How to build a data pipeline without data

> *Synthetic data generation and testing with Python*

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About me

Hi there, I'm Ruan Pretorius 👋

- ☕ I turn coffee into data pipelines and AI
- 💻 I am a data scientist at *melio.ai*
  - We help you build and deploy your data intensive apps to unlock value from your data, follow us on LinkedIn
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🚏 Outline

- What are data pipelines and why do we need them?
- Challenges of building and testing data pipelines
- How to use synthetic data to test data pipelines
- Tools and methods to use when generating reliable synthetic data in Python
- Benefits and challenges of using synthetic data for testing data pipelines

🛠️ What is a data pipeline?

- A data pipeline is a series of operations used to extract, load, transform, validate, or write data
- From various sources into a target file system, database, or data warehouse

🔍 Data pipelines without real data

- Sometimes, we may not have access to the real data that we want to process in our data pipeline.
- It could be:
  - Sensitive or confidential and can't be shared
  - Not yet collected or available
  - Too large or complex to handle for initial testing

🔍 Data pipelines without real data

- Without real data, it is challenging to:
    - Design and build downstream apps that consume the data
    - Develop the data extract, transform, and load (ETL) logic
    - Test the functionality and performance of the data pipeline

🧪 Synthetic data to test data pipelines

- Synthetic data is artificially generated data that mimics the characteristics and behavior of real data
- Synthetic data can help us to test our data pipelines by:
  - Providing realistic sample data
  - Allowing control of the size, shape, and distribution of the data
  - Enabling simulations of different scenarios and edge cases
  - Reducing the risk of exposing sensitive or confidential information

💃 Demo

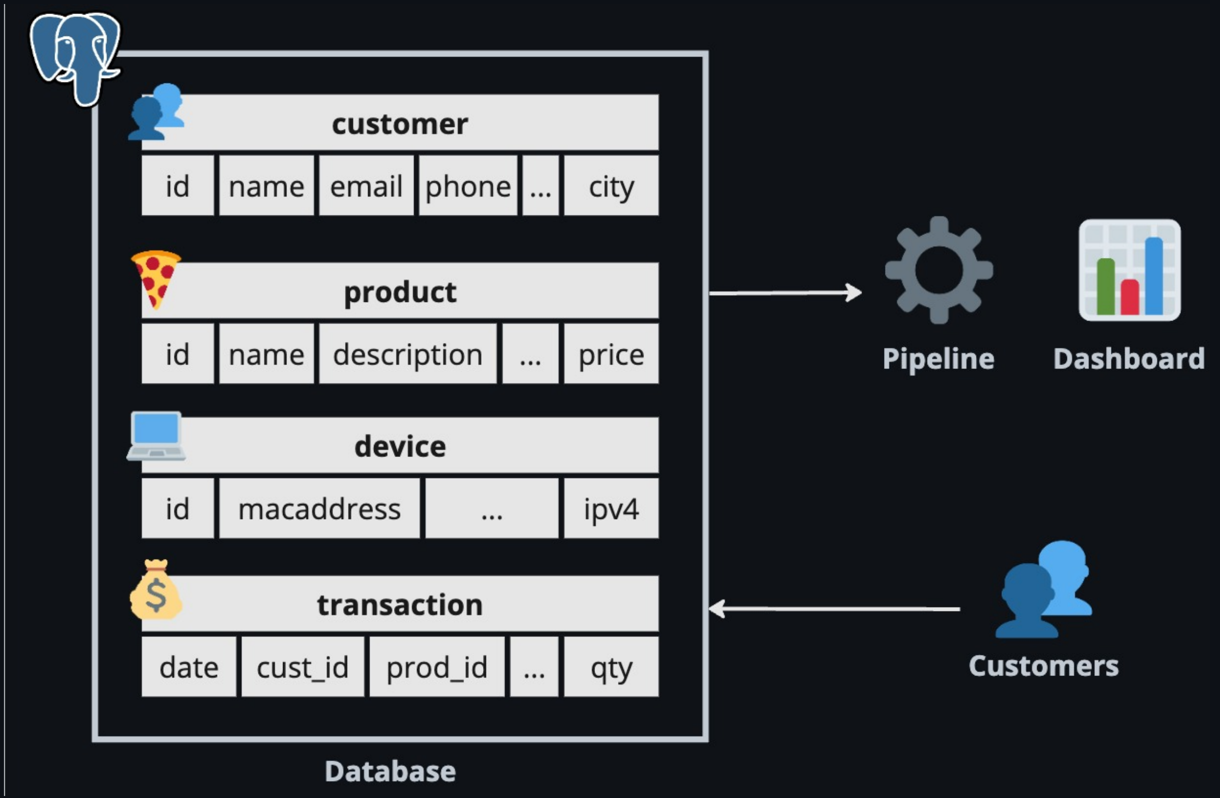
- In this demo, I'll show you how you can create synthetic data
- Using a Python package called `Faker`
- And how to use `Flyway` to load the synthetic data into a `Postgres` database for repeatable deployments
- So that you can test your pipelines without real data

