , 0.00908167,
       0.01161067, 0.010715  , 0.00975953, 0.00903582])
```