Universidad Austral

Maestría en Explotación de Datos y Gestión del Conocimiento

Cohorte 2023 - 2024

Modalidad Virtual

Análisis de Series Temporales

Trabajo Práctico N.º 2

CÓDIGO UTILIZADO

Alumnos

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Ciclo Académico 2024

PROPHET CV GRIDSEARCH

TRAIN 90%

TEST 10%

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
# TRAIN TEST
train_copa = dataframes[0].iloc[:round(len(dataframes[0])*.8)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*.8):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*.8)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*.8):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*.8)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*.8):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1275,)), test((319,))
Recursos: train((1626,)), test((406,))
Regalias: train((460,)), test((115,))
```

In [ ]:
```python
parametros = []
for i, df in enumerate(dataframes_train):
    df_train = df.to_frame().reset_index(drop=False)
    df_train.columns = ["ds", "y"]

    param_grid = {
        'changepoint_prior_scale': [0.001, 0.01, 0.1, 0.5],
        'seasonality_prior_scale': [0.01, 0.1, 1.0, 10.0],
        'daily_seasonality': [True, False],
        'yearly_seasonality': [True, False],
        'holidays_prior_scale': [0.01, 0.1, 1, 10],
        'seasonality_mode': ['additive', 'multiplicative'],
        'changepoint_range': [0.8, 0.9, 0.95]
    }

    # Generate all combinations of parameters
    all_params = [dict(zip(param_grid.keys(), v)) for v in itertools.product(*pa
```

```
    rmses = []  # Store the RMSEs for each params here

    # Use cross validation to evaluate all parameters
    for params in all_params:
        m = Prophet(**params).fit(df_train)  # Fit model with given params
        df_cv = cross_validation(m, period='180 days', horizon = '365 days')
        df_p = performance_metrics(df_cv, rolling_window=1)
        rmses.append(df_p['rmse'].values[0])

    # Find the best parameters
    tuning_results = pd.DataFrame(all_params)
    tuning_results['rmse'] = rmses
    best_params = all_params[np.argmin(rmses)]
    parametros.append({ "df": dataframes_train[i].name,"best_params": best_param
    print(f"Entrenamiento de {dataframes_train[i].name} finalizado")
```

In [12]:
```
pd.DataFrame(parametros)
```

Out[12]:

	df	best_params
0	CHU_COPA_AJUST	{'changepoint_prior_scale': 0.1, 'seasonality_...
1	CHU_REC_PROPIOS_AJUST	{'changepoint_prior_scale': 0.001, 'seasonalit...
2	CHU_REGALIAS_AJUST	{'changepoint_prior_scale': 0.5, 'seasonality_...

In [13]:
```
pd.DataFrame(pd.DataFrame(parametros)).to_csv("best_params.csv", index=False)
```

In [ ]:
```

```

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
# TRAIN TEST
n_train = 0.9
train_copa = dataframes[0].iloc[:round(len(dataframes[0])*n_train)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*n_train):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*n_train)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*n_train):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*n_train)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*n_train):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1584,)), test((176,))
Recursos: train((1995,)), test((222,))
Regalias: train((1985,)), test((221,))
```

In [ ]:
```python
from prophet.diagnostics import cross_validation, performance_metrics

fourier_y_list = []
for df in dataframes_train:
    name = df.name
    df = df.to_frame()
    df = df.reset_index()
    df.columns = ['ds', 'y']
    for fourier in [3, 5, 7, 10]:
        model = Prophet(yearly_seasonality=False)
```

```
        model.add_seasonality(name='yearly', period=365.25, fourier_order=fourie
        model.fit(df)

        df_cv = cross_validation(model, initial='730 days', period='180 days', h
        df_p = performance_metrics(df_cv)
        print(f'Fourier Order: {fourier}, mae: {df_p["mae"].mean()}')
        fourier_y_list.append({
            'name': name,
            'fourier_order': fourier,
            'mae': df_p["mae"].mean(),
            'mse': df_p["mse"].mean(),
            'rmse': df_p["rmse"].mean(),

        })
```

In [ ]:
```
from prophet.diagnostics import cross_validation, performance_metrics
fourier_m_list = []
for df in dataframes_train:
    name = df.name
    df = df.to_frame()
    df = df.reset_index()
    df.columns = ['ds', 'y']
    for fourier in [3, 5, 7, 10]:
        model = Prophet(yearly_seasonality=False)
        model.add_seasonality(name='monthly', period=30.5, fourier_order=fourier
        model.fit(df)

        df_cv = cross_validation(model, initial='730 days', period='180 days', h
        df_p = performance_metrics(df_cv)
        print(f'Fourier Order: {fourier}, mae: {df_p["mae"].mean()}')
        fourier_m_list.append({
            'name': name,
            'fourier_order': fourier,
            'mae': df_p["mae"].mean(),
            'mse': df_p["mse"].mean(),
            'rmse': df_p["rmse"].mean(),

        })
```

In [24]:
```
pd.DataFrame(fourier_m_list)
```

Out[24]:

	name	fourier_order	mae	mse	rm
0	CHU_COPA_AJUST	3	1,295,550.58	3,368,417,717,852.50	1,829,278.
1	CHU_COPA_AJUST	5	1,292,136.70	3,382,102,160,158.99	1,833,572.
2	CHU_COPA_AJUST	7	1,289,267.78	3,403,619,136,925.37	1,839,180.
3	CHU_COPA_AJUST	10	1,292,343.45	3,435,217,624,484.17	1,847,424.
4	CHU_REC_PROPIOS_AJUST	3	875,832.51	1,354,696,658,529.47	1,160,714.
5	CHU_REC_PROPIOS_AJUST	5	876,294.82	1,360,751,514,817.23	1,163,577.
6	CHU_REC_PROPIOS_AJUST	7	884,354.91	1,384,814,129,416.05	1,173,991.
7	CHU_REC_PROPIOS_AJUST	10	886,719.39	1,389,622,924,478.05	1,175,983.
8	CHU_REGALIAS_AJUST	3	2,981,291.15	33,617,382,219,021.43	5,786,977.
9	CHU_REGALIAS_AJUST	5	2,881,989.42	34,018,833,939,631.12	5,820,355.
10	CHU_REGALIAS_AJUST	7	2,887,115.68	34,332,503,235,722.89	5,847,218.
11	CHU_REGALIAS_AJUST	10	2,896,604.65	34,623,962,264,283.60	5,872,018.

In [28]:
```
pd.options.display.float_format = '{:,.2f}'.format
pd.DataFrame(fourier_y_list)
```

Out[28]:

	name	fourier_order	mae	mse	rm
0	CHU_COPA_AJUST	3	1,659,037.26	4,493,518,123,189.03	2,114,628.
1	CHU_COPA_AJUST	5	1,659,235.07	4,492,317,272,786.19	2,114,568.
2	CHU_COPA_AJUST	7	1,662,586.82	4,503,776,502,703.05	2,117,144.
3	CHU_COPA_AJUST	10	1,662,410.64	4,524,420,159,270.77	2,120,638.
4	CHU_REC_PROPIOS_AJUST	3	1,007,027.71	1,554,772,294,789.62	1,244,465.
5	CHU_REC_PROPIOS_AJUST	5	1,006,999.60	1,550,073,308,813.71	1,242,539.
6	CHU_REC_PROPIOS_AJUST	7	1,005,906.47	1,551,414,785,218.95	1,242,870.
7	CHU_REC_PROPIOS_AJUST	10	1,004,277.36	1,548,804,571,628.49	1,241,865.
8	CHU_REGALIAS_AJUST	3	2,975,730.22	36,804,980,074,407.97	6,054,561.
9	CHU_REGALIAS_AJUST	5	2,981,596.93	36,810,240,630,045.30	6,054,990.
10	CHU_REGALIAS_AJUST	7	2,961,931.77	36,818,174,730,371.95	6,055,578.
11	CHU_REGALIAS_AJUST	10	2,970,283.20	36,865,017,859,487.95	6,059,508.

In [35]:
```
def get_best_fourier_orders(fourier_list):
  best_orders = {}
  for item in fourier_list:
    name = item['name']
    if name not in best_orders or item['rmse'] < best_orders[name]['rmse']:
      best_orders[name] = {
```

```
        'fourier_order': item['fourier_order'],
        'rmse': item['rmse']
      }
  return best_orders

best_fourier_orders_y = get_best_fourier_orders(fourier_y_list)
best_fourier_orders_m = get_best_fourier_orders(fourier_m_list)

print("Best Fourier Orders (Yearly):", best_fourier_orders_y)
print("Best Fourier Orders (Monthly):", best_fourier_orders_m)
result = pd.DataFrame([best_fourier_orders_y, best_fourier_orders_m]).T
result.columns = ['Fourier_yearly', 'Fourier_monthly']
result
```

```
Best Fourier Orders (Yearly): {'CHU_COPA_AJUST': {'fourier_order': 5, 'rmse': 211
4568.5994672766}, 'CHU_REC_PROPIOS_AJUST': {'fourier_order': 10, 'rmse': 1241865.
2497155124}, 'CHU_REGALIAS_AJUST': {'fourier_order': 3, 'rmse': 6054561.27930790
9}}
Best Fourier Orders (Monthly): {'CHU_COPA_AJUST': {'fourier_order': 3, 'rmse': 18
29278.0979960766}, 'CHU_REC_PROPIOS_AJUST': {'fourier_order': 3, 'rmse': 1160714.
3127307887}, 'CHU_REGALIAS_AJUST': {'fourier_order': 3, 'rmse': 5786977.88651003
3}}
```

Out[35]:

	Fourier_yearly	Fourier_monthly
CHU_COPA_AJUST	{'fourier_order': 5, 'rmse': 2114568.5994672766}	{'fourier_order': 3, 'rmse': 1829278.0979960766}
CHU_REC_PROPIOS_AJUST	{'fourier_order': 10, 'rmse': 1241865.2497155124}	{'fourier_order': 3, 'rmse': 1160714.3127307887}
CHU_REGALIAS_AJUST	{'fourier_order': 3, 'rmse': 6054561.279307909}	{'fourier_order': 3, 'rmse': 5786977.886510033}

In [36]:
```
result.to_csv("best_fourier_orders.csv")
```

In [ ]:
```

```

PROPHET

TRAIN 90%

TEST 10%

In [7]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
```

In [8]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [9]:
```python
# TRAIN TEST
n_train = 0.9
train_copa = dataframes[0].iloc[:round(len(dataframes[0])*n_train)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*n_train):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*n_train)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*n_train):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*n_train)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*n_train):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1584,)), test((176,))
Recursos: train((1995,)), test((222,))
Regalias: train((1985,)), test((221,))
```

In [19]:
```python
model.predict(future)
```

Out[19]:

	ds	trend	yhat_lower	yhat_upper	trend_lower	trend_upper
0	2018-01-02	2.244932e+06	-669003.795682	4.370992e+06	2.244932e+06	2.244932e+06
1	2018-01-03	2.244625e+06	-295740.561883	4.843847e+06	2.244625e+06	2.244625e+06
2	2018-01-04	2.244318e+06	-227764.824909	4.710549e+06	2.244318e+06	2.244318e+06
3	2018-01-05	2.244011e+06	-241790.890588	4.897786e+06	2.244011e+06	2.244011e+06
4	2018-01-08	2.243090e+06	-709402.692045	4.526881e+06	2.243090e+06	2.243090e+06
...	...	...	...	...	...	...
1755	2024-09-24	2.881273e+06	46619.465574	5.376678e+06	2.870376e+06	2.892725e+06
1756	2024-09-25	2.881827e+06	504211.934660	5.675143e+06	2.870773e+06	2.893353e+06
1757	2024-09-26	2.882382e+06	324626.675420	5.514598e+06	2.871118e+06	2.893978e+06
1758	2024-09-27	2.882937e+06	334686.836801	5.772139e+06	2.871469e+06	2.894602e+06
1759	2024-09-30	2.884602e+06	137319.920679	5.109929e+06	2.873045e+06	2.896327e+06

1760 rows × 22 columns

In [ ]:

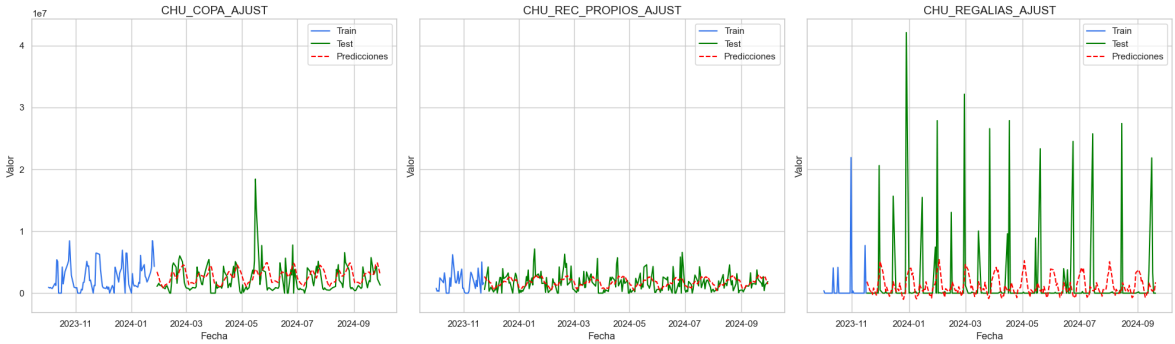
```
results_train_test = []
predictions_test = []
from prophet.make_holidays import make_holidays_df
best_params = pd.read_csv("prophet_best_params.csv")
best_fourier = pd.read_csv("best_fourier_orders.csv")

for i, df_train in enumerate(dataframes_train):
    df_train = df_train.to_frame()
    df_train.reset_index(inplace=True)
    df_train.columns = ["ds", "y"]
    df_test = dataframes_test[i]
    params = eval(best_params.iloc[i]["best_params"])
    year_list = dataframes[i].index.year.unique()
    holidays = make_holidays_df(year_list=year_list, country='AR')
    model = Prophet(**params,holidays=holidays)

    fourier_yearly = eval(best_fourier.iloc[i]["Fourier_yearly"])["fourier_order
    fourier_monthly = eval(best_fourier.iloc[i]["Fourier_monthly"])["fourier_ord
    model.add_seasonality(name='monthly', period=30.5, fourier_order=fourier_mon
    model.add_seasonality(name='yearly', period=365.25, fourier_order=fourier_ye

    model.fit(df_train)
    fechas = pd.date_range(start=df_test.index.min(), end=df_test.index.max(), f
    future = model.make_future_dataframe(periods=len(fechas), freq='B')
```

```
    pred_test = model.predict(future)
    pred_test.index = pred_test["ds"]
    pred_test = pred_test["yhat"]
    pred_test = pred_test[-len(df_test):]

    predictions_test.append(pred_test)
    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": model,
        "name": titulos[i],
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

```
15:47:26 - cmdstanpy - INFO - Chain [1] start processing
15:47:26 - cmdstanpy - INFO - Chain [1] done processing
15:47:27 - cmdstanpy - INFO - Chain [1] start processing
15:47:27 - cmdstanpy - INFO - Chain [1] done processing
15:47:28 - cmdstanpy - INFO - Chain [1] start processing
15:47:28 - cmdstanpy - INFO - Chain [1] done processing
```

In [54]:
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=dataframes_train,
    dataframes_test=dataframes_test,
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2023-10-01'
))
```

	model	name	len_train	len_test	
0	<prophet.forecaster.Prophet object at 0x000002...	CHU_COPA_AJUST	1584	176	958,736,396,89
1	<prophet.forecaster.Prophet object at 0x000002...	CHU_REC_PROPIOS_AJUST	1995	222	552,112,145,06
2	<prophet.forecaster.Prophet object at 0x000002...	CHU_REGALIAS_AJUST	1985	221	3,911,866,127,92


CHU_COPA_AJUST
CHU_REC_PROPIOS_AJUST
CHU_REGALIAS_AJUST
Train
Test
Predicciones
Valor
Fecha
1e7
0
1
2
3
4
2023-11
2024-01
2024-03
2024-05
2024-07
2024-09

None

In [ ]:

XGBOOST

TRAIN 90%

TEST 10%

In [4]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
import xgboost as xgb
```

In [6]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [7]:
```python
def extract_time_features(index):
    return pd.Series({
        'dayofweek': index.dayofweek,
        'quarter': index.quarter,
        'month': index.month,
        'year': index.year,
        'dayofyear': index.dayofyear,
        'dayofmonth': index.day,
        'weekofyear': index.isocalendar().week
    })
def add_lags(df, titulo):
    target_map = df[titulo].to_dict()
    df['lag1'] = (df.index - pd.Timedelta('364 days')).map(target_map) # df_1['P
    df['lag2'] = (df.index - pd.Timedelta('728 days')).map(target_map) # df_1['P
    df['lag3'] = (df.index - pd.Timedelta('1092 days')).map(target_map) # df_1['
    return df

for i in range(len(dataframes)):
    time_features = dataframes[i].index.to_series().apply(extract_time_features)
    dataframes[i] = pd.concat([dataframes[i], time_features], axis=1)
    dataframes[i] = add_lags(dataframes[i], titulos[i])
```

In [8]:
```python
# TRAIN TEST
n_train = 0.9
train_copa = dataframes[0].iloc[:round(len(dataframes[0])*n_train)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*n_train):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")
```

```
train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*n_train)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*n_train):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*n_train)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*n_train):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

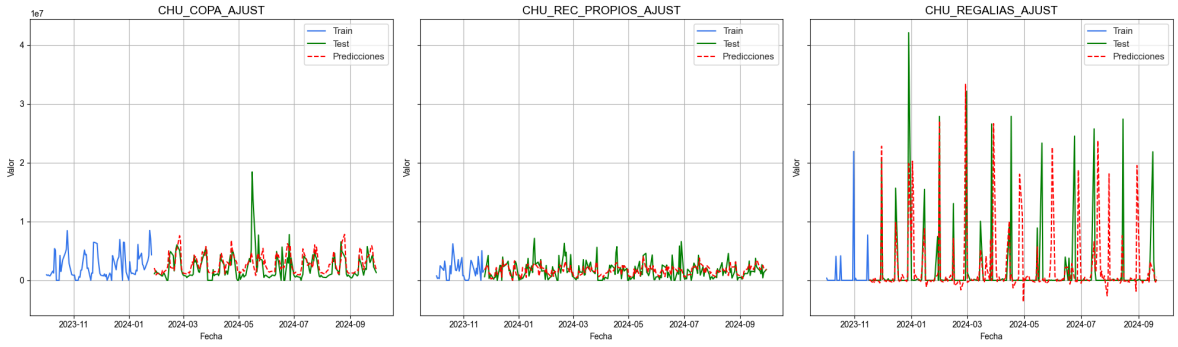
```
Coparticipacion: train((1584, 11)), test((176, 11))
Recursos: train((1995, 11)), test((222, 11))
Regalias: train((1985, 11)), test((221, 11))
```

In [ ]:

```
results_train_test = []
predictions_test = []
best_params = pd.read_csv("xgb_best_params.csv",sep=";")

for i, df_train in enumerate(dataframes_train):

    params = eval(best_params.iloc[i]["best_params"])

    FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmon
    TARGET = titulos[i]

    df_test = dataframes_test[i][TARGET]
    model = xgb.XGBRegressor(**params )

    X_train = dataframes_train[i][FEATURES]
    y_train = dataframes_train[i][TARGET]
    X_test= dataframes_test[i][FEATURES]
    y_test= dataframes_test[i][TARGET]

    model.fit(
        X_train, y_train,
        eval_set=[(X_test, y_test)]
    )

    pred_test = model.predict(X_test)
    pred_test = pd.Series(pred_test, index=dataframes_test[i].index)
    predictions_test.append(pred_test)