💵 Our scenario

- Let's pretend we just started a new e-commerce website
- We have an idea of what kind of data we'll have for
  - Customers
  - Products
  - Transactions

📚 The data problem

- Now we want to start building different data pipelines and visualisations to see how well our business is doing
- We want our systems to work as soon as we get customers



customer

id	name	email	phone	...	city

product

id	name	description	...	price

device

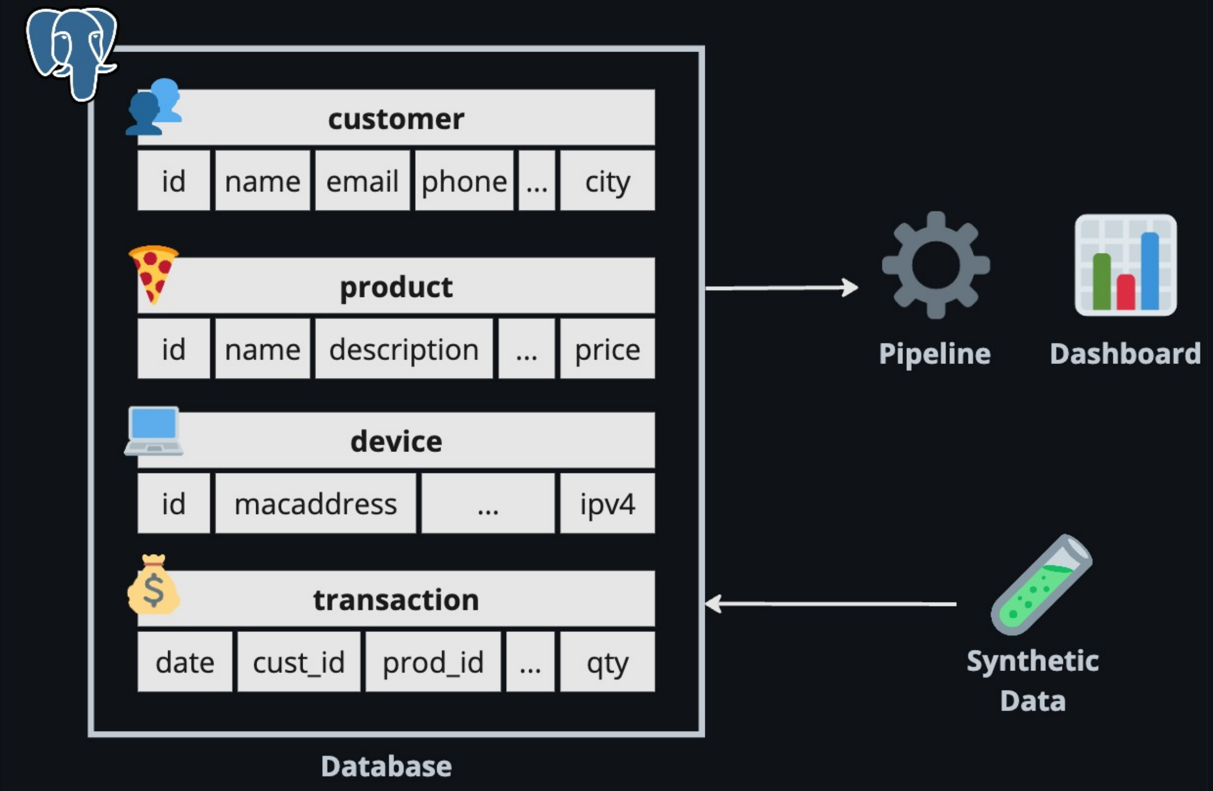
id	macaddress	...	ipv4

transaction

date	cust_id	prod_id	...	qty

📚 The data problem

- But we don't have customers yet (or data for them)
- So let's make some
- Then we can build everything downstream and it should work when we get real data



🪚 Install and import tools

```
pip install SQLAlchemy Faker
```

- `SQLAlchemy` to create database objects

  ```python
  from sqlalchemy import Column, Integer, String, DateTime
  from sqlalchemy.orm import declarative_base
  Base = declarative_base()
  ```

- `Faker` to generate synthetic data

  ```python
  from faker import Faker
  fake = Faker()
  ```

👥 Customer object

Class to store customer information

```
class Customer(Base):
  __tablename__ = "customers"
  id = Column(Integer, primary_key=True)
  name = Column(String(100))
  email = Column(String(100))
  phone = Column(String(25))
  address = Column(String(250))
  city = Column(String(100))
  country = Column(String(100))
```

👥 Customer data

Customer generator using `Faker` for synthetic data

```python
def generate_customer(id: int):
  customer = Customer(
      id=id,
      name=fake.name(),
      email=fake.email(),
      phone=fake.phone_number(),
      address=fake.street_address(),
      city=fake.city(),
      country=fake.country()
  )
  return customer
```

🍕 Product object

Class to store product information

```
class Product(Base):
    __tablename__ = "products"
    id = Column(Integer, primary_key=True)
    name = Column(String(50))
    description = Column(String(200))