    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": model,
        "name": titulos[i],
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [10]:
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=[pd.Series(dataframes_train[i][titulos[i]], index=dataframe
    dataframes_test=[pd.Series(dataframes_test[i][titulos[i]], index=dataframes_
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2023-10-01'
))
```

	model	name	len_train	len_test	
0	XGBRegressor(base_score=None, booster=None, ca...	CHU_COPA_AJUST	1584	176	696,802,9
1	XGBRegressor(base_score=None, booster=None, ca...	CHU_REC_PROPIOS_AJUST	1995	222	390,317,6
2	XGBRegressor(base_score=None, booster=None, ca...	CHU_REGALIAS_AJUST	1985	221	6,052,706,5



None

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
def extract_time_features(index):
    return pd.Series({
        'dayofweek': index.dayofweek,
        'quarter': index.quarter,
        'month': index.month,
        'year': index.year,
        'dayofyear': index.dayofyear,
        'dayofmonth': index.day,
        'weekofyear': index.isocalendar().week
    })
def add_lags(df, titulo):
    target_map = df[titulo].to_dict()
    df['lag1'] = (df.index - pd.Timedelta('364 days')).map(target_map) # df_1['P
    df['lag2'] = (df.index - pd.Timedelta('728 days')).map(target_map) # df_1['P
    df['lag3'] = (df.index - pd.Timedelta('1092 days')).map(target_map) # df_1['
    return df

for i in range(len(dataframes)):
    time_features = dataframes[i].index.to_series().apply(extract_time_features)
    dataframes[i] = pd.concat([dataframes[i], time_features], axis=1)
    dataframes[i] = add_lags(dataframes[i], titulos[i])
```

In [4]:
```python
# TRAIN TEST
n_train = 0.9
train_copa = dataframes[0].iloc[:round(len(dataframes[0])*n_train)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*n_train):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*n_train)]
```

```
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*n_train):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*n_train)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*n_train):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

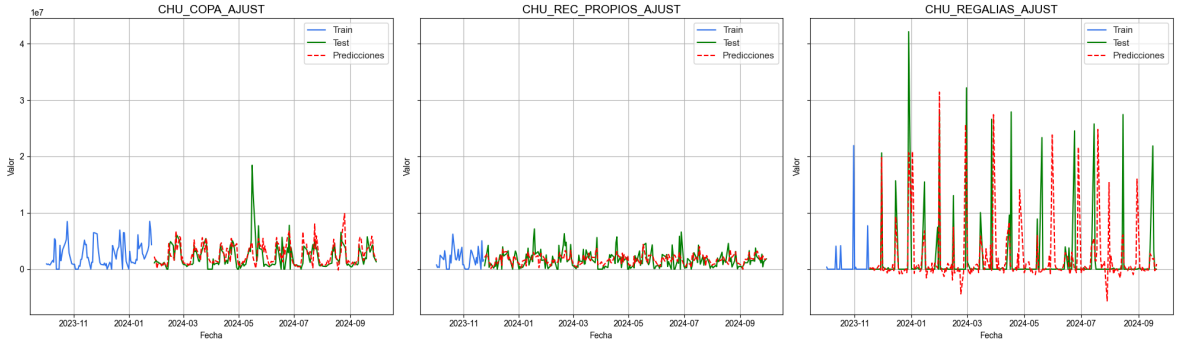
```
Coparticipacion: train((1584, 11)), test((176, 11))
Recursos: train((1995, 11)), test((222, 11))
Regalias: train((1985, 11)), test((221, 11))
```

In [ ]:

```
results_train_test = []
predictions_test = []
best_params = pd.read_csv("lgbm_best_params.csv",sep=";")
import lightgbm as lgb

for i, df_train in enumerate(dataframes_train):

    params = eval(best_params.iloc[i]["best_params"])

    FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmon
    TARGET = titulos[i]

    df_test = dataframes_test[i][TARGET]
    model = lgb.LGBMRegressor(**params )

    X_train = dataframes_train[i][FEATURES]
    y_train = dataframes_train[i][TARGET]
    X_test= dataframes_test[i][FEATURES]
    y_test= dataframes_test[i][TARGET]

    model.fit(df_train[FEATURES], df_train[TARGET],
              eval_set=[(X_train, y_train), (X_test, y_test)], eval_metric="rmse

    pred_test = model.predict(dataframes_test[i][FEATURES])
    pred_test = pd.Series(pred_test, index=dataframes_test[i].index)
    predictions_test.append(pred_test)

    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": model,
        "name": titulos[i],
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [6]:
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=[pd.Series(dataframes_train[i][titulos[i]], index=dataframe
    dataframes_test=[pd.Series(dataframes_test[i][titulos[i]], index=dataframes_
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2023-10-01'
))
```

	model	name	len_train	l
0	LGBMRegressor(colsample_bytree=0.8076995248364...	CHU_COPA_AJUST	1584	
1	LGBMRegressor(colsample_bytree=0.5125884353625...	CHU_REC_PROPIOS_AJUST	1995	
2	LGBMRegressor(colsample_bytree=0.8651927912102...	CHU_REGALIAS_AJUST	1985	



None

In [ ]:

LIGHTGBM

TRAIN 90%

TEST 10%

AUTOTS

TRAIN 90%

TEST 10%

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from autots import AutoTS
import matplotlib.pyplot as plt
import funciones
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
# TRAIN TEST
n_train = 0.9
train_copa = dataframes[0].iloc[:round(len(dataframes[0])*n_train)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*n_train):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*n_train)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*n_train):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*n_train)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*n_train):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1584,)), test((176,))
Recursos: train((1995,)), test((222,))
Regalias: train((1985,)), test((221,))
```

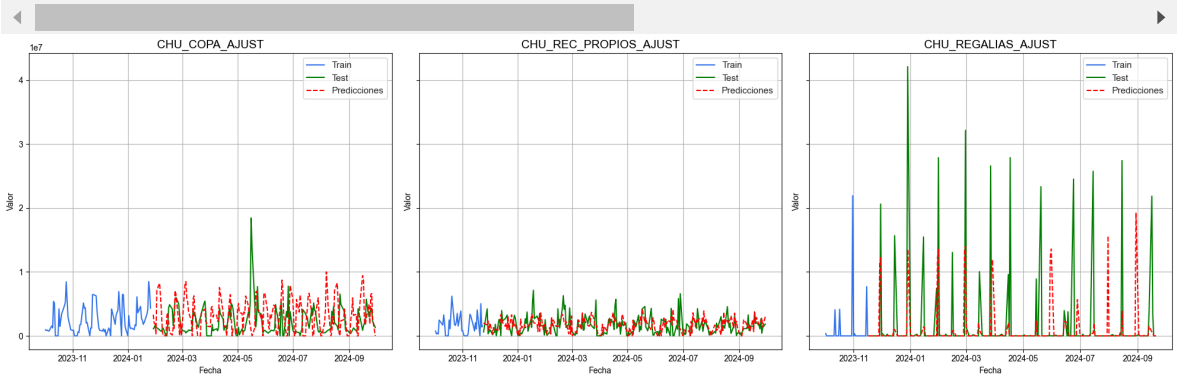
In [ ]:
```python
results_train_test = []
predictions_test = []
for i, df in enumerate(dataframes_train):
    df_train = df
    df_test = dataframes_test[i]

    model = AutoTS(
        forecast_length=len(dataframes_test[i]),
        frequency="B",
        prediction_interval=0.95,
        ensemble=None,
        models_mode='deep',
        model_list = 'superfast',
```

```
        max_generations=10,   # intenta optimizar el modelo a traves de 10 itera
        num_validations=3,
        no_negatives=True,
        n_jobs='auto')
    modelAutoTS = model.fit(df_train)
    # Find the best parameters

    fechas = pd.date_range(start=df_test.index.min(), end=df_test.index.max(), f
    pred_test = model.predict(forecast_length=len(fechas)).forecast
    predictions_test.append(pred_test)
    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": modelAutoTS,
        "name": df_train.name,
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [5]:

```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=dataframes_train,
    dataframes_test=dataframes_test,
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2023-10-01'
))
```

	model	name	len_train	len_test	mape_test	
0	Initiated AutoTS object with best model: \nSea...	CHU_COPA_AJUST	1584	176	1,069,270,913,042,505,662,464.00	1
1	Initiated AutoTS object with best model: \nGLS...	CHU_REC_PROPIOS_AJUST	1995	222	476,620,172,305,521,311,744.00	
2	Initiated AutoTS object with best model: \nSea...	CHU_REGALIAS_AJUST	1985	221	2,174,434,595,027,651,395,584.00	3



None

In [6]:
```
results = pd.DataFrame(results_train_test)

for i, row in results.iterrows():
    display(row["name"])
    print(row.model)
```

```
'CHU_COPA_AJUST'
Initiated AutoTS object with best model:
SeasonalNaive
{'fillna': 'pchip', 'transformations': {'0': 'SeasonalDifference', '1': 'MaxAbsSc
aler'}, 'transformation_params': {'0': {'lag_1': 7, 'method': 'LastValue'}, '1':
{}}}
{'method': 'lastvalue', 'lag_1': 96, 'lag_2': 28}
Validation: 0, 1, 2, 3
SMAPE: nan, nan, nan, nan
MAE: 2822593.394881551, 2705886.889956714, 2266922.725699413, 2126160.779481562
SPL: 0.34733674670580267, 0.33363305331363236, 0.3567839576534018, 0.398042596097
04773
'CHU_REC_PROPIOS_AJUST'
```

```
Initiated AutoTS object with best model:
GLS
{'fillna': 'ffill', 'transformations': {'0': 'DatepartRegression', '1': 'Historic
Values', '2': 'SeasonalDifference'}, 'transformation_params': {'0': {'regression_
model': {'model': 'ElasticNet', 'model_params': {'l1_ratio': 0.1, 'fit_intercep
t': True, 'selection': 'cyclic'}}, 'datepart_method': 'simple_2', 'polynomial_deg
ree': 2, 'transform_dict': {'fillna': None, 'transformations': {'0': 'ClipOutlier
s'}, 'transformation_params': {'0': {'method': 'clip', 'std_threshold': 4}}}, 'ho
liday_countries_used': False, 'lags': None, 'forward_lags': None}, '1': {'windo
w': 730}, '2': {'lag_1': 24, 'method': 2}}}
{}
Validation: 0, 1, 2, 3
SMAPE: nan, nan, nan, nan
MAE: 1226828.4737256807, 958627.634529741, 872269.9874219908, 777486.4746628217
SPL: 0.2207936109057398, 0.20243127261189903, 0.1972549963009233, 0.1784455234438
5997
'CHU_REGALIAS_AJUST'
Initiated AutoTS object with best model:
SeasonalityMotif
{'fillna': 'pchip', 'transformations': {'0': 'PositiveShift', '1': 'HistoricValue
s'}, 'transformation_params': {'0': {}, '1': {'window': None}}}
{'window': 10, 'point_method': 'midhinge', 'distance_metric': 'minkowski', 'k': 1
0, 'datepart_method': 'recurring', 'independent': True}
Validation: 0, 1, 2, 3
SMAPE: nan, nan, nan, nan
MAE: 1399081.8144796381, 1430369.8235294118, 1441480.6425339365, 1386704.18099547
5
SPL: 0.13252659123779703, 0.11893795878406024, 0.09366669094475673, 0.20322019724
881865
```

In [ ]:

PROPHET

TEST 30 DÍAS

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
# TRAIN TEST
n_test = 30
train_copa = dataframes[0].iloc[:-n_test]
test_copa = dataframes[0].iloc[-n_test:]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:-n_test]
test_recursos = dataframes[1].iloc[-n_test:]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:-n_test]
test_regalias = dataframes[2].iloc[-n_test:]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1730,)), test((30,))
Recursos: train((2187,)), test((30,))
Regalias: train((2176,)), test((30,))
```

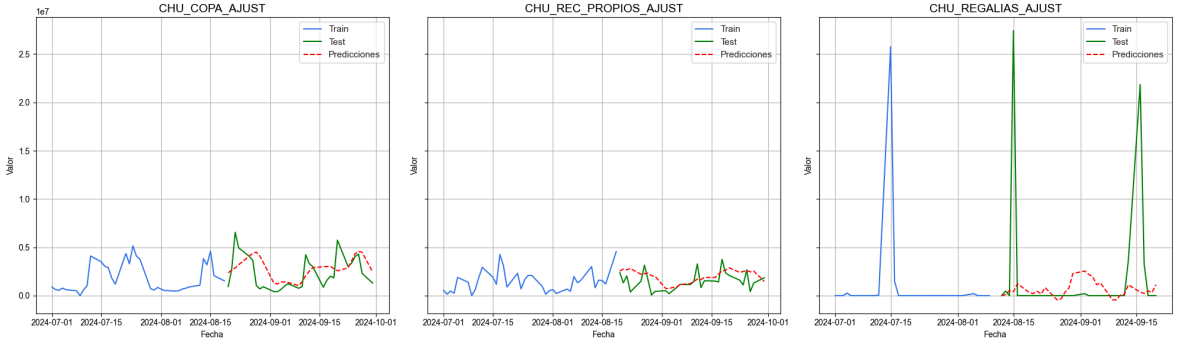
In [4]:
```python
results_train_test = []
predictions_test = []
from prophet.make_holidays import make_holidays_df
best_params = pd.read_csv("prophet_best_params.csv")
best_fourier = pd.read_csv("best_fourier_orders.csv")

for i, df_train in enumerate(dataframes_train):
    df_train = df_train.to_frame()
    df_train.reset_index(inplace=True)
    df_train.columns = ["ds", "y"]
```

```
    df_test = dataframes_test[i]
    params = eval(best_params.iloc[i]["best_params"])
    year_list = dataframes[i].index.year.unique()
    holidays = make_holidays_df(year_list=year_list, country='AR')
    model = Prophet(**params,holidays=holidays)

    fourier_yearly = eval(best_fourier.iloc[i]["Fourier_yearly"])["fourier_order
    fourier_monthly = eval(best_fourier.iloc[i]["Fourier_monthly"])["fourier_ord
    model.add_seasonality(name='monthly', period=30.5, fourier_order=fourier_mon
    model.add_seasonality(name='yearly', period=365.25, fourier_order=fourier_ye

    model.fit(df_train)
    fechas = pd.date_range(start=df_test.index.min(), end=df_test.index.max(), f
    future = model.make_future_dataframe(periods=len(fechas), freq='B')
    pred_test = model.predict(future)
    pred_test.index = pred_test["ds"]
    pred_test = pred_test["yhat"]
    pred_test = pred_test[-len(df_test):]

    predictions_test.append(pred_test)
    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": model,
        "name": titulos[i],
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

```
13:00:15 - cmdstanpy - INFO - Chain [1] start processing
13:00:15 - cmdstanpy - INFO - Chain [1] done processing
13:00:16 - cmdstanpy - INFO - Chain [1] start processing
13:00:16 - cmdstanpy - INFO - Chain [1] done processing
13:00:17 - cmdstanpy - INFO - Chain [1] start processing
13:00:17 - cmdstanpy - INFO - Chain [1] done processing
```

In [5]:
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=dataframes_train,
    dataframes_test=dataframes_test,
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2024-07-01'
))
```

	model	name	len_train	len_test	
0	<prophet.forecaster.Prophet object at 0x000002...	CHU_COPA_AJUST	1730	30	
1	<prophet.forecaster.Prophet object at 0x000002...	CHU_REC_PROPIOS_AJUST	2187	30	
2	<prophet.forecaster.Prophet object at 0x000002...	CHU_REGALIAS_AJUST	2176	30	2,422,839,158,73



None

In [ ]:

XBOOST

TEST 30 DÍAS

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
import xgboost as xgb
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
def extract_time_features(index):
    return pd.Series({
        'dayofweek': index.dayofweek,
        'quarter': index.quarter,
        'month': index.month,
        'year': index.year,
        'dayofyear': index.dayofyear,
        'dayofmonth': index.day,
        'weekofyear': index.isocalendar().week
    })
def add_lags(df, titulo):
    target_map = df[titulo].to_dict()
    df['lag1'] = (df.index - pd.Timedelta('364 days')).map(target_map) # df_1['P
    df['lag2'] = (df.index - pd.Timedelta('728 days')).map(target_map) # df_1['P
    df['lag3'] = (df.index - pd.Timedelta('1092 days')).map(target_map) # df_1['
    return df

for i in range(len(dataframes)):
    time_features = dataframes[i].index.to_series().apply(extract_time_features)
    dataframes[i] = pd.concat([dataframes[i], time_features], axis=1)
    dataframes[i] = add_lags(dataframes[i], titulos[i])
```

In [4]:
```python
# TRAIN TEST
n_test = 30
train_copa = dataframes[0].iloc[:-n_test]
test_copa = dataframes[0].iloc[-n_test:]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")
```

```
train_recursos = dataframes[1].iloc[:-n_test]
test_recursos = dataframes[1].iloc[-n_test:]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:-n_test]
test_regalias = dataframes[2].iloc[-n_test:]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

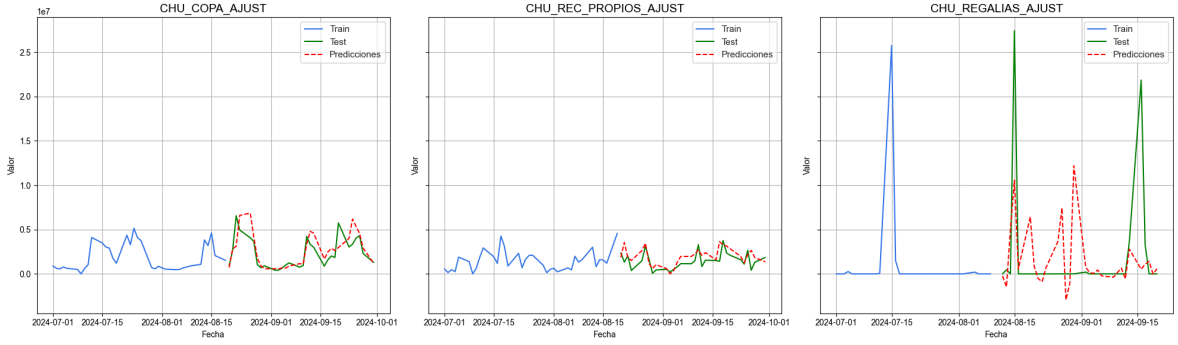
```
Coparticipacion: train((1730, 11)), test((30, 11))
Recursos: train((2187, 11)), test((30, 11))
Regalias: train((2176, 11)), test((30, 11))
```

In [ ]:

```
results_train_test = []
predictions_test = []
best_params = pd.read_csv("xgb_best_params.csv",sep=";")

for i, df_train in enumerate(dataframes_train):

    params = eval(best_params.iloc[i]["best_params"])

    FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmon
    TARGET = titulos[i]

    df_test = dataframes_test[i][TARGET]
    model = xgb.XGBRegressor(**params )

    X_train = dataframes_train[i][FEATURES]
    y_train = dataframes_train[i][TARGET]
    X_test= dataframes_test[i][FEATURES]
    y_test= dataframes_test[i][TARGET]

    model.fit(
        X_train, y_train,
        eval_set=[(X_test, y_test)]
    )

    pred_test = model.predict(X_test)
    pred_test = pd.Series(pred_test, index=dataframes_test[i].index)
    predictions_test.append(pred_test)

    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": model,
        "name": titulos[i],
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [6]:
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=[pd.Series(dataframes_train[i][titulos[i]], index=dataframe
    dataframes_test=[pd.Series(dataframes_test[i][titulos[i]], index=dataframes_
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2024-07-01'
))
```

	model	name	len_train	len_test	
0	XGBRegressor(base_score=None, booster=None, ca...	CHU_COPA_AJUST	1730	30	
1	XGBRegressor(base_score=None, booster=None, ca...	CHU_REC_PROPIOS_AJUST	2187	30	
2	XGBRegressor(base_score=None, booster=None, ca...	CHU_REGALIAS_AJUST	2176	30	5,880,061,7



None

In [ ]:

LIGHTGBM

TEST 30 DÍAS

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from prophet import Prophet
from prophet.diagnostics import cross_validation
from prophet.diagnostics import performance_metrics
import matplotlib.pyplot as plt
from prophet.plot import plot_cross_validation_metric
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import funciones
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
def extract_time_features(index):
    return pd.Series({
        'dayofweek': index.dayofweek,
        'quarter': index.quarter,
        'month': index.month,
        'year': index.year,
        'dayofyear': index.dayofyear,
        'dayofmonth': index.day,
        'weekofyear': index.isocalendar().week
    })
def add_lags(df, titulo):
    target_map = df[titulo].to_dict()
    df['lag1'] = (df.index - pd.Timedelta('364 days')).map(target_map) # df_1['P
    df['lag2'] = (df.index - pd.Timedelta('728 days')).map(target_map) # df_1['P
    df['lag3'] = (df.index - pd.Timedelta('1092 days')).map(target_map) # df_1['
    return df

for i in range(len(dataframes)):
    time_features = dataframes[i].index.to_series().apply(extract_time_features)
    dataframes[i] = pd.concat([dataframes[i], time_features], axis=1)
    dataframes[i] = add_lags(dataframes[i], titulos[i])
```

In [4]:
```python
# TRAIN TEST
n_test = 30
train_copa = dataframes[0].iloc[:-n_test]
test_copa = dataframes[0].iloc[-n_test:]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:-n_test]
```

```
test_recursos = dataframes[1].iloc[-n_test:]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:-n_test]
test_regalias = dataframes[2].iloc[-n_test:]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

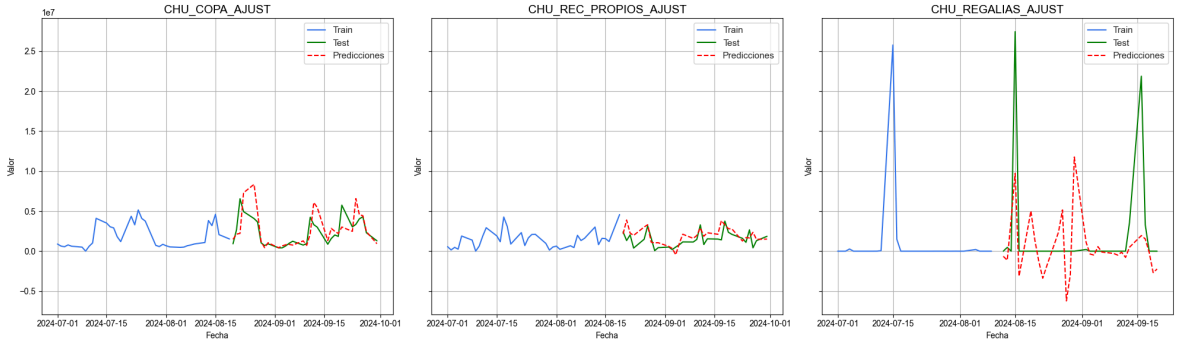
```
Coparticipacion: train((1730, 11)), test((30, 11))
Recursos: train((2187, 11)), test((30, 11))
Regalias: train((2176, 11)), test((30, 11))
```

In [ ]:

```
results_train_test = []
predictions_test = []
best_params = pd.read_csv("lgbm_best_params.csv",sep=";")
import lightgbm as lgb

for i, df_train in enumerate(dataframes_train):

    params = eval(best_params.iloc[i]["best_params"])

    FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmon
    TARGET = titulos[i]

    df_test = dataframes_test[i][TARGET]
    model = lgb.LGBMRegressor(**params )

    X_train = dataframes_train[i][FEATURES]
    y_train = dataframes_train[i][TARGET]
    X_test= dataframes_test[i][FEATURES]
    y_test= dataframes_test[i][TARGET]

    model.fit(df_train[FEATURES], df_train[TARGET],
              eval_set=[(X_train, y_train), (X_test, y_test)], eval_metric="rmse

    pred_test = model.predict(dataframes_test[i][FEATURES])
    pred_test = pd.Series(pred_test, index=dataframes_test[i].index)
    predictions_test.append(pred_test)

    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": model,
        "name": titulos[i],
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [6]:
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=[pd.Series(dataframes_train[i][titulos[i]], index=dataframe
    dataframes_test=[pd.Series(dataframes_test[i][titulos[i]], index=dataframes_
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2024-07-01'
))
```

	model	name	len_train	l
0	LGBMRegressor(colsample_bytree=0.8076995248364...	CHU_COPA_AJUST	1730	
1	LGBMRegressor(colsample_bytree=0.5125884353625...	CHU_REC_PROPIOS_AJUST	2187	
2	LGBMRegressor(colsample_bytree=0.8651927912102...	CHU_REGALIAS_AJUST	2176	



None

In [ ]:

AUTOTS

TEST 30 DÍAS

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from autots import AutoTS
import matplotlib.pyplot as plt
import funciones
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
# TRAIN TEST
n_test = 30
train_copa = dataframes[0].iloc[:-n_test]
test_copa = dataframes[0].iloc[-n_test:]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:-n_test]
test_recursos = dataframes[1].iloc[-n_test:]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:-n_test]
test_regalias = dataframes[2].iloc[-n_test:]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1730,)), test((30,))
Recursos: train((2187,)), test((30,))
Regalias: train((2176,)), test((30,))
```

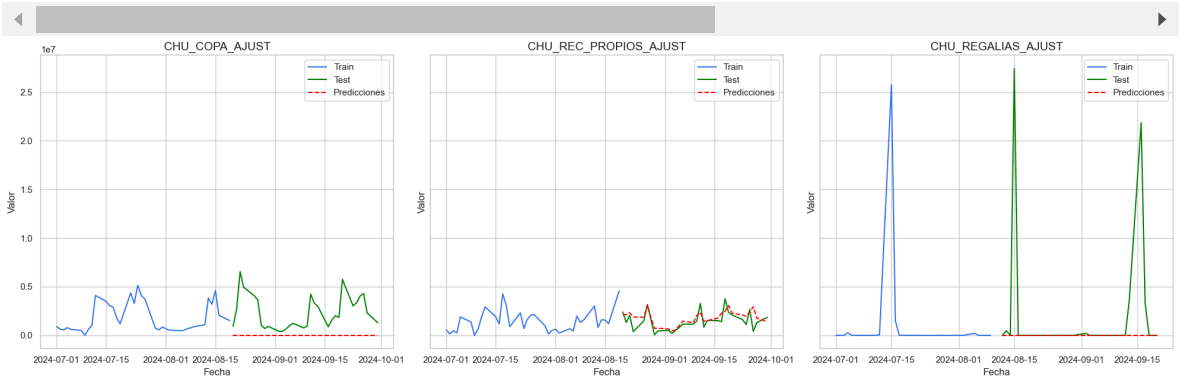
In [ ]:
```python
results_train_test = []
predictions_test = []
for i, df in enumerate(dataframes_train):
    df_train = df
    df_test = dataframes_test[i]

    model = AutoTS(
        forecast_length=len(dataframes_test[i]),
        frequency="B",
        prediction_interval=0.95,
        ensemble=None,
        models_mode='deep',
        model_list = 'superfast',
```

```
        max_generations=10,   # intenta optimizar el modelo a traves de 10 itera
        num_validations=3,
        no_negatives=True,
        n_jobs='auto')
    modelAutoTS = model.fit(df_train)
    # Find the best parameters

    fechas = pd.date_range(start=df_test.index.min(), end=df_test.index.max(), f
    pred_test = model.predict(forecast_length=len(fechas)).forecast
    predictions_test.append(pred_test)
    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": modelAutoTS,
        "name": df_train.name,
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [7]:

```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=dataframes_train,
    dataframes_test=dataframes_test,
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2024-07-01'
))
```

	model	name	len_train	len_test	mape_test	mse_test
0	Initiated AutoTS object with best model: \nLas...	CHU_COPA_AJUST	1730	30	1.00	8,545,162,889,493.53
1	Initiated AutoTS object with best model: \nSea...	CHU_REC_PROPIOS_AJUST	2187	30	0.99	547,894,342,942.74
2	Initiated AutoTS object with best model: \nSea...	CHU_REGALIAS_AJUST	2176	30	0.27	41,804,929,164,773.93



None

In [6]:
```
results = pd.DataFrame(results_train_test)

for i, row in results.iterrows():
    display(row["name"])
    print(row.model)
```

'CHU_COPA_AJUST'

```
Initiated AutoTS object with best model:
LastValueNaive
{'fillna': 'quadratic', 'transformations': {'0': 'RollingMeanTransformer', '1':
'AnomalyRemoval', '2': 'bkfilter', '3': 'ScipyFilter'}, 'transformation_params':
{'0': {'fixed': True, 'window': 360, 'macro_micro': True, 'center': True}, '1':
{'method': 'zscore', 'method_params': {'distribution': 'uniform', 'alpha': 0.05},
'fillna': 'ffill', 'transform_dict': {'fillna': None, 'transformations': {'0': 'E
WMAFilter'}, 'transformation_params': {'0': {'span': 7}}}, 'isolated_only': Fals
e}, '2': {}, '3': {'method': 'butter', 'method_args': {'N': 2, 'btype': 'highpas
s', 'analog': False, 'output': 'sos', 'Wn': 0.015384615384615385}}}}
{}
Validation: 0, 1, 2, 3
SMAPE: 80.45022147190438, nan, nan, nan
MAE: 1457881.601770488, 1754848.8054795982, 3351528.787366555, 1944707.5176069036
SPL: 0.18310796907270413, 0.3516077000937226, 1.516704946141438, 0.23639689726808
616
'CHU_REC_PROPIOS_AJUST'
Initiated AutoTS object with best model:
SeasonalityMotif
{'fillna': 'akima', 'transformations': {'0': 'PositiveShift', '1': 'Detrend'}, 't
ransformation_params': {'0': {}, '1': {'model': 'GLS', 'phi': 1, 'window': 365,
'transform_dict': None}}}
{'window': 15, 'point_method': 'midhinge', 'distance_metric': 'mae', 'k': 20, 'da
tepart_method': 'simple', 'independent': False}
Validation: 0, 1, 2, 3
SMAPE: 46.63511981455654, 81.92051984679205, 67.9873722891953, 59.817692083104504
MAE: 672472.5785951081, 1013335.51811632, 1024976.4424628529, 665533.8818280211
SPL: 0.14172371881288814, 0.22842532323077214, 0.16493539716519867, 0.16548226664
122395
'CHU_REGALIAS_AJUST'
Initiated AutoTS object with best model:
SeasonalityMotif
{'fillna': 'ffill', 'transformations': {'0': 'CenterLastValue', '1': 'QuantileTra
nsformer'}, 'transformation_params': {'0': {'rows': 6}, '1': {'output_distributio
n': 'uniform', 'n_quantiles': 1000}}}
{'window': 15, 'point_method': 'midhinge', 'distance_metric': 'mse', 'k': 20, 'da
tepart_method': 'simple', 'independent': True}
Validation: 0, 1, 2, 3
SMAPE: nan, nan, nan, nan
MAE: 926159.4666666667, 1861666.2666666666, 1564803.1333333333, 2344361.266666666
6
SPL: 0.19809204672333816, 0.5484111223643126, 0.21565462335433694, 0.159545677128
9861
```

In [ ]:

TIME-GPT

TEST 30 DÍAS

In [1]:
```python
# Python
import itertools
import numpy as np
import pandas as pd
import pandas as pd
import numpy as np
from autots import AutoTS
import matplotlib.pyplot as plt
import funciones
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
```

In [2]:
```python
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
for i in range(len(dataframes)):
  dataframes[i] = dataframes[i].reindex(pd.date_range(start=dataframes[i].index.
  dataframes[i] = dataframes[i].fillna(0)

titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```python
# TRAIN TEST
n_test = 30
train_copa = dataframes[0].iloc[:-n_test]
test_copa = dataframes[0].iloc[-n_test:]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:-n_test]
test_recursos = dataframes[1].iloc[-n_test:]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:-n_test]
test_regalias = dataframes[2].iloc[-n_test:]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1730,)), test((30,))
Recursos: train((2187,)), test((30,))
Regalias: train((2176,)), test((30,))
```

In [4]:
```python
from nixtla import NixtlaClient
import warnings
warnings.filterwarnings("ignore")
pd.options.display.float_format = '{:,.2f}'.format
nixtla_client = NixtlaClient(
    # defaults to os.environ.get("NIXTLA_API_KEY")
    api_key = 'nixak-P7309LQjFeXHr6GYXQlH41AsZEadk15X66HvvheepbODf11yrBGLBt6bPxX
)
```

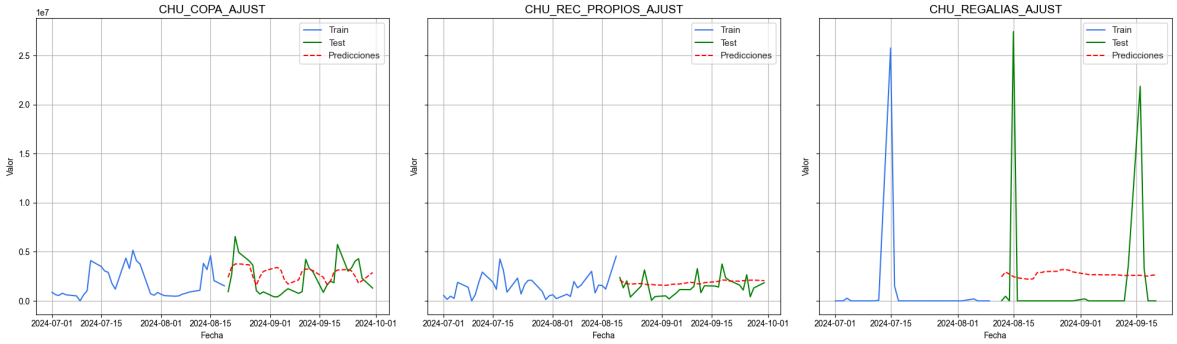
In [ ]:
```python
results_train_test = []
predictions_test = []
forecast = []
for i, df in enumerate(dataframes_train):
```

```
    name = df.name
    df_train = df.to_frame()
    df_train = df_train.reset_index()
    df_test = dataframes_test[i]
    fechas = pd.date_range(start=df_test.index.min(), end=df_test.index.max(), f

    response = nixtla_client.forecast(
    df=df_train,  # Entrenamiento solo con los datos de train
    time_col="index",  # Nombre del índice de tiempo (columna de fecha)
    target_col=name,  # Columna objetivo
    freq="B",  # Frecuencia de los datos (diaria)
    h=len(fechas),  # El tamaño del conjunto de test
    level=[80],  # Niveles de confianza
    finetune_loss='rmse',
    finetune_steps=20,
    )
    # Convertir la respuesta a DataFrame
    forecast_df = pd.DataFrame(response)
    forecast.append(forecast_df)
    # Find the best parameters

    pred_test = forecast_df["TimeGPT"].values
    pred_test = pd.Series(pred_test, index=df_test.index)
    predictions_test.append(pred_test)
    # Cálculo del MSE en el conjunto de prueba
    mape_test = mean_absolute_percentage_error(df_test, pred_test)
    mape_mean = mean_absolute_percentage_error(df_test, [df_test.mean()] * len(d
    mse_test = mean_squared_error(df_test, pred_test)
    mae_test = mean_absolute_error(df_test, pred_test)
    rmse = np.sqrt(mean_squared_error(df_test, pred_test))
    results_train_test.append({
        "model": "TimeGPT",
        "name": name,
        "len_train": len(df_train),
        "len_test": len(df_test),
        "mape_test": mape_test,
        "mse_test":mse_test,
        "mape_mean": mape_mean,
        "mae_test": mae_test,
        "rmse": rmse
    })
```

In [6]:

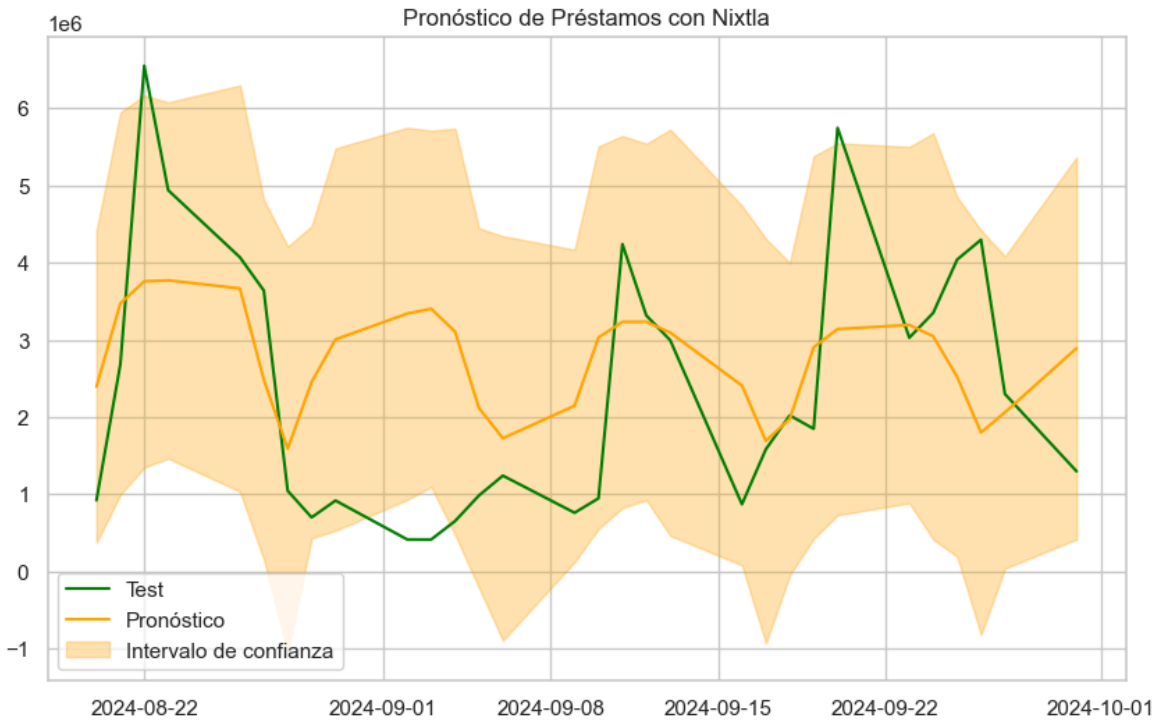
```
pd.options.display.float_format = '{:,.2f}'.format
display(pd.DataFrame(results_train_test))

display(funciones.plot_train_test_predictions(
    dataframes_train=dataframes_train,
    dataframes_test=dataframes_test,
    predictions_test=predictions_test,
    series_names=titulos,
    start_date='2024-07-01'
))
```

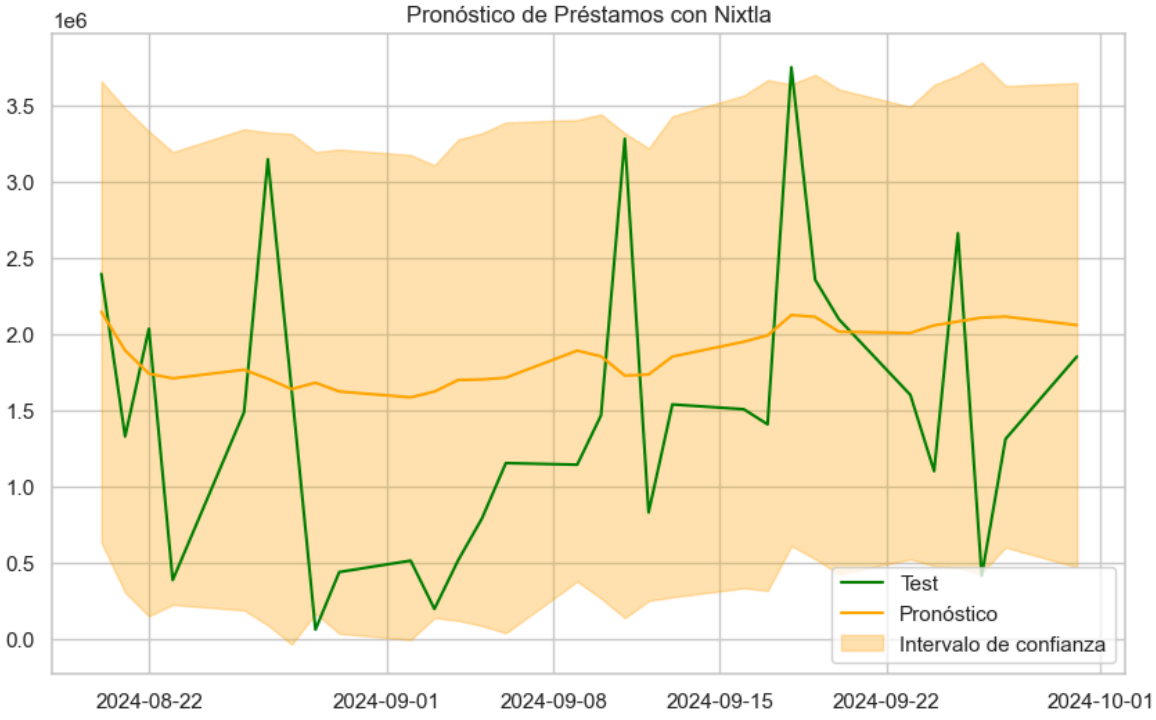
	model	name	len_train	len_test	mape_test
0	TimeGPT	CHU_COPA_AJUST	1730	30	1.25
1	TimeGPT	CHU_REC_PROPIOS_AJUST	2187	30	1.90
2	TimeGPT	CHU_REGALIAS_AJUST	2176	30	8,908,123,590,758,549,684,224.00