    category = Column(String(50))
    price = Column(Numeric(10, 2))
```

🍕 Product data

Product generator using `Faker` for synthetic data

```python
def generate_product(id: int):
  product = Product(
      id=id,
      name=fake.word(),
      description=fake.sentence(),
      category=fake.random_element(
        elements=("Electronics", "Fashion", "Books", "Games", "Sports", "Food")
      ),
      price=fake.pydecimal(left_digits=3, right_digits=2, positive=True)
  )
  return product
```

💻 Device object

Class to store device information

```python
class Device(Base):
  __tablename__ = "devices"
  id = Column(Integer, primary_key=True)
  platform = Column(String(250))
  ipv4 = Column(String(50))
  macaddress = Column(String(50))
```

💻 Device data

Device generator using `Faker` for synthetic data

```python
def generate_device(id: int):
  device = Device(
      id=id,
      platform=fake.user_agent(),
      ipv4=fake.ipv4(),
      macaddress=fake.mac_address()
  )
  return device
```

💰 Transaction object

Class to store transaction information

```python
class Transaction(Base):
  __tablename__ = "transactions"
  id = Column(Integer, primary_key=True)
  date_time = Column(DateTime)
  customer_id = Column(Integer)
  product_id = Column(Integer)
  quantity = Column(Integer)
  device_id = Column(Integer)
  payment_method = Column(String(50))
```

💰 Transaction data

Transaction generator using `Faker` for synthetic data

```python
def generate_transaction(
  id: int,
  customers: list[Customer],
  products: list[Product],
  devices: list[Device]
):
  tr = Transaction(
      id=id,
      date_time=fake.date_between(start_date=START_DATE, end_date=END_DATE),
      customer_id=random.choice(customers).id,
      product_id=random.choice(products).id,
      quantity=fake.random_int(min=1, max=20),
      device_id=random.choice(devices).id,
      payment_method=fake.random_element(
        elements=("Credit Card", "EFT", "Bitcoin", "Reward Points")
      )
  )
  return tr
```

📊 Generate data

Use our functions to generate synthetic data

```python
customers = [generate_customer(i) for i in range(1000)]
products = [generate_product(i) for i in range(60)]
devices = [generate_device(i) for i in range(1000)]

transactions = [
  generate_transaction(i, customers, products, devices) for i in range(5000)
]
```

✏️ Write data do database

> We have a choice

- Just use `SQLAlchemy` to write to our database
- Or use `Flyway` (we'll use this option)
    - It handles version control of our SQL scripts
    - And handles database migrations
        - For repeatable deployments
        - And certainty about our database state
    - This all makes it easier to collaborate with other developers

💬 Generate SQL scripts

- `Flyway` is almost like `git` for your database
- So we need to get the `CREATE` and `INSERT` statements
  - That will create our tables
  - And to insert our synthetic data

💬 Generate SQL scripts

> Create SQL string > Write to `.sql` file

- You can do some simple string manipulation:

```
sql = f"""CREATE TABLE {table} (
  id SERIAL NOT NULL,
  name VARCHAR(100) NOT NULL
);"""
```

- Or you can use `SQLAlchemy`:

```
from sqlalchemy import create_engine
from sqlalchemy.schema import CreateTable

engine = create_engine("postgresql:///:memory:")
sql = str(CreateTable(cls.__table__).compile(engine))
```

💬 Generate SQL scripts

> Create SQL string > Write to `.sql` file

- You can do some simple string manipulation:

```
sql = f"INSERT INTO {table} VALUES ({object.id}, {object.name})"
```

- Or you can use `SQLAlchemy`:

```
from sqlalchemy.sql.expression import insert

insert_stmt = insert(cls.__table__)\
  .values(records)\ # list of records from helper function
  .compile(compile_kwargs={"literal_binds": True})
sql = str(insert_stmt)
```

🪽 Use Flyway to create tables and data

> Install the CLI (instructions online)

- Configure Flyway by creating a new project and specifying database connections
- Drop all tables, views, procedures etc. in the configured schemas to start fresh

  ```
  flyway clean
  ```

- Migrate schemas to the latest version by applying SQL scripts

  ```
  flyway migrate
  ```