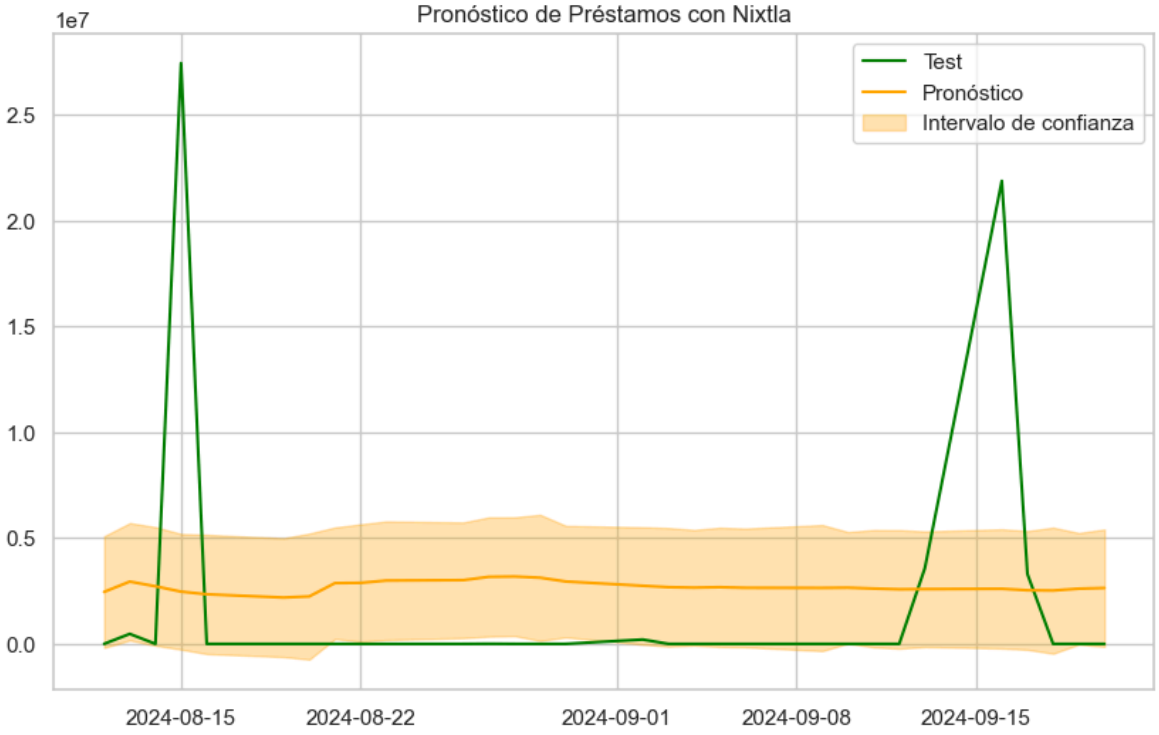


None

In [66]:
```
import matplotlib.pyplot as plt
def plot_pred(i):
  plt.figure(figsize=(10, 6))
  #plt.plot(train.index, train['CHU_COPA_AJUST'], label='Train', color='blue')
  plt.plot(dataframes_test[i].index, dataframes_test[i], label='Test', color='gr
  plt.plot(predictions_test[i].index, predictions_test[i], label='Pronóstico', c
  plt.fill_between(
      forecast[i]["index"],
      forecast[i]["TimeGPT-lo-80"],
      forecast[i]["TimeGPT-hi-80"],
      color='orange',
      alpha=0.3,
      label='Intervalo de confianza'
  )
  plt.legend()
  plt.title("Pronóstico de Préstamos con Nixtla")
  plt.show()
for i in range(len(dataframes_test)):
  plot_pred(i)
```


Pronóstico de Préstamos con Nixtla
1e6
6
5
4
3
2
1
0
−1
Test
Pronóstico
Intervalo de confianza
2024-08-22
2024-09-01
2024-09-08
2024-09-15
2024-09-22
2024-10-01


Pronóstico de Préstamos con Nixtla
1e6
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Test
Pronóstico
Intervalo de confianza
2024-08-22
2024-09-01
2024-09-08
2024-09-15
2024-09-22
2024-10-01


Pronóstico de Préstamos con Nixtla
1e7
2.5
2.0
1.5
1.0
0.5
0.0
2024-08-15
2024-08-22
2024-09-01
2024-09-08
2024-09-15
Test
Pronóstico
Intervalo de confianza

HIPER PARAMETROS OPTIMIZADOS

PROPHET

df	best_params
CHU_COPA_AJUST	{'changepoint_prior_scale': 0.1, 'seasonality_prior_scale': 0.01, 'daily_seasonality': True, 'yearly_seasonality': True, 'holidays_prior_scale': 0.01, 'seasonality_mode': 'additive', 'changepoint_range': 0.8}
CHU_REC_PROPIOS_AJUST	{'changepoint_prior_scale': 0.001, 'seasonality_prior_scale': 10.0, 'daily_seasonality': True, 'yearly_seasonality': True, 'holidays_prior_scale': 0.01, 'seasonality_mode': 'additive', 'changepoint_range': 0.9}
CHU_REGALIAS_AJUST	{'changepoint_prior_scale': 0.5, 'seasonality_prior_scale': 0.1, 'daily_seasonality': True, 'yearly_seasonality': False, 'holidays_prior_scale': 0.01, 'seasonality_mode': 'multiplicative', 'changepoint_range': 0.8}

PROPHET FOURIER ORDER

df	Fourier_yearly	Fourier_monthly
CHU_COPA_AJUST	{'fourier_order': 5, 'rmse': 2114568.5994672766}	{'fourier_order': 3, 'rmse': 1829278.0979960766}
CHU_REC_PROPIOS_AJUST	{'fourier_order': 10, 'rmse': 1241865.2497155124}	{'fourier_order': 3, 'rmse': 1160714.3127307887}
CHU_REGALIAS_AJUST	{'fourier_order': 3, 'rmse': 6054561.279307909}	{'fourier_order': 3, 'rmse': 5786977.886510033}

XGBOOST

df	best_params
CHU_COPA_AJUST	{'n_estimators': 453, 'learning_rate': 0.052251207169970344, 'max_depth': 3, 'min_child_weight': 2, 'subsample': 0.9052659212939362, 'colsample_bytree': 0.9700609066338445, 'gamma': 0.4972981188401708, 'reg_alpha': 0.49902287558195313, 'reg_lambda': 1.390212005740913}
CHU_REC_PROPIOS_AJUST	{'n_estimators': 370, 'learning_rate': 0.07063010235445233, 'max_depth': 7, 'min_child_weight': 4, 'subsample': 0.6846124207200684, 'colsample_bytree': 0.7520959246442501, 'gamma': 0.34727747835872463, 'reg_alpha': 0.10152547979284736, 'reg_lambda': 1.4618068656153174}
CHU_REGALIAS_AJUST	{'n_estimators': 500, 'learning_rate': 0.09909913615269426, 'max_depth': 7, 'min_child_weight': 2, 'subsample': 0.708172616764662, 'colsample_bytree': 0.9508794978508508, 'gamma': 0.49887376061225946, 'reg_alpha': 0.26891921056341245, 'reg_lambda': 0.5637625884315804}

LIGHTGBM

df	best_params
CHU_COPA_AJUST	{'n_estimators': 1670, 'learning_rate': 0.05434009138012196, 'max_depth': 9, 'num_leaves': 43, 'min_child_samples': 27, 'subsample': 0.9577724287559277, 'colsample_bytree': 0.8076995248364037, 'reg_alpha': 0.014464297652987318, 'reg_lambda': 0.6299036642292266}
CHU_REC_PROPIOS_AJUST	{'n_estimators': 1236, 'learning_rate': 0.048922724434304524, 'max_depth': 8, 'num_leaves': 79, 'min_child_samples': 33, 'subsample': 0.7343992892058865, 'colsample_bytree': 0.5125884353625726, 'reg_alpha': 0.09322166284457188, 'reg_lambda': 0.7334602723962557}
CHU_REGALIAS_AJUST	{'n_estimators': 1330, 'learning_rate': 0.09969430566201748, 'max_depth': 9, 'num_leaves': 42, 'min_child_samples': 10, 'subsample': 0.5086757934277606, 'colsample_bytree': 0.8651927912102433, 'reg_alpha': 0.40673825228466354, 'reg_lambda': 0.012809939668950783}

LIGHTGBM

Five Fold Cross Validation

LightGBM

In [1]:
```
import numpy as np
import pandas as pd
from IPython.display import display, HTML
import importlib

import plotly.express as px
import matplotlib.pyplot as plt
import statsmodels.api as sm

from sklearn.metrics import mean_absolute_error, mean_squared_error, mean_absolu

import warnings
import os
import pickle

warnings.filterwarnings("ignore")
pd.options.display.float_format = '{:,.2f}'.format
```

In [2]:
```
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [3]:
```
def extract_time_features(index):
    return pd.Series({
        'dayofweek': index.dayofweek,
        'quarter': index.quarter,
        'month': index.month,
        'year': index.year,
        'dayofyear': index.dayofyear,
        'dayofmonth': index.day,
        'weekofyear': index.isocalendar().week
    })


def add_lags(df, titulo):
    target_map = df[titulo].to_dict()
    df['lag1'] = (df.index - pd.Timedelta('364 days')).map(target_map) # df_1['P
    df['lag2'] = (df.index - pd.Timedelta('728 days')).map(target_map) # df_1['P
    df['lag3'] = (df.index - pd.Timedelta('1092 days')).map(target_map) # df_1['
    return df
```

In [4]:
```
time_features = dataframes[0].index.to_series().apply(extract_time_features)
dataframes[0] = pd.concat([dataframes[0], time_features], axis=1)
dataframes[0] = add_lags(dataframes[0], titulos[0])

time_features = dataframes[1].index.to_series().apply(extract_time_features)
dataframes[1] = pd.concat([dataframes[1], time_features], axis=1)
dataframes[1] = add_lags(dataframes[1], titulos[1])
```

```
time_features = dataframes[2].index.to_series().apply(extract_time_features)
dataframes[2] = pd.concat([dataframes[2], time_features], axis=1)
dataframes[2] = add_lags(dataframes[2], titulos[2])
```

In [5]:
```
dataframes[2].head()
```

Out[5]:

FECHA	CHU_REGALIAS_AJUST	dayofweek	quarter	month	year	dayofyear	dayofmo
2016-04-08	212,159.00	4	2	4	2016	99	
2016-04-14	26,246.00	3	2	4	2016	105	
2016-04-15	16,002,725.00	4	2	4	2016	106	
2016-04-20	5,582.00	2	2	4	2016	111	
2016-04-29	11,066,374.00	4	2	4	2016	120	

In [6]:
```
# TRAIN TEST
dataframes_train = []
dataframes_test = []

# for i in range(3):
#     train = dataframes[i].iloc[:round(len(dataframes[0])*.8)]
#     test = dataframes[i].iloc[round(len(dataframes[0])*.8):]
#     dataframes_train.append(train)
#     dataframes_test.append(test)

train_copa = dataframes[0].iloc[:round(len(dataframes[0])*.8)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*.8):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*.8)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*.8):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*.8)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*.8):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1275, 11)), test((319, 11))
Recursos: train((1626, 11)), test((406, 11))
Regalias: train((460, 11)), test((115, 11))
```

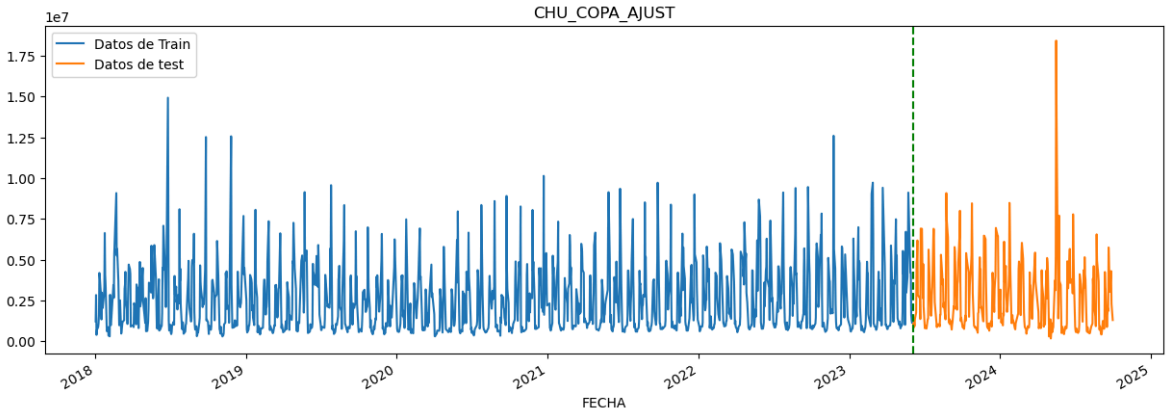
In [7]:
```
train_recursos.head()
```

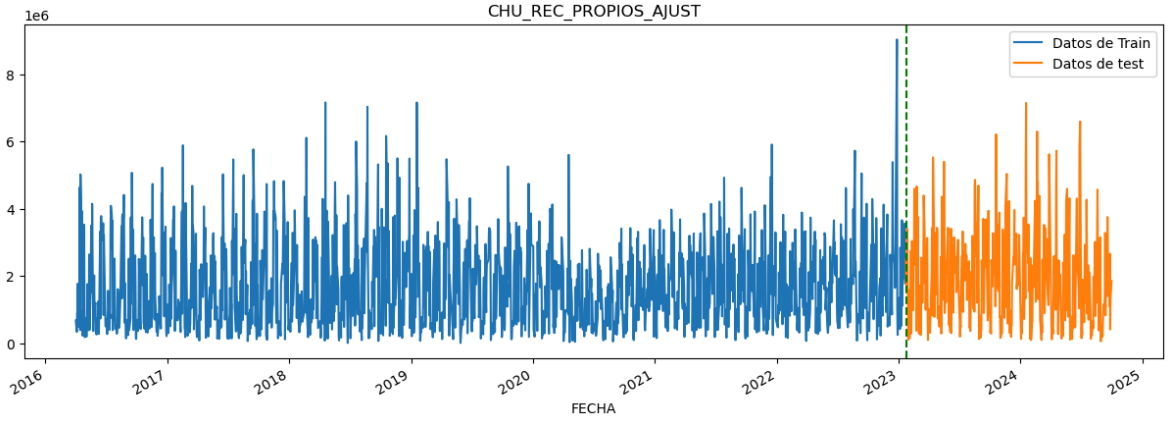
Out[7]:

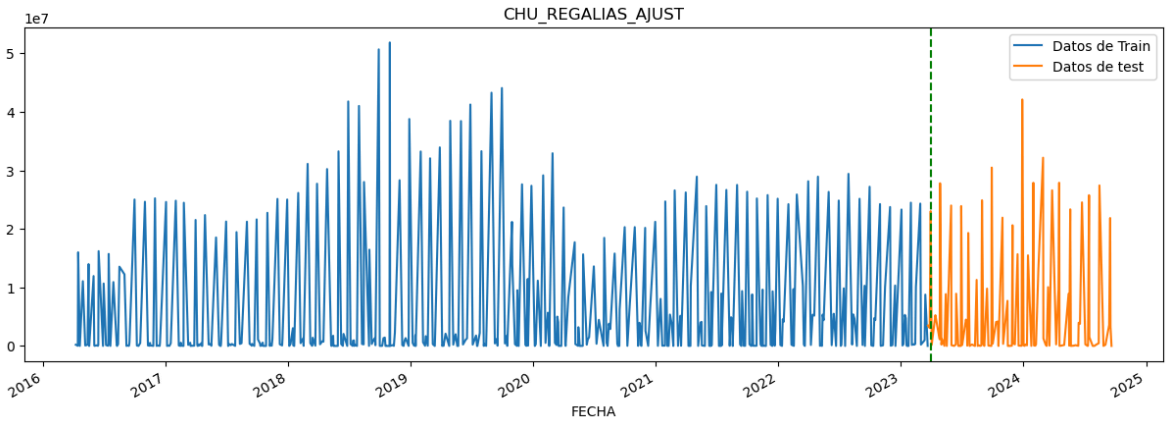
FECHA	CHU_REC_PROPIOS_AJUST	dayofweek	quarter	month	year	dayofyear	dayof
2016-04-01	679233	4	2	4	2016	92	
2016-04-04	339379	0	2	4	2016	95	
2016-04-05	903634	1	2	4	2016	96	
2016-04-06	858197	2	2	4	2016	97	
2016-04-07	1774956	3	2	4	2016	98	

In [7]:

```
for i in range(len(dataframes)):
    # Separamos los datos en train y test
    fig, ax = plt.subplots(figsize=(15, 5))

    dataframes_train[i][titulos[i]].plot(ax=ax, label='Datos de Train', title=f'
    dataframes_test[i][titulos[i]].plot(ax=ax, label='Datos de test')
    ax.axvline(f'{dataframes_test[i].index[i]}', color='green', ls='--')
    ax.legend(['Datos de Train', 'Datos de test'])
    plt.show()
```







In [8]:
```
FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmonth',
TARGET = 'CHU_COPA_AJUST'
```

In [9]:
```
X_train = dataframes_train[0][FEATURES]
y_train = dataframes_train[0][TARGET]

X_test = dataframes_test[0][FEATURES]
y_test = dataframes_test[0][TARGET]
```

In [62]:
```
import optuna
import lightgbm as lgb
import numpy as np
from sklearn.model_selection import TimeSeriesSplit
from sklearn.metrics import mean_squared_error



def objective(trial, df):
    param = {
        "n_estimators": trial.suggest_int("n_estimators", 500, 2000),
        "learning_rate": trial.suggest_loguniform("learning_rate", 0.001, 0.1),
        "max_depth": trial.suggest_int("max_depth", 3, 10),
        "num_leaves": trial.suggest_int("num_leaves", 20, 150),
        "min_child_samples": trial.suggest_int("min_child_samples", 10, 100),
        "subsample": trial.suggest_uniform("subsample", 0.5, 1.0),
        "colsample_bytree": trial.suggest_uniform("colsample_bytree", 0.5, 1.0),
        "reg_alpha": trial.suggest_loguniform("reg_alpha", 0.01, 1.0),
        "reg_lambda": trial.suggest_loguniform("reg_lambda", 0.01, 1.0),
        "random_state": 42,
    }

    test_size = 100
    tss = TimeSeriesSplit(n_splits=5, test_size=252, gap=7) # 252 son los dias h
    df = df.sort_index()
    scores = []

    for train_idx, val_idx in tss.split(df):
        train = df.iloc[train_idx]
        test = df.iloc[val_idx]