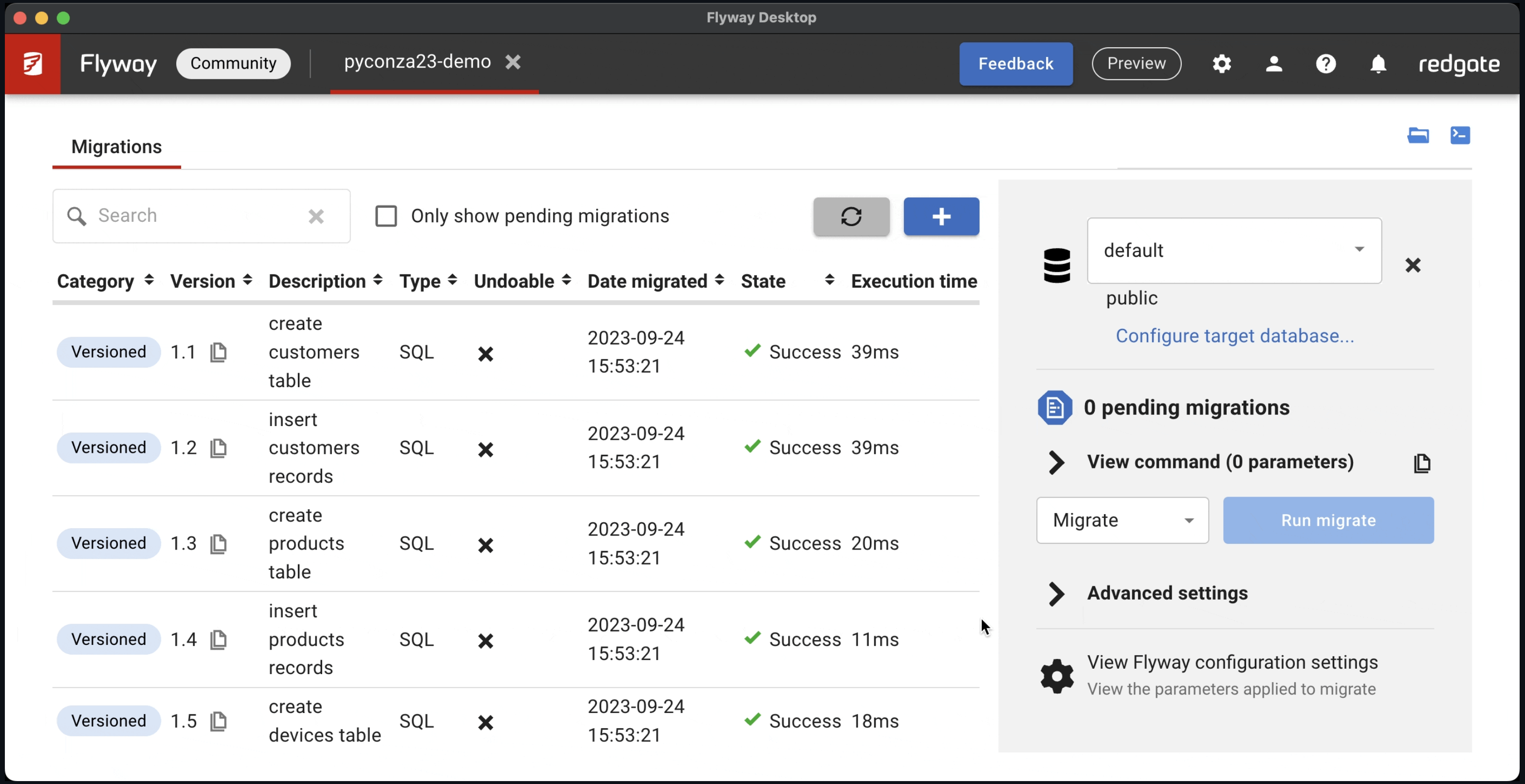
🪽 Use Flyway to create tables and data

> After downloading and installing Flyway Desktop

- Configure Flyway by creating a new project and specifying database connections

🪽 Use Flyway to create tables and data

> To start fresh, perform a `clean` to drop all tables, views, procedures etc. in the configured schemas



Category	Version	Description	Type	Undoable	Date migrated	State	Execution time
Versioned	1.1	create customers table	SQL	✗	2023-09-24 15:53:21	✓ Success	39ms
Versioned	1.2	insert customers records	SQL	✗	2023-09-24 15:53:21	✓ Success	39ms
Versioned	1.3	create products table	SQL	✗	2023-09-24 15:53:21	✓ Success	20ms
Versioned	1.4	insert products records	SQL	✗	2023-09-24 15:53:21	✓ Success	11ms
Versioned	1.5	create devices table	SQL	✗	2023-09-24 15:53:21	✓ Success	18ms

default

public

Configure target database...

0 pending migrations

View command (0 parameters)