        FEATURES = ['dayofyear', 'dayofweek', 'quarter', 'month', 'year',
                    'lag1', 'lag2', 'lag3']
        TARGET = df.columns[0]

        # Verificar características y dropna
        #assert all(feature in train.columns for feature in FEATURES), "Faltan c
```

```
        #assert all(feature in test.columns for feature in FEATURES), "Faltan co

        # X_train = train[FEATURES].dropna()
        # y_train = train[TARGET].loc[X_train.index]
        # X_test = test[FEATURES].dropna()
        # y_test = test[TARGET].loc[X_test.index]

        # if X_train.empty or X_test.empty:
        #     raise ValueError("X_train o X_test está vacío después de dropna")

        X_train = train[FEATURES]
        y_train = train[TARGET]

        X_test = test[FEATURES]
        y_test = test[TARGET]

        model = lgb.LGBMRegressor(**param, early_stopping_rounds=50)
        model.fit(
            X_train, y_train,
            eval_set=[(X_test, y_test)],
            eval_metric="rmse"
        )

        y_pred = model.predict(X_test)
        rmse = mean_squared_error(y_test, y_pred, squared=False)
        scores.append(rmse)

    return np.mean(scores)
```

In [27]:
```
df = dataframes[0].copy()
# df = df[df.index.year != 2024]

# # Agrupar por año y contar los datos
# counts_per_year = df.resample('Y').size()

# # Mostrar el conteo
# print(counts_per_year)
```

In [ ]:
```
# Ejecutar la optimización con Optuna
# df = dataframes_train[0].copy() ### ACACAACACACACACACACA
df = dataframes[0].copy() ### ACA TORTUGA: TODO EL DATASET O SOLO TRAIN ???
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective(trial, df), n_trials=100)


copa_best_params = study.best_params
copa_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para COPA:", study.best_params)
print("Mejor RMSE promedio para COPA:", study.best_value)
```

RMSE promedio para COPA: 1718582.9603018877

In [ ]:
```
# Ejecutar la optimización con Optuna
# df = dataframes_train[1].copy()
df = dataframes[1].copy() # ACA TORTUGON
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective(trial, df), n_trials=100)
```

```
rec_propios_best_params = study.best_params
rec_propios_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para REC_PROPIOS:", study.best_params)
print("Mejor RMSE promedio para REC_PROPIOS:", study.best_value)
```

In [35]:
```
df = df_main["CHU_REGALIAS_AJUST"]
df.head(20)
# df = df[df.index.year != 2024]

# # Agrupar por año y contar los datos
# counts_per_year = df.resample('Y').size()

# # # Mostrar el conteo
# print(counts_per_year)
```

Out[35]:
```
FECHA
2016-04-01             NaN
2016-04-04             NaN
2016-04-05             NaN
2016-04-06             NaN
2016-04-07             NaN
2016-04-08      212,159.00
2016-04-11             NaN
2016-04-12             NaN
2016-04-13             NaN
2016-04-14       26,246.00
2016-04-15   16,002,725.00
2016-04-18             NaN
2016-04-19             NaN
2016-04-20        5,582.00
2016-04-21             NaN
2016-04-22             NaN
2016-04-25             NaN
2016-04-26             NaN
2016-04-27             NaN
2016-04-28             NaN
Name: CHU_REGALIAS_AJUST, dtype: float64
```

In [ ]:
```
# Ejecutar la optimización con Optuna
# df = dataframes_train[1].copy()
df = dataframes[2].copy() # ACA TORTUGON
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective(trial, df), n_trials=100)



regalias_best_params = study.best_params
regalias_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para REGALIAS:", study.best_params)
print("Mejor RMSE promedio para REGALIAS:", study.best_value)
```

In [36]:
```
def objective_2(trial, df):

    FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmon
    TARGET = df.columns[0]
```

```
    X_train = df[FEATURES]
    y_train = df[TARGET]

    X_test = df[FEATURES]
    y_test = df[TARGET]

    param = {
        "n_estimators": trial.suggest_int("n_estimators", 500, 2000),
        "learning_rate": trial.suggest_loguniform("learning_rate", 0.001, 0.1),
        "max_depth": trial.suggest_int("max_depth", 3, 10),
        "num_leaves": trial.suggest_int("num_leaves", 20, 150),
        "min_child_samples": trial.suggest_int("min_child_samples", 10, 100),
        "subsample": trial.suggest_uniform("subsample", 0.5, 1.0),
        "colsample_bytree": trial.suggest_uniform("colsample_bytree", 0.5, 1.0),
        "reg_alpha": trial.suggest_loguniform("reg_alpha", 0.01, 1.0),
        "reg_lambda": trial.suggest_loguniform("reg_lambda", 0.01, 1.0),
        "random_state": 42,
    }

    model = lgb.LGBMRegressor(**param, early_stopping_rounds=50)
    model.fit(X_train, y_train, eval_set=[(X_train, y_train), (X_test, y_test)],









    # Puedes usar la métrica de tu preferencia aquí
    y_pred = model.predict(X_test)
    rmse = mean_squared_error(y_test, y_pred, squared=False)
    return rmse
```

In [ ]:
```
# Ejecutar la optimización con Optuna
df = dataframes[2].copy()
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective_2(trial, df), n_trials=100)



regalias_best_params = study.best_params
regalias_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para REGALIAS:", study.best_params)
print("Mejor RMSE promedio para REGALIAS:", study.best_value)
```

In [53]:
```
FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmonth',
TARGET = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]

X_train_COPA = dataframes_train[0][FEATURES]
y_train_COPA = dataframes_train[0][TARGET[0]]
X_test_COPA = dataframes_test[0][FEATURES]
y_test_COPA = dataframes_test[0][TARGET[0]]

X_train_REC_PROPIOS = dataframes_train[1][FEATURES]
y_train_REC_PROPIOS = dataframes_train[1][TARGET[1]]
X_test_REC_PROPIOS = dataframes_test[1][FEATURES]
```

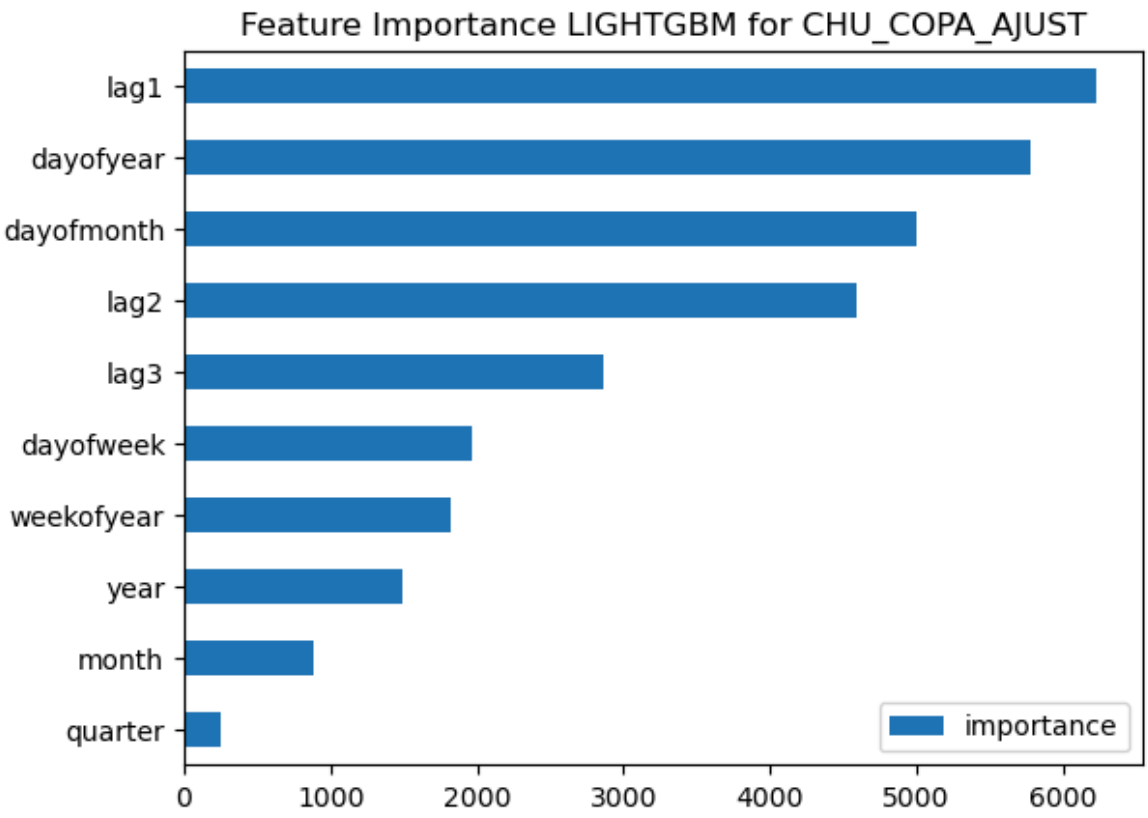
```
y_test_REC_PROPIOS = dataframes_test[1][TARGET[1]]

X_train_REGALIAS = dataframes_train[2][FEATURES]
y_train_REGALIAS = dataframes_train[2][TARGET[2]]
X_test_REGALIAS = dataframes_test[2][FEATURES]
y_test_REGALIAS = dataframes_test[2][TARGET[2]]
```

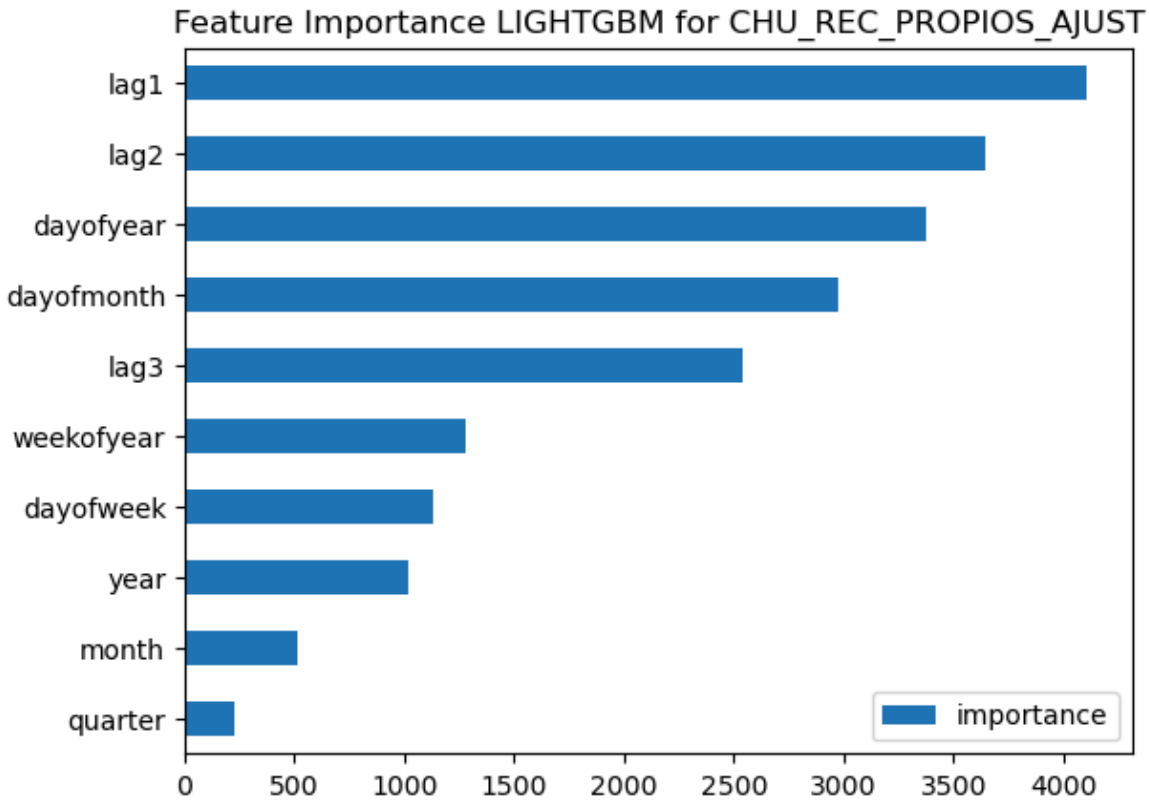
In [ ]:
```
lgb_copa = lgb.LGBMRegressor(**copa_best_params )
lgb_copa.fit(X_train_COPA, y_train_COPA,
        eval_set=[(X_train_COPA, y_train_COPA), (X_test_COPA, y_test_COPA)], eva
```

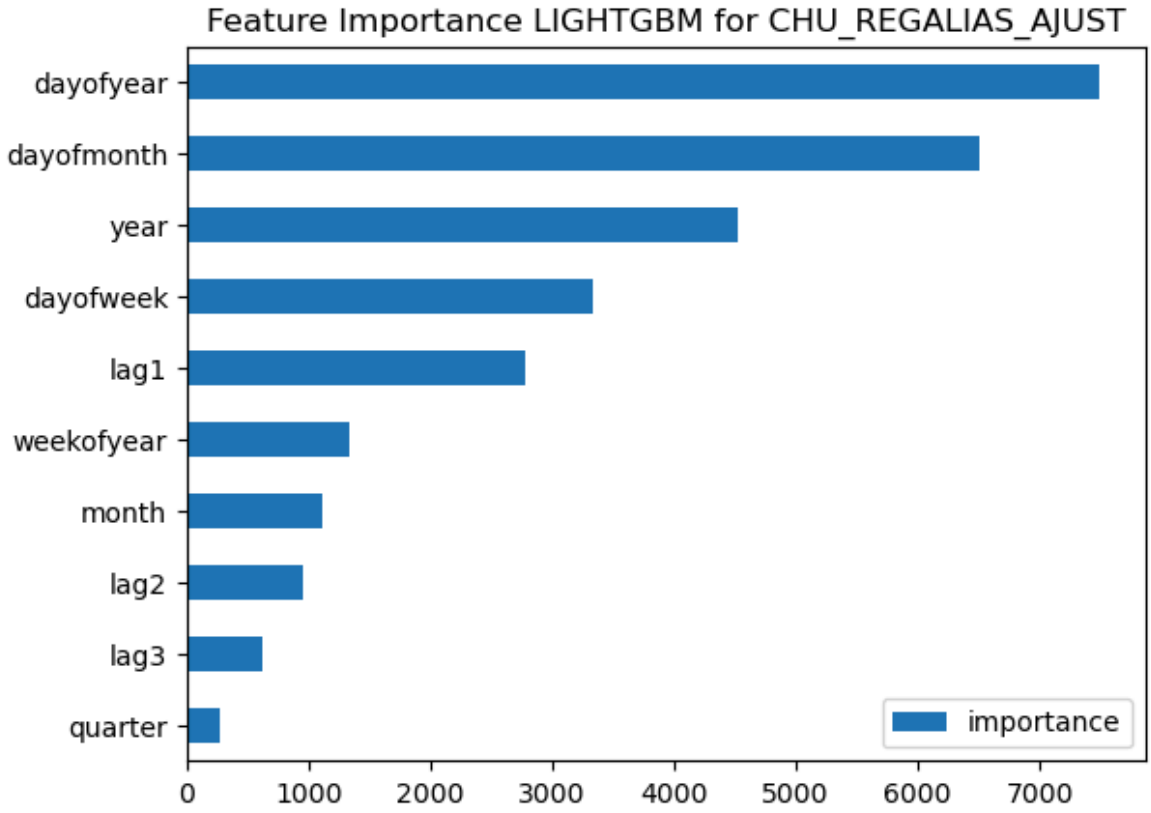
In [ ]:
```
lgb_rec_propios = lgb.LGBMRegressor(**rec_propios_best_params )
lgb_rec_propios.fit(X_train_REC_PROPIOS, y_train_REC_PROPIOS,
        eval_set=[(X_train_REC_PROPIOS, y_train_REC_PROPIOS), (X_test_REC_PROPIO
```

In [ ]:
```
lgb_regalias = lgb.LGBMRegressor(**regalias_best_params )
lgb_regalias.fit(X_train_REGALIAS, y_train_REGALIAS,
        eval_set=[(X_train_REGALIAS, y_train_REGALIAS), (X_test_REGALIAS, y_test
```

In [57]:
```
models = [lgb_copa, lgb_rec_propios, lgb_regalias]
i = 0
for model in models:

    feature_names = model.booster_.feature_name()  # Obtiene nombres desde el mo
    fi = pd.DataFrame(data=model.feature_importances_,
                      index=feature_names,
                      columns=['importance'])
    fi.sort_values('importance').plot(kind='barh', title=f'Feature Importance LI
    i += 1
    plt.show()
```





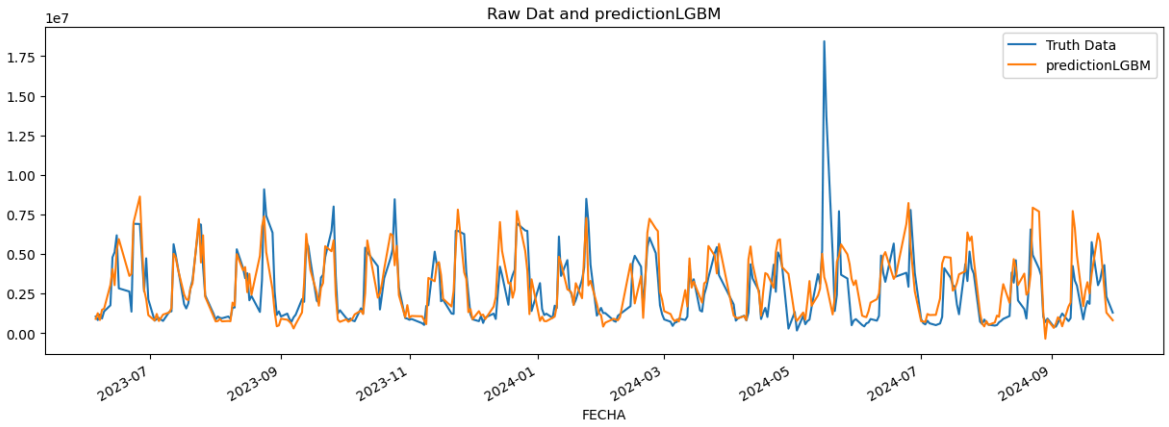


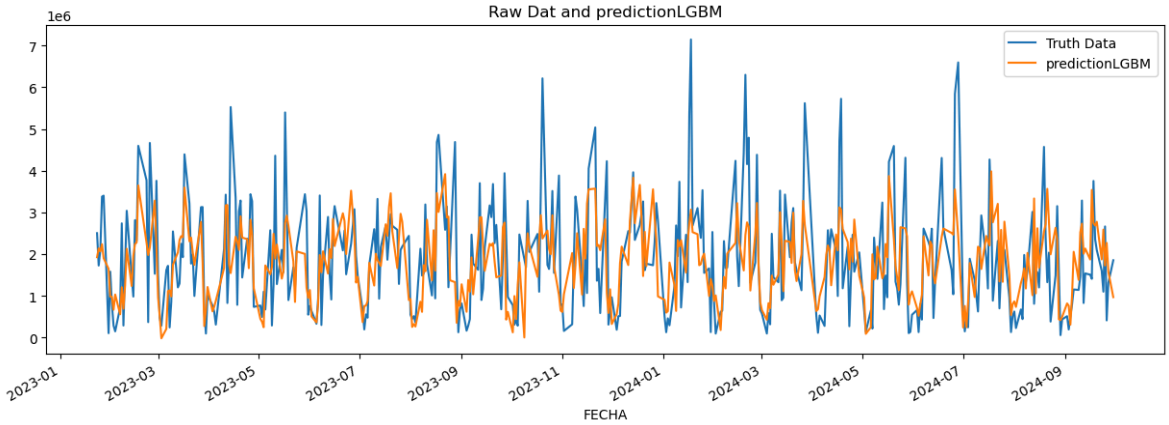
In [58]:

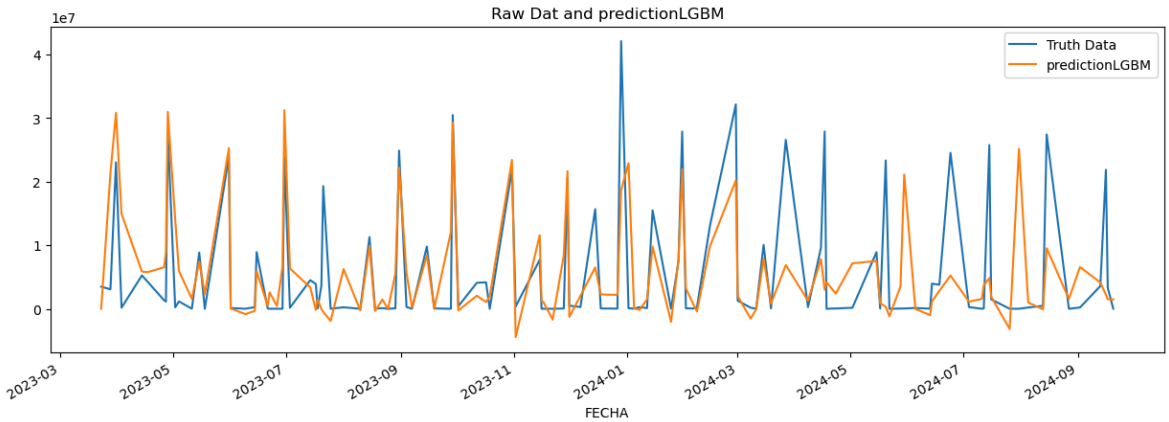
```
def plotear_predicciones(df_aux, model, X_test):
    df = df_aux.copy()
    test = df.copy()
    test['predictionLGBM'] = model.predict(X_test)
    df = df.merge(test[['predictionLGBM']], how='left', left_index=True, right_i
    ax = df[df.columns[0]].plot(figsize=(15, 5))
    df['predictionLGBM'].plot(ax=ax)
    plt.legend(['Truth Data', 'predictionLGBM'])
```