Migrate

Run migrate

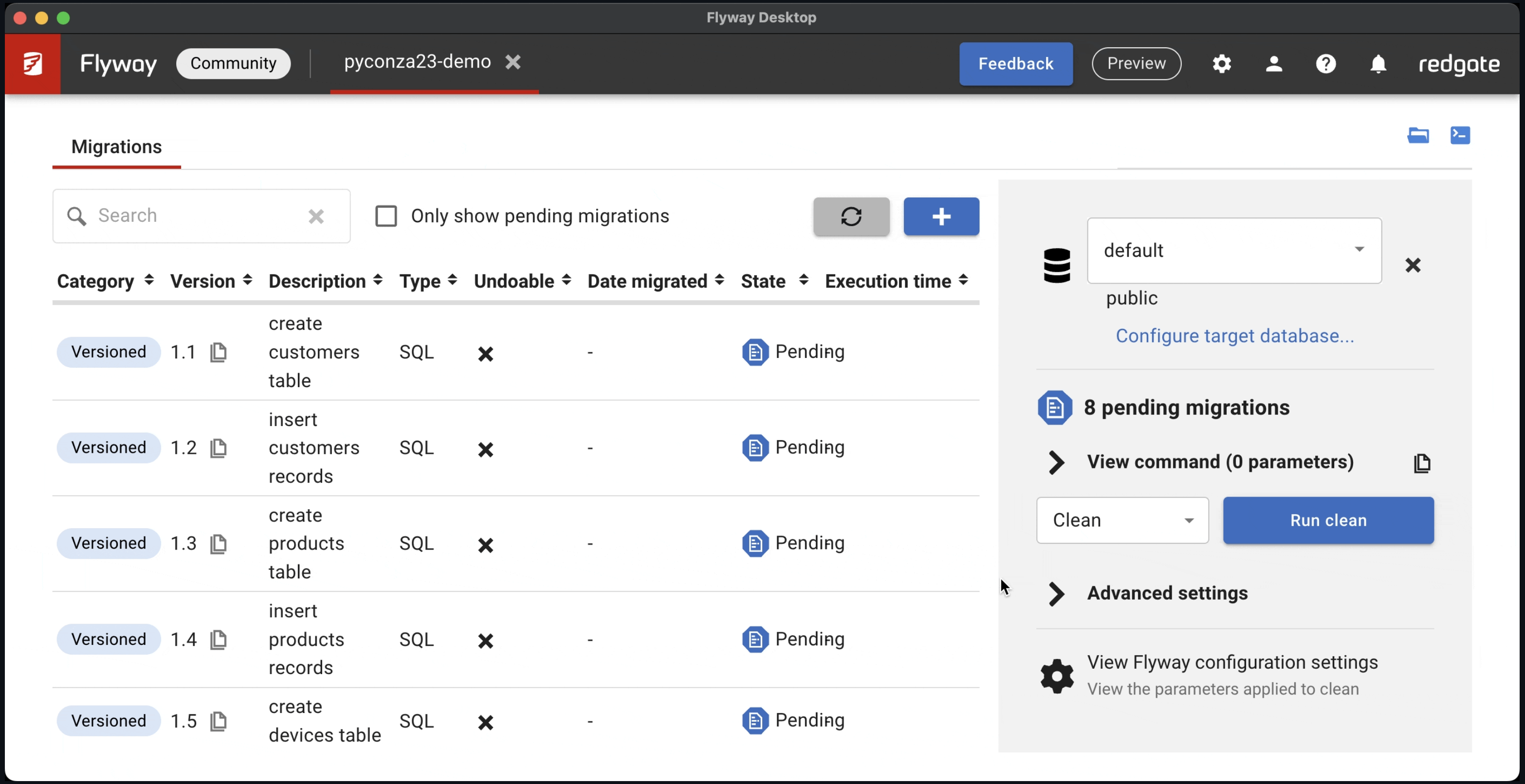
Advanced settings

View Flyway configuration settings

View the parameters applied to migrate

🪽 Use Flyway to create tables and data

> Perform a `migrate` to update schemas to the latest version by applying SQL scripts



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Versioned	1.4	insert products records	SQL	✗	-	Pending	
Versioned	1.5	create devices table	SQL	✗	-	Pending	

default

public

Configure target database...