```
    ax.set_title('Raw Dat and predictionLGBM')
    plt.show()
```

In [65]:
```
models = [lgb_copa, lgb_rec_propios, lgb_regalias]
X_test = [X_test_COPA, X_test_REC_PROPIOS, X_test_REGALIAS]

for i in range(len(dataframes)):
    plotear_predicciones(dataframes_test[i], models[i], X_test[i])
```







In [ ]:
```
import seaborn as sns

def plot_train_test_predictions(dataframes_train, dataframes_test, predictions_t

    num_series = len(dataframes_train)
    fig, axes = plt.subplots(1, num_series, figsize=(20, 6), sharey=True)
    sns.set(style="whitegrid")

    for i in range(num_series):
        ax = axes[i]
```

```
        # Filtrar datos desde la fecha indicada (si se especifica)
        train = dataframes_train[i][start_date:] if start_date else dataframes_t
        test = dataframes_test[i][start_date:] if start_date else dataframes_tes
        pred = predictions_test[i][start_date:] if start_date else predictions_t
        # Graficar series
        #sns.lineplot(data=train, label='Train', ax=ax, color='#3477eb')
        #sns.lineplot(data=test, label='Test', ax=ax, color='green')
        #sns.lineplot(data=pred, ax=ax, color='#f72525', linestyle='--')
        ax.plot(train, label='Train', color='#3477eb')
        ax.plot(test, label='Test', color='green')
        ax.plot(pred, label='Predicciones', color='red', linestyle='--')

        # Configuración del gráfico
        ax.set_title(series_names[i], fontsize=14)
        ax.set_xlabel('Fecha')
        ax.set_ylabel('Valor')
        ax.legend(loc='best')
        ax.grid(True)

    plt.tight_layout()
    plt.show()
```

In [40]:

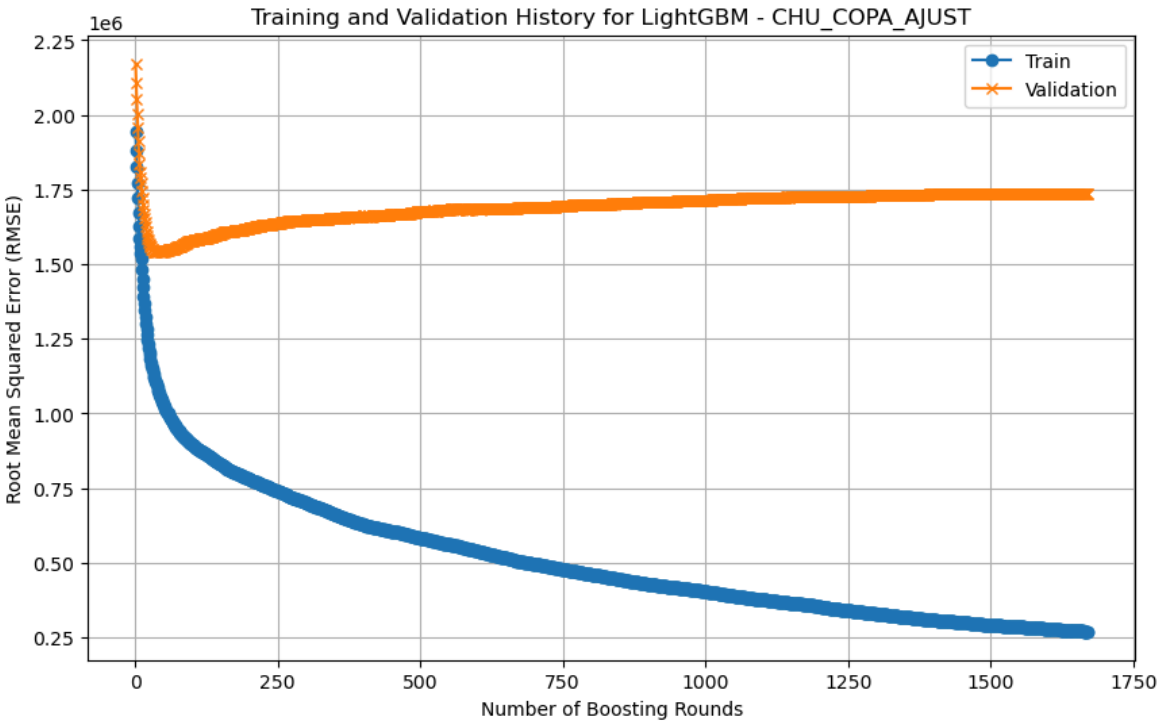
```
import matplotlib.pyplot as plt
import seaborn as sns

def plot_train_test_predictions(dataframes_train, dataframes_test, predictions_t
    """
    Grafica las series de entrenamiento, prueba y predicciones.

    Parámetros:
    - dataframes_train: Lista de dataframes con los datos de entrenamiento.
    - dataframes_test: Lista de dataframes con los datos de prueba.
    - predictions_test: Lista de arreglos con las predicciones.
    - series_names: Lista de nombres para las series (uno por gráfico).
    - target_column: Nombre de la columna objetivo a graficar.
    - start_date: Fecha de inicio para filtrar las series (opcional).
    """
    sns.set(style="whitegrid")
    num_series = len(dataframes_train)
    fig, axes = plt.subplots(1, num_series, figsize=(20, 6), sharey=True)

    for i in range(num_series):
        ax = axes[i]

        # Filtrar datos desde la fecha indicada
        train = dataframes_train[i][titulos[i]][start_date:] if start_date else
        test = dataframes_test[i][titulos[i]][start_date:] if start_date else da
        pred = predictions_test[i]  # Asumimos que ya tiene las predicciones ali

        # Graficar series
        ax.plot(train.index, train.values, label='Train', color='#3477eb')
        ax.plot(test.index, test.values, label='Test', color='green')
        ax.plot(test.index, pred, label='Predicciones', color='red', linestyle='

        # Configuración del gráfico
        ax.set_title(series_names[i], fontsize=14)
        ax.set_xlabel('Fecha')
        ax.set_ylabel('Valor')
        ax.legend(loc='best')
        ax.grid(True)
```

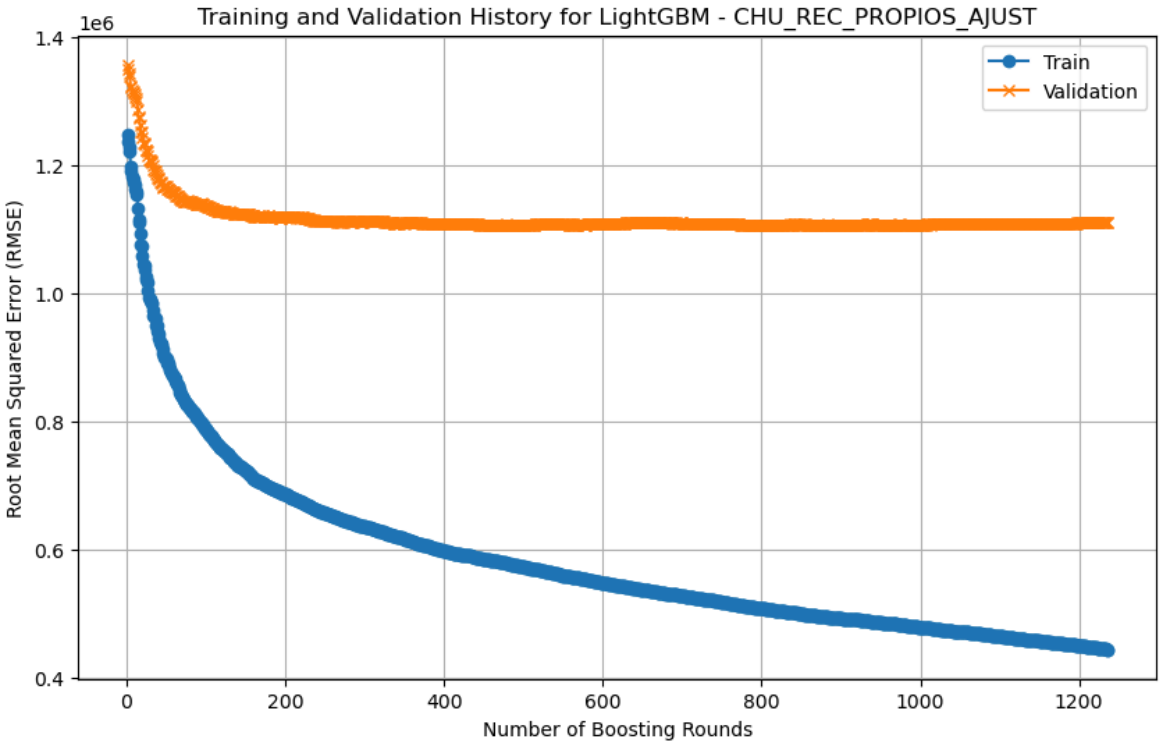
```
    plt.tight_layout()
    plt.show()
```

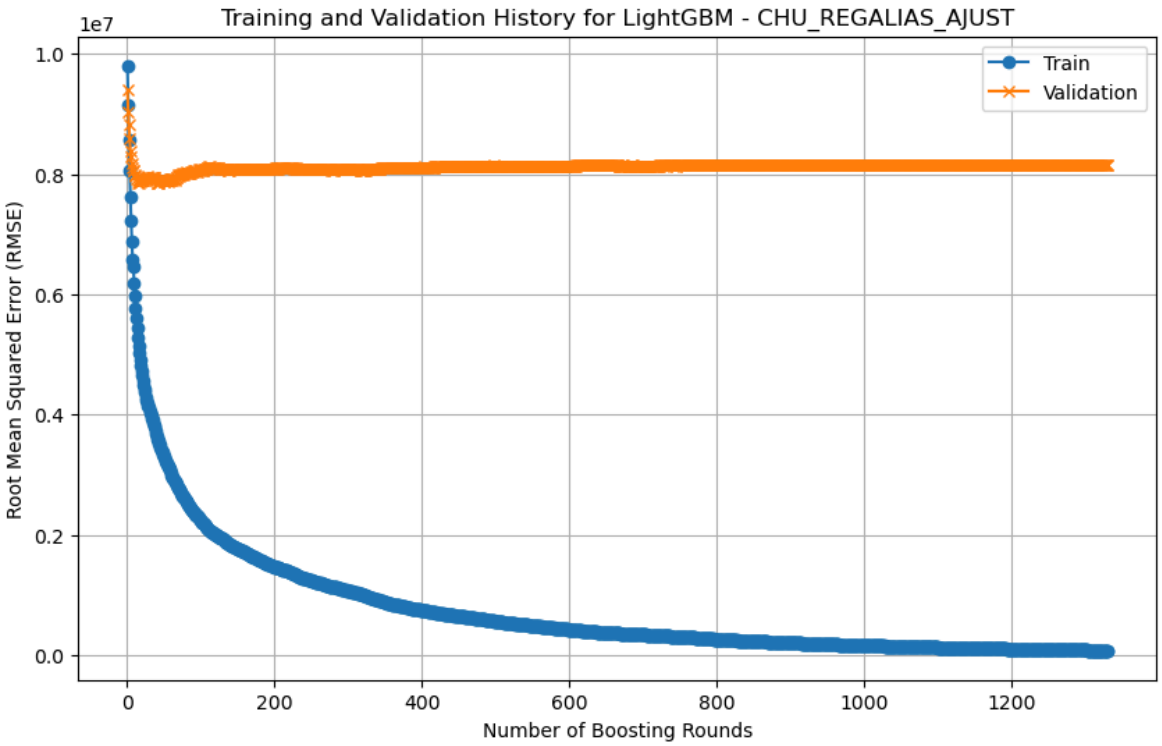
In [66]:
```
from sklearn.metrics import mean_absolute_error as mae

models = [lgb_copa, lgb_rec_propios, lgb_regalias]
X_test = [X_test_COPA, X_test_REC_PROPIOS, X_test_REGALIAS]
y_test = [y_test_COPA, y_test_REC_PROPIOS, y_test_REGALIAS]

for i in range(len(models)):
    rmse_score = np.sqrt(mean_squared_error(y_test[i], model.predict(X_test[i])))
    mae_score = mae(y_test[i], model.predict(X_test[i]))
    print(f'RMSE en conjunto de Test Modelo LGBM: {rmse_score:0.2f}')
    print(f'MAE en conjunto de Test Modelo LGBM: {mae_score:0.2f}')
    print('--------------')
```

```
RMSE en conjunto de Test Modelo LGBM: 7011235.04
MAE en conjunto de Test Modelo LGBM: 4665551.00
--------------
RMSE en conjunto de Test Modelo LGBM: 7115328.98
MAE en conjunto de Test Modelo LGBM: 4461281.37
--------------
RMSE en conjunto de Test Modelo LGBM: 8158900.92
MAE en conjunto de Test Modelo LGBM: 4903632.74
--------------
```

In [67]:
```
models = [lgb_copa, lgb_rec_propios, lgb_regalias]

for i in range(len(models)):

    # Obtener los resultados de evaluación del modelo
    results = models[i].evals_result_  # 'reg_lightgbm' es tu modelo LightGBM en

    # Extraer los errores de entrenamiento y validación
    train_error = results['training']['rmse']  # Asumiendo que usaste RMSE como
    val_error = results['valid_1']['rmse']  # 'valid_1' corresponde al conjunto

    # Número de rondas de boosting
    epoch = range(1, len(train_error) + 1)

    # Crear el gráfico
    plt.figure(figsize=(10, 6))
    plt.plot(epoch, train_error, label='Train', marker='o')
    plt.plot(epoch, val_error, label='Validation', marker='x')
    plt.xlabel('Number of Boosting Rounds')
    plt.ylabel('Root Mean Squared Error (RMSE)')
    plt.title(f'Training and Validation History for LightGBM - {titulos[i]}')
    plt.legend()
    plt.grid()
    plt.show()
```


Training and Validation History for LightGBM - CHU_COPA_AJUST
1e6
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
Root Mean Squared Error (RMSE)
0
250
500
750
1000
1250
1500
1750
Number of Boosting Rounds
Train
Validation


Training and Validation History for LightGBM - CHU_REC_PROPIOS_AJUST
1e6
1.4
1.2
1.0
0.8
0.6
0.4
Root Mean Squared Error (RMSE)
0
200
400
600
800
1000
1200
Number of Boosting Rounds
Train
Validation

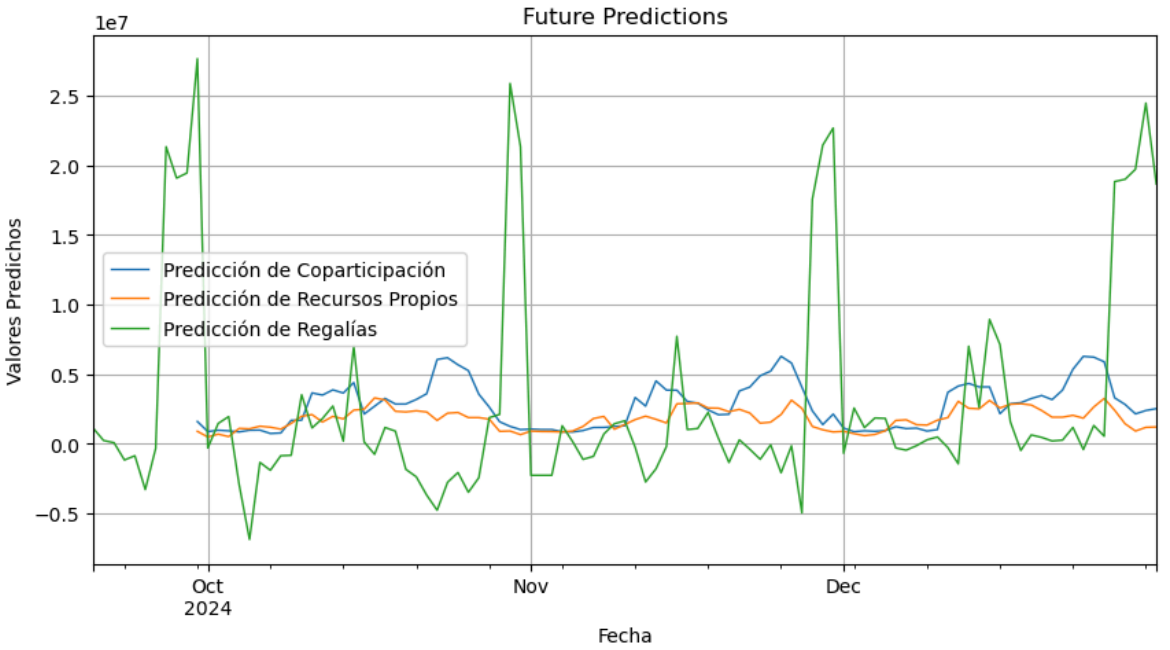


In [ ]:
```
dataframes[2].index.max()
```

Out[ ]:
```
Timestamp('2024-09-20 00:00:00')
```

In [47]:
```
import matplotlib.pyplot as plt

models = [lgb_copa, lgb_rec_propios, lgb_regalias]
titles = ["Predicción de Coparticipación", "Predicción de Recursos Propios", "Pr

plt.figure(figsize=(10, 5))  # Crear una figura para graficar

for i in range(len(models)):
    df_aux = dataframes[i].copy()
    df_aux.drop(columns=['dayofweek', 'quarter', 'month', 'year', 'dayofyear',
                         'dayofmonth', 'weekofyear', 'lag1', 'lag2', 'lag3'], in

    # Generar datos futuros
    future = pd.date_range(dataframes[i].index.max(), '2024-12-31', freq='1d')
    future_df = pd.DataFrame(index=future)
    future_df['isFuture'] = True
    df_aux['isFuture'] = False
    df_and_future = pd.concat([df_aux, future_df])

    # Agregar características de tiempo y lags
    time_features = df_and_future.index.to_series().apply(extract_time_features)
    df_and_future = pd.concat([df_and_future, time_features], axis=1)
    df_and_future = add_lags(df_and_future, titulos[i])

    # Predicciones futuras
    future_w_features = df_and_future.query('isFuture').copy()
    future_w_features['pred'] = models[i].predict(future_w_features[FEATURES])

    # Graficar las predicciones
    future_w_features['pred'].plot(
        ms=1,
        lw=1,
```

```
        label=titles[i]  # Etiqueta para la leyenda
    )

# Personalizar el gráfico
plt.title("Future Predictions")
plt.xlabel("Fecha")
plt.ylabel("Valores Predichos")
plt.legend()  # Mostrar leyenda
plt.grid(True)
plt.show()
```



XGBOOST

Five Fold Cross Validation

XGBoost (Extreme Gradient Boosting)

In [3]:
```
import numpy as np
import pandas as pd
from IPython.display import display, HTML
import importlib

import plotly.express as px
import matplotlib.pyplot as plt
import statsmodels.api as sm

from sklearn.metrics import mean_absolute_error, mean_squared_error, mean_absolu
import xgboost as xgb


import warnings
import os
import pickle

warnings.filterwarnings("ignore")
pd.options.display.float_format = '{:,.2f}'.format
```

In [4]:
```
df_main = pd.read_excel("https://raw.githubusercontent.com/carrenogf/MCD-Series-
df_main = df_main.sort_values("FECHA",ascending=True)
df_main.set_index("FECHA", inplace=True)
df_copa = df_main["CHU_COPA_AJUST"].dropna()
df_recprop = df_main["CHU_REC_PROPIOS_AJUST"].dropna()
df_regal = df_main["CHU_REGALIAS_AJUST"].dropna()
dataframes = [df_copa, df_recprop, df_regal]
titulos = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]
```

In [5]:
```
def extract_time_features(index):
    return pd.Series({
        'dayofweek': index.dayofweek,
        'quarter': index.quarter,
        'month': index.month,
        'year': index.year,
        'dayofyear': index.dayofyear,
        'dayofmonth': index.day,
        'weekofyear': index.isocalendar().week
    })


def add_lags(df, titulo):
    target_map = df[titulo].to_dict()
    df['lag1'] = (df.index - pd.Timedelta('364 days')).map(target_map) # df_1['P
    df['lag2'] = (df.index - pd.Timedelta('728 days')).map(target_map) # df_1['P
    df['lag3'] = (df.index - pd.Timedelta('1092 days')).map(target_map) # df_1['
    return df
```

In [6]:
```
time_features = dataframes[0].index.to_series().apply(extract_time_features)
dataframes[0] = pd.concat([dataframes[0], time_features], axis=1)
dataframes[0] = add_lags(dataframes[0], titulos[0])

time_features = dataframes[1].index.to_series().apply(extract_time_features)
```

```
dataframes[1] = pd.concat([dataframes[1], time_features], axis=1)
dataframes[1] = add_lags(dataframes[1], titulos[1])

time_features = dataframes[2].index.to_series().apply(extract_time_features)
dataframes[2] = pd.concat([dataframes[2], time_features], axis=1)
dataframes[2] = add_lags(dataframes[2], titulos[2])
```

In [5]:
```
dataframes[2].head()
```

Out[5]:

FECHA	CHU_REGALIAS_AJUST	dayofweek	quarter	month	year	dayofyear	dayofmo
2016-04-08	212,159.00	4	2	4	2016	99	
2016-04-14	26,246.00	3	2	4	2016	105	
2016-04-15	16,002,725.00	4	2	4	2016	106	
2016-04-20	5,582.00	2	2	4	2016	111	
2016-04-29	11,066,374.00	4	2	4	2016	120	

In [7]:
```
# TRAIN TEST
dataframes_train = []
dataframes_test = []

# for i in range(3):
#     train = dataframes[i].iloc[:round(len(dataframes[0])*.8)]
#     test = dataframes[i].iloc[round(len(dataframes[0])*.8):]
#     dataframes_train.append(train)
#     dataframes_test.append(test)

train_copa = dataframes[0].iloc[:round(len(dataframes[0])*.8)]
test_copa = dataframes[0].iloc[round(len(dataframes[0])*.8):]
print(f"Coparticipacion: train({train_copa.shape}), test({test_copa.shape})")

train_recursos = dataframes[1].iloc[:round(len(dataframes[1])*.8)]
test_recursos = dataframes[1].iloc[round(len(dataframes[1])*.8):]
print(f"Recursos: train({train_recursos.shape}), test({test_recursos.shape})")

train_regalias = dataframes[2].iloc[:round(len(dataframes[2])*.8)]
test_regalias = dataframes[2].iloc[round(len(dataframes[2])*.8):]
print(f"Regalias: train({train_regalias.shape}), test({test_regalias.shape})")

dataframes_train = [ train_copa, train_recursos, train_regalias ]
dataframes_test = [ test_copa, test_recursos, test_regalias ]
```

```
Coparticipacion: train((1275, 11)), test((319, 11))
Recursos: train((1626, 11)), test((406, 11))
Regalias: train((460, 11)), test((115, 11))
```

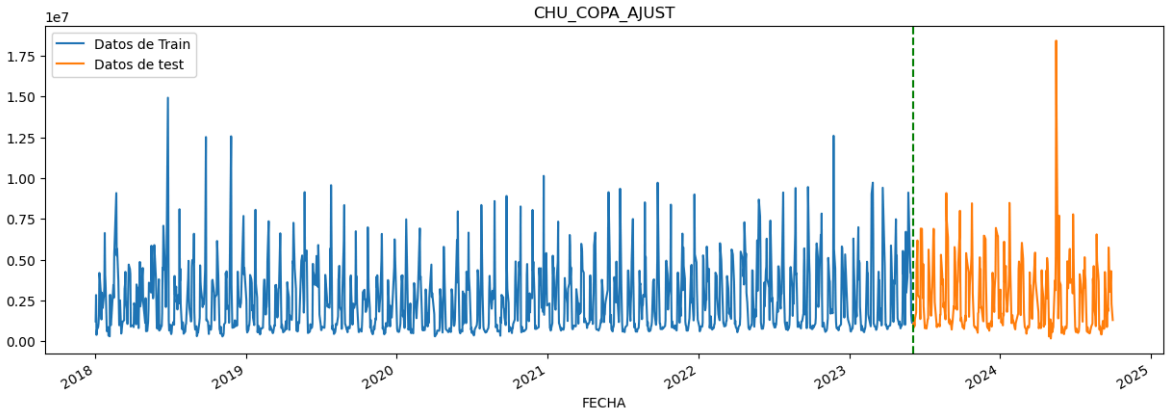
In [8]:
```
train_recursos.head()
```

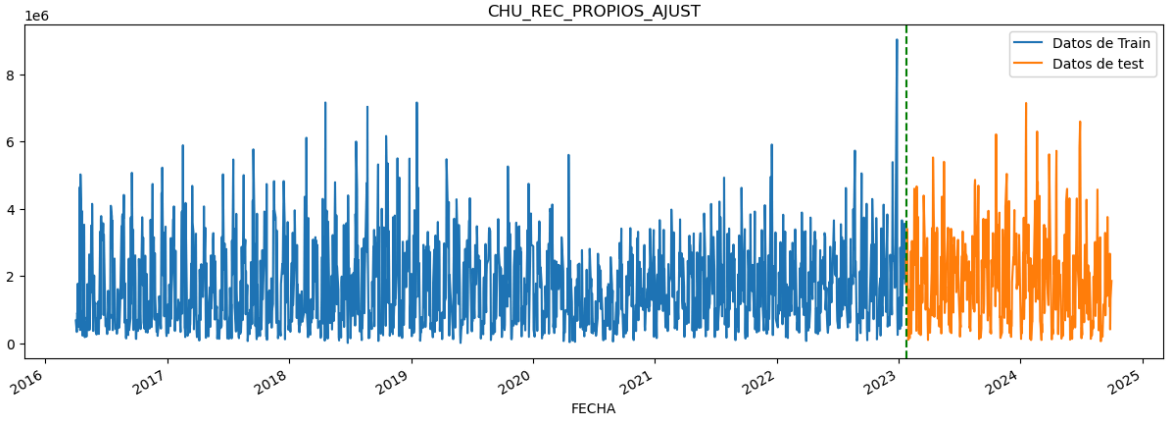
Out[8]:

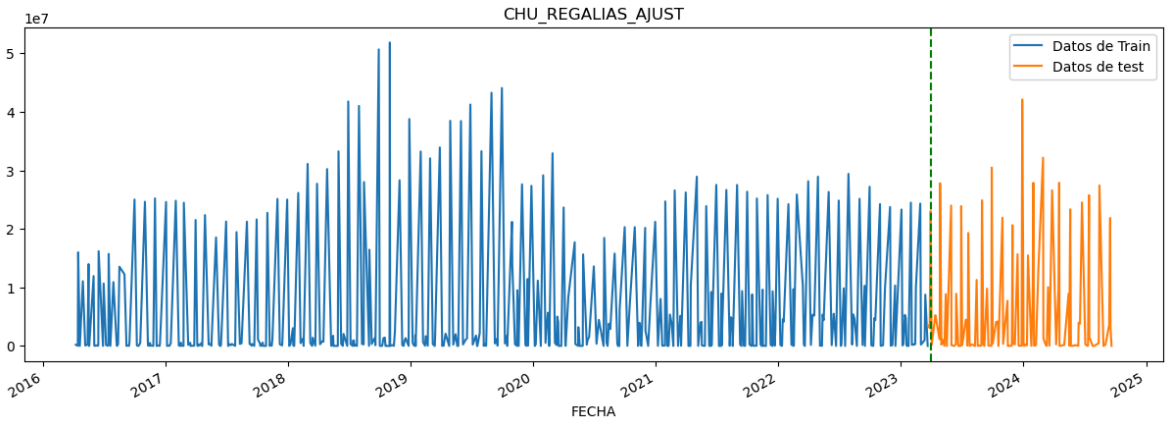
FECHA	CHU_REC_PROPIOS_AJUST	dayofweek	quarter	month	year	dayofyear	dayof
2016-04-01	679233	4	2	4	2016	92	
2016-04-04	339379	0	2	4	2016	95	
2016-04-05	903634	1	2	4	2016	96	
2016-04-06	858197	2	2	4	2016	97	
2016-04-07	1774956	3	2	4	2016	98	

In [8]:

```
for i in range(len(dataframes)):
    # Separamos los datos en train y test
    fig, ax = plt.subplots(figsize=(15, 5))

    dataframes_train[i][titulos[i]].plot(ax=ax, label='Datos de Train', title=f'
    dataframes_test[i][titulos[i]].plot(ax=ax, label='Datos de test')
    ax.axvline(f'{dataframes_test[i].index[i]}', color='green', ls='--')
    ax.legend(['Datos de Train', 'Datos de test'])
    plt.show()
```







In [9]:
```
FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmonth',
TARGET = 'CHU_COPA_AJUST'
```

In [10]:
```
X_train = dataframes_train[0][FEATURES]
y_train = dataframes_train[0][TARGET]

X_test = dataframes_test[0][FEATURES]
y_test = dataframes_test[0][TARGET]
```

In [9]:
```
import optuna
import lightgbm as lgb
import numpy as np
from sklearn.model_selection import TimeSeriesSplit
from sklearn.metrics import mean_squared_error



def objective(trial, df):
    param = {
        "n_estimators": trial.suggest_int("n_estimators", 100, 500),  # Reducido
        "learning_rate": trial.suggest_float("learning_rate", 0.01, 0.1, log=Tru
        "max_depth": trial.suggest_int("max_depth", 3, 7),  # Reducido de 3 a 7
        "min_child_weight": trial.suggest_int("min_child_weight", 1, 5),  # Redu
        "subsample": trial.suggest_float("subsample", 0.6, 1.0),  # Reducido de
        "colsample_bytree": trial.suggest_float("colsample_bytree", 0.6, 1.0),
        "gamma": trial.suggest_float("gamma", 0, 0.5),  # Reducido de 0 a 0.5
        "reg_alpha": trial.suggest_float("reg_alpha", 0.0, 0.5),  # Regularizaci
        "reg_lambda": trial.suggest_float("reg_lambda", 0.5, 1.5),  # Regulariza
        "random_state": 42,
        "objective": "reg:squarederror",
        "early_stopping_rounds": 50,
    }

    test_size = 100
    tss = TimeSeriesSplit(n_splits=5, test_size=252, gap=1) # 252 son los dias h
    scores = []
    df = df.sort_index()

    for train_idx, val_idx in tss.split(df):
        train = df.iloc[train_idx]
        test = df.iloc[val_idx]

        FEATURES = ['dayofyear', 'dayofweek', 'quarter', 'month', 'year',
                    'lag1', 'lag2', 'lag3']
        TARGET = df.columns[0]
```

```
        # Verificar características y dropna
        # assert all(feature in train.columns for feature in FEATURES), "Faltan
        # assert all(feature in test.columns for feature in FEATURES), "Faltan c

        X_train = train[FEATURES]
        y_train = train[TARGET]

        X_test = test[FEATURES]
        y_test = test[TARGET]

        # if X_train.empty or X_test.empty:
        #     raise ValueError("X_train o X_test está vacío después de dropna")

        model = xgb.XGBRegressor(**param)
        model.fit(
            X_train, y_train,
            eval_set=[(X_test, y_test)]
        )

        y_pred = model.predict(X_test)
        rmse = mean_squared_error(y_test, y_pred, squared=False)
        scores.append(rmse)

    return np.mean(scores)
```

In [ ]:
```
# Ejecutar la optimización con Optuna
# df = dataframes_train[0].copy() ### ACACAACACACACACACACA
df = dataframes[0].copy() # ACA TORTUGA NINJA
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective(trial, df), n_trials=100)


copa_best_params = study.best_params
copa_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para COPA:", study.best_params)
print("Mejor RMSE promedio para COPA:", study.best_value)
```

RMSE promedio para COPA: 1718582.9603018877

In [ ]:
```
# Ejecutar la optimización con Optuna
#df = dataframes_train[1].copy()
df = dataframes[1].copy()
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective(trial, df), n_trials=100)



rec_propios_best_params = study.best_params
rec_propios_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para REC_PROPIOS:", study.best_params)
print("Mejor RMSE promedio para REC_PROPIOS:", study.best_value)
```

In [12]:
```
def objective_2(trial, df):

    FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmon
    TARGET = df.columns[0]
```

```
    X_train = df[FEATURES]
    y_train = df[TARGET]

    X_test = df[FEATURES]
    y_test = df[TARGET]

    param = {
        "n_estimators": trial.suggest_int("n_estimators", 100, 500),  # Reducido
        "learning_rate": trial.suggest_float("learning_rate", 0.01, 0.1, log=Tru
        "max_depth": trial.suggest_int("max_depth", 3, 7),  # Reducido de 3 a 7
        "min_child_weight": trial.suggest_int("min_child_weight", 1, 5),  # Redu
        "subsample": trial.suggest_float("subsample", 0.6, 1.0),  # Reducido de
        "colsample_bytree": trial.suggest_float("colsample_bytree", 0.6, 1.0),
        "gamma": trial.suggest_float("gamma", 0, 0.5),  # Reducido de 0 a 0.5
        "reg_alpha": trial.suggest_float("reg_alpha", 0.0, 0.5),  # Regularizaci
        "reg_lambda": trial.suggest_float("reg_lambda", 0.5, 1.5),  # Regulariza
        "random_state": 42,
        "objective": "reg:squarederror",
        "early_stopping_rounds": 50,
    }

    model = xgb.XGBRegressor(**param)
    model.fit(X_train, y_train, eval_set=[(X_train, y_train), (X_test, y_test)])









    # Puedes usar la métrica de tu preferencia aquí
    y_pred = model.predict(X_test)
    rmse = mean_squared_error(y_test, y_pred, squared=False)
    return rmse
```

In [ ]:
```
# Ejecutar la optimización con Optuna
df = dataframes[2].copy()
study = optuna.create_study(direction="minimize")
study.optimize(lambda trial: objective_2(trial, df), n_trials=100)



regalias_best_params = study.best_params
regalias_rmse = study.best_value
# Imprimir los mejores parámetros y el mejor RMSE
print("Mejores parámetros para REGALIAS:", study.best_params)
print("Mejor RMSE promedio para REGALIAS:", study.best_value)
```

In [14]:
```
FEATURES = ['dayofweek', 'quarter', 'month', 'year', 'dayofyear' , 'dayofmonth',
TARGET = ["CHU_COPA_AJUST", "CHU_REC_PROPIOS_AJUST", "CHU_REGALIAS_AJUST"]

X_train_COPA = dataframes_train[0][FEATURES]
y_train_COPA = dataframes_train[0][TARGET[0]]
X_test_COPA = dataframes_test[0][FEATURES]
y_test_COPA = dataframes_test[0][TARGET[0]]

X_train_REC_PROPIOS = dataframes_train[1][FEATURES]
y_train_REC_PROPIOS = dataframes_train[1][TARGET[1]]
```

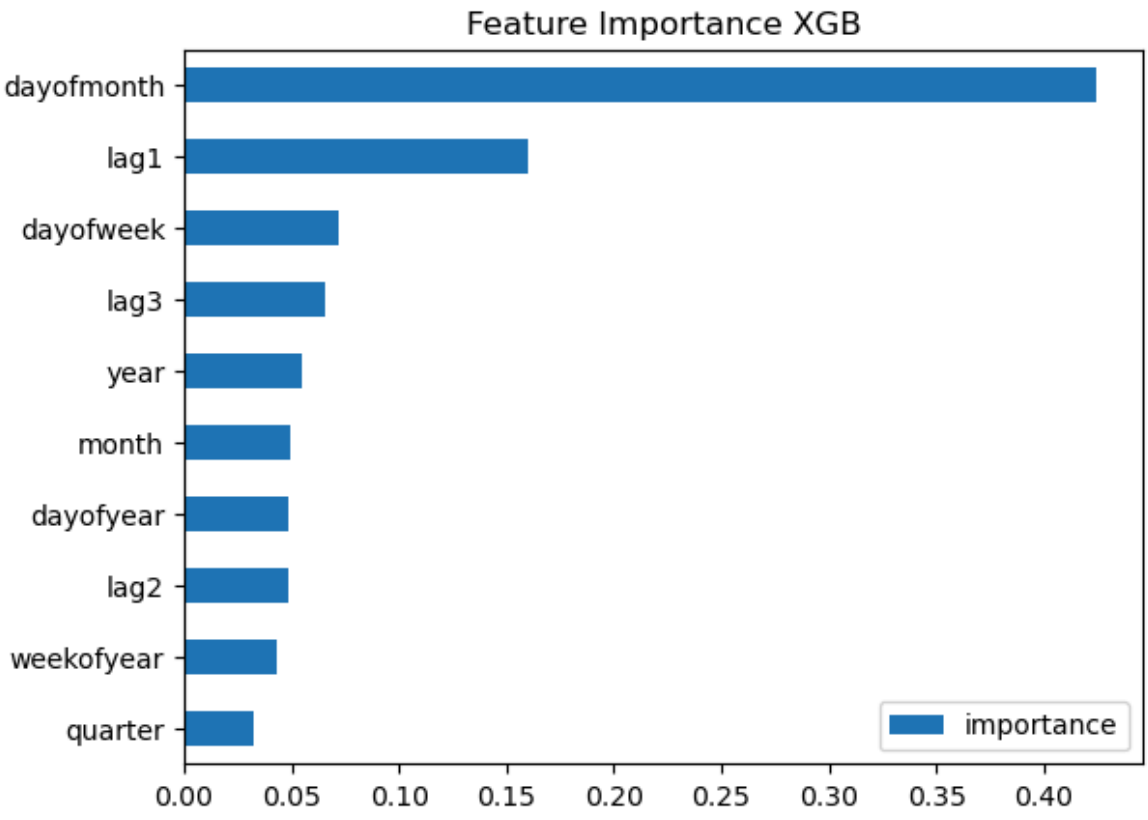
```
X_test_REC_PROPIOS = dataframes_test[1][FEATURES]
y_test_REC_PROPIOS = dataframes_test[1][TARGET[1]]