8 pending migrations

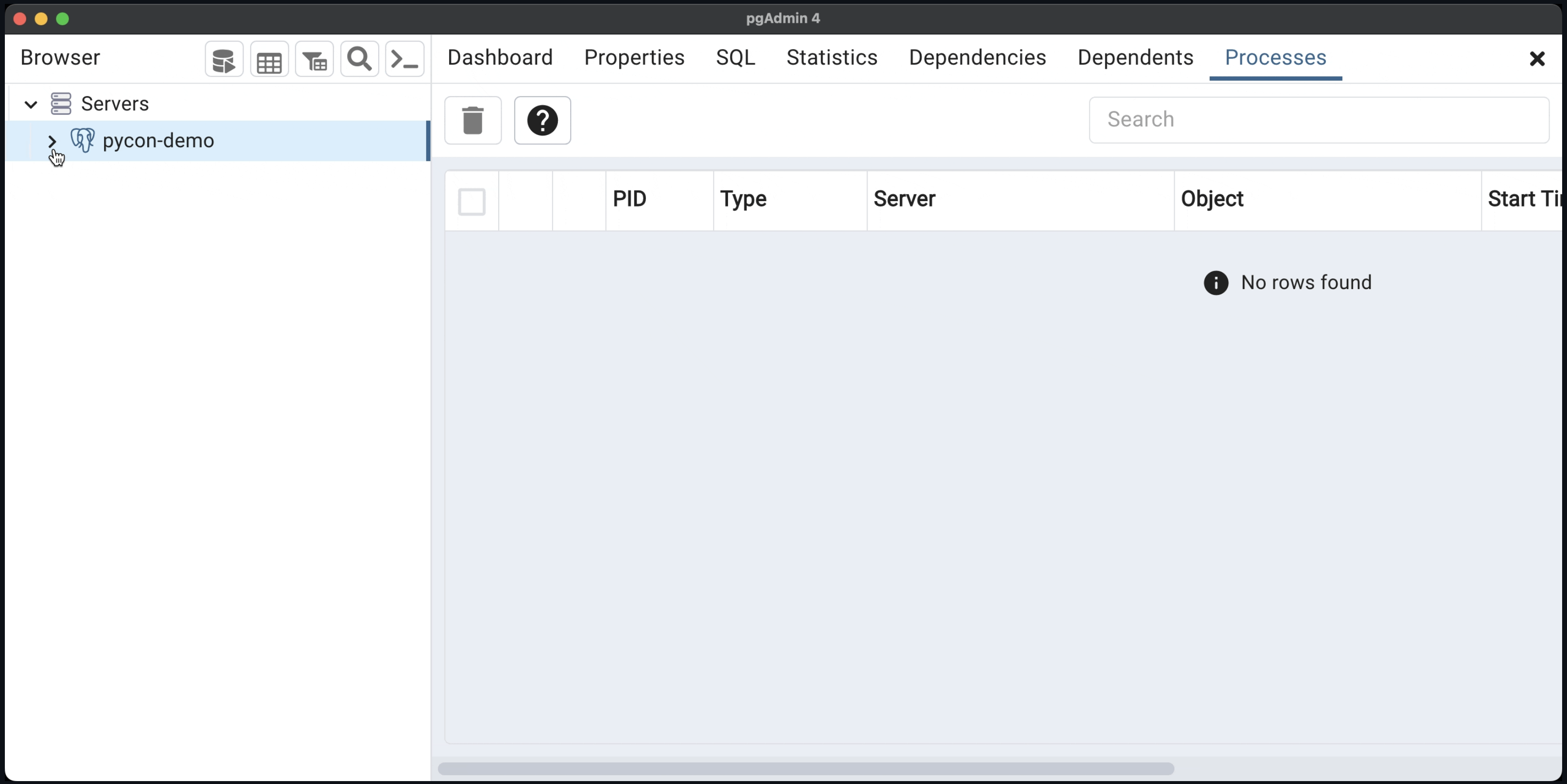
View command (0 parameters)

Clean

View Flyway configuration settings
View the parameters applied to clean

👀 Inspect data

> Inspect database with `pgAdmin` to see if your synthetic data is ready



⚖️ Pros and cons of synthetic data

- Benefits:
  - It can speed up the development and testing process
  - It can increase the coverage and quality of testing
- Challenges & limitations:
  - It may not capture all the nuances and variations of real data
  - It may require additional effort and resources to create and maintain synthetic data

💡 Tips & best practices

- Define the scope and purpose of your synthetic data before starting
- Be careful of wasting time trying to make perfectly realistic data
- Use existing tools and libraries to generate synthetic data where possible
- Validate and verify your synthetic data against your real data schema and business rules
- Document your synthetic data generation process and code

📜 Summary

- We discussed some challenges of building and testing data pipelines without real data
- We learned how to build synthetic data in Python to test our data pipelines
- We also showed how we used Flyway to load the synthetic data into a Postgres database

🐍 Thank you!

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