X_train_REGALIAS = dataframes_train[2][FEATURES]
y_train_REGALIAS = dataframes_train[2][TARGET[2]]
X_test_REGALIAS = dataframes_test[2][FEATURES]
y_test_REGALIAS = dataframes_test[2][TARGET[2]]
```

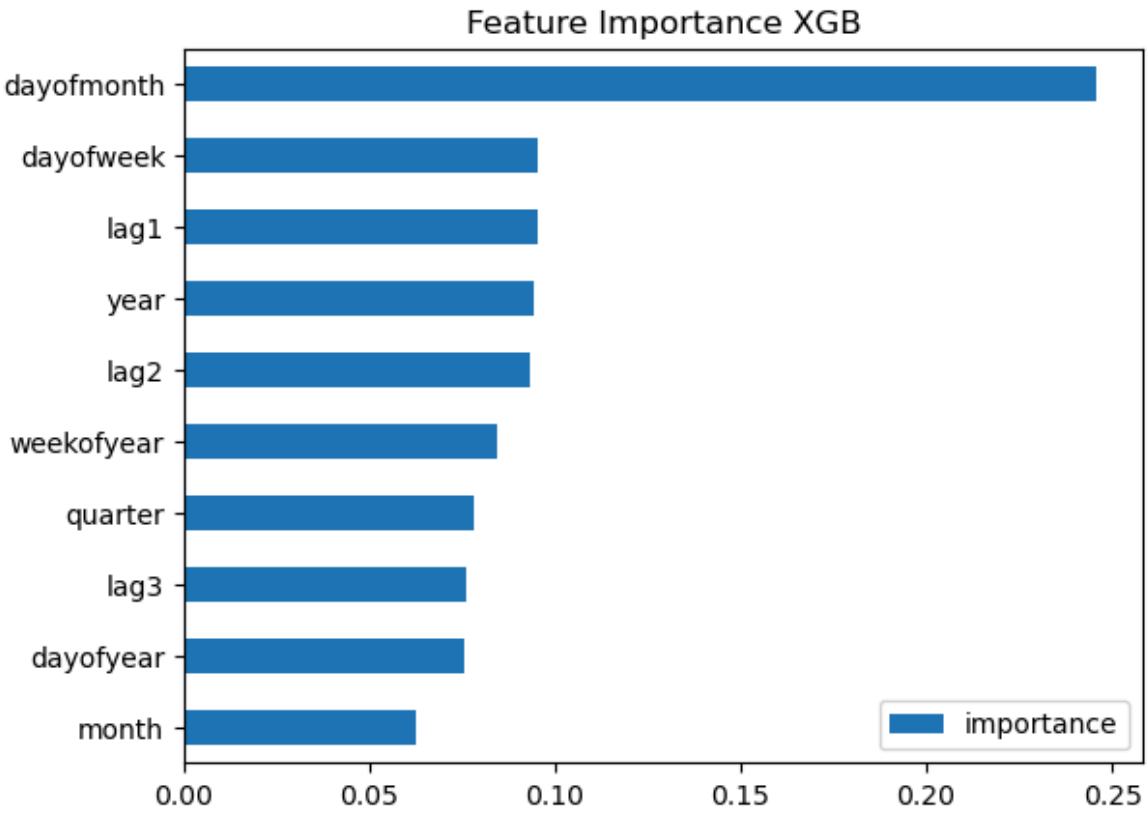
In [ ]:
```
xgb_copa = xgb.XGBRegressor(**copa_best_params )
xgb_copa.fit(X_train_COPA, y_train_COPA,
        eval_set=[(X_train_COPA, y_train_COPA), (X_test_COPA, y_test_COPA)])
```

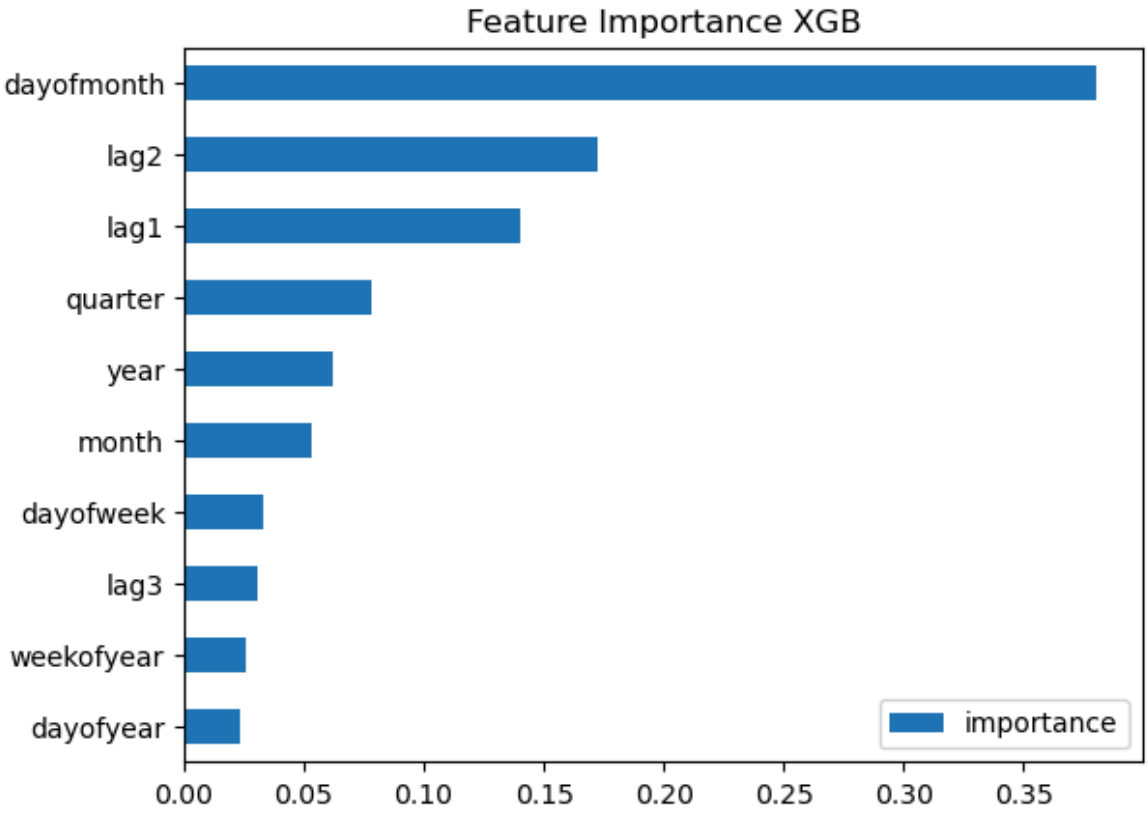
In [ ]:
```
xgb_rec_propios =  xgb.XGBRegressor(**rec_propios_best_params )
xgb_rec_propios.fit(X_train_REC_PROPIOS, y_train_REC_PROPIOS,
        eval_set=[(X_train_REC_PROPIOS, y_train_REC_PROPIOS), (X_test_REC_PROPIO
```

In [ ]:
```
xgb_regalias =  xgb.XGBRegressor(**regalias_best_params )
xgb_regalias.fit(X_train_REGALIAS, y_train_REGALIAS,
        eval_set=[(X_train_REGALIAS, y_train_REGALIAS), (X_test_REGALIAS, y_test
```

In [20]:
```
models = [xgb_copa, xgb_rec_propios, xgb_regalias]
i = 0
for model in models:

    fi = pd.DataFrame(data=model.feature_importances_,
             index=model.feature_names_in_,
             columns=['importance'])
    fi.sort_values('importance').plot(kind='barh', title='Feature Importance XGB
    plt.show()
```



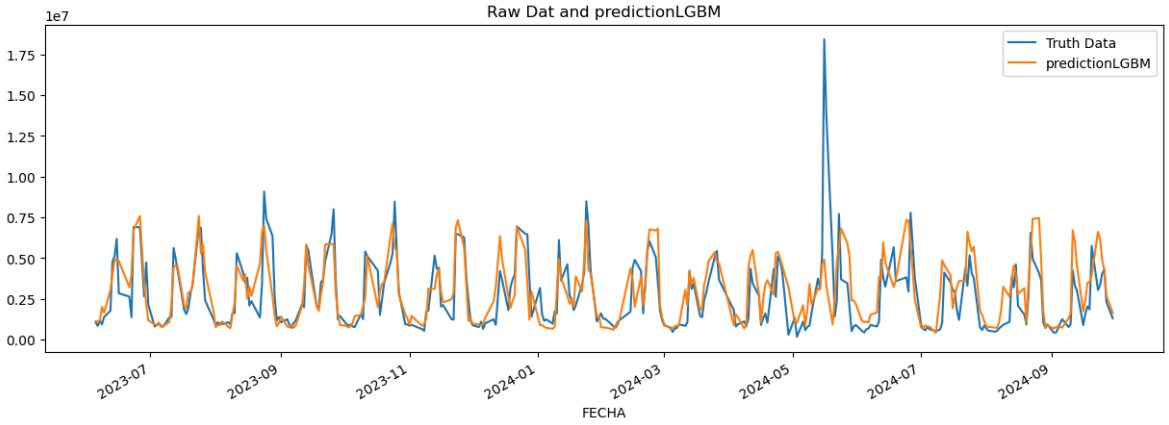


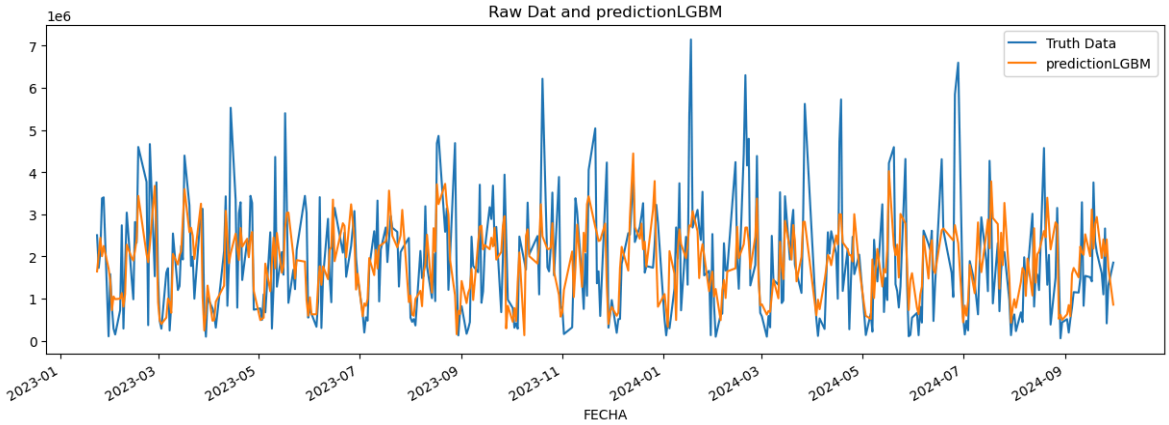


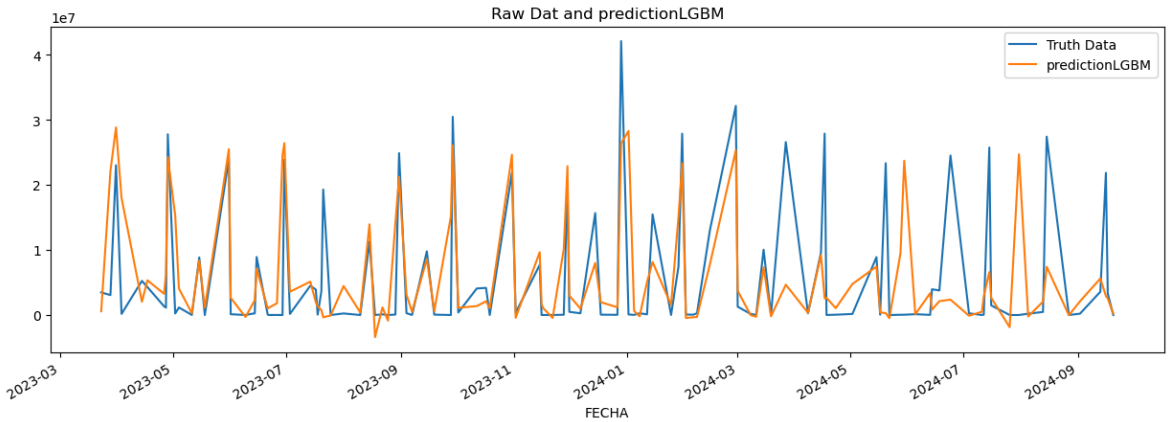
In [21]:
```
def plotear_predicciones(df_aux, model, X_test):
    df = df_aux.copy()
    test = df.copy()
    test['predictionLGBM'] = model.predict(X_test)
    df = df.merge(test[['predictionLGBM']], how='left', left_index=True, right_i
    ax = df[df.columns[0]].plot(figsize=(15, 5))
    df['predictionLGBM'].plot(ax=ax)
    plt.legend(['Truth Data', 'predictionLGBM'])
```

```
    ax.set_title('Raw Dat and predictionLGBM')
    plt.show()
```

In [22]:
```
models = [xgb_copa, xgb_rec_propios, xgb_regalias]
X_test = [X_test_COPA, X_test_REC_PROPIOS, X_test_REGALIAS]

for i in range(len(dataframes)):
    plotear_predicciones(dataframes_test[i], models[i], X_test[i])
```







In [ ]:
```
import seaborn as sns

def plot_train_test_predictions(dataframes_train, dataframes_test, predictions_t

    num_series = len(dataframes_train)
    fig, axes = plt.subplots(1, num_series, figsize=(20, 6), sharey=True)
    sns.set(style="whitegrid")

    for i in range(num_series):
        ax = axes[i]
```

```
        # Filtrar datos desde la fecha indicada (si se especifica)
        train = dataframes_train[i][start_date:] if start_date else dataframes_t
        test = dataframes_test[i][start_date:] if start_date else dataframes_tes
        pred = predictions_test[i][start_date:] if start_date else predictions_t
        # Graficar series
        #sns.lineplot(data=train, label='Train', ax=ax, color='#3477eb')
        #sns.lineplot(data=test, label='Test', ax=ax, color='green')
        #sns.lineplot(data=pred, ax=ax, color='#f72525', linestyle='--')
        ax.plot(train, label='Train', color='#3477eb')
        ax.plot(test, label='Test', color='green')
        ax.plot(pred, label='Predicciones', color='red', linestyle='--')

        # Configuración del gráfico
        ax.set_title(series_names[i], fontsize=14)
        ax.set_xlabel('Fecha')
        ax.set_ylabel('Valor')
        ax.legend(loc='best')
        ax.grid(True)

    plt.tight_layout()
    plt.show()
```

In [40]:

```
import matplotlib.pyplot as plt
import seaborn as sns

def plot_train_test_predictions(dataframes_train, dataframes_test, predictions_t
    """
    Grafica las series de entrenamiento, prueba y predicciones.

    Parámetros:
    - dataframes_train: Lista de dataframes con los datos de entrenamiento.
    - dataframes_test: Lista de dataframes con los datos de prueba.
    - predictions_test: Lista de arreglos con las predicciones.
    - series_names: Lista de nombres para las series (uno por gráfico).
    - target_column: Nombre de la columna objetivo a graficar.
    - start_date: Fecha de inicio para filtrar las series (opcional).
    """
    sns.set(style="whitegrid")
    num_series = len(dataframes_train)
    fig, axes = plt.subplots(1, num_series, figsize=(20, 6), sharey=True)

    for i in range(num_series):
        ax = axes[i]

        # Filtrar datos desde la fecha indicada
        train = dataframes_train[i][titulos[i]][start_date:] if start_date else
        test = dataframes_test[i][titulos[i]][start_date:] if start_date else da
        pred = predictions_test[i]  # Asumimos que ya tiene las predicciones ali

        # Graficar series
        ax.plot(train.index, train.values, label='Train', color='#3477eb')
        ax.plot(test.index, test.values, label='Test', color='green')
        ax.plot(test.index, pred, label='Predicciones', color='red', linestyle='

        # Configuración del gráfico
        ax.set_title(series_names[i], fontsize=14)
        ax.set_xlabel('Fecha')
        ax.set_ylabel('Valor')
        ax.legend(loc='best')
        ax.grid(True)
```

```
    plt.tight_layout()
    plt.show()
```

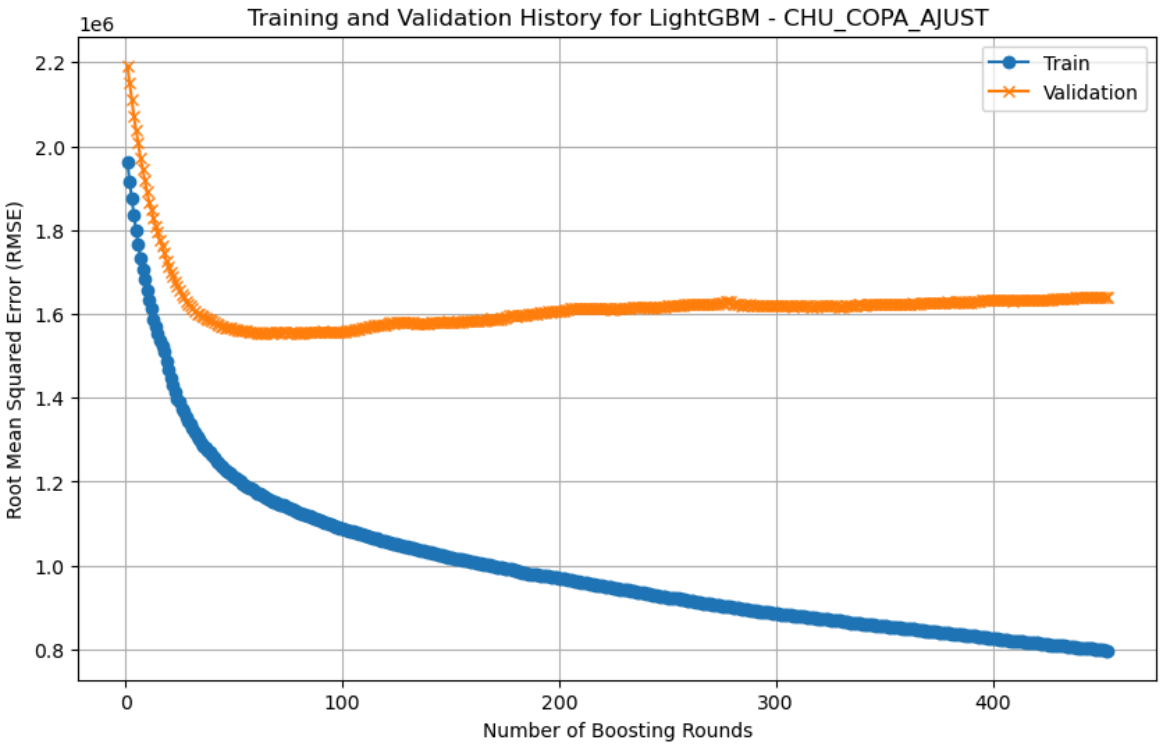
In [42]:
```
# models = [lgb_copa, lgb_rec_propios, lgb_regalias]
# X_test = [X_test_COPA, X_test_REC_PROPIOS, X_test_REGALIAS]
# X_train = [X_train_COPA, X_train_REC_PROPIOS, X_train_REGALIAS]
# y_pred_copa = lgb_copa.predict(X_test_COPA)
# y_pred_rec_propios = lgb_rec_propios.predict(X_test_REC_PROPIOS)
# y_pred_regalias = lgb_regalias.predict(X_test_REGALIAS)
# y_pred = [y_pred_copa, y_pred_rec_propios, y_pred_regalias]


# plot_train_test_predictions(
#     dataframes_train,       # Lista de dataframes de entrenamiento
#     dataframes_test,        # Lista de dataframes de prueba
#     y_pred,         # Lista de arreglos con las predicciones
#     titulos,        # Lista de nombres para los gráficos
#     target_column='hola',  # Nombre de la columna objetivo
#     start_date='2023-10-01'          # Fecha de inicio opcional
# )
```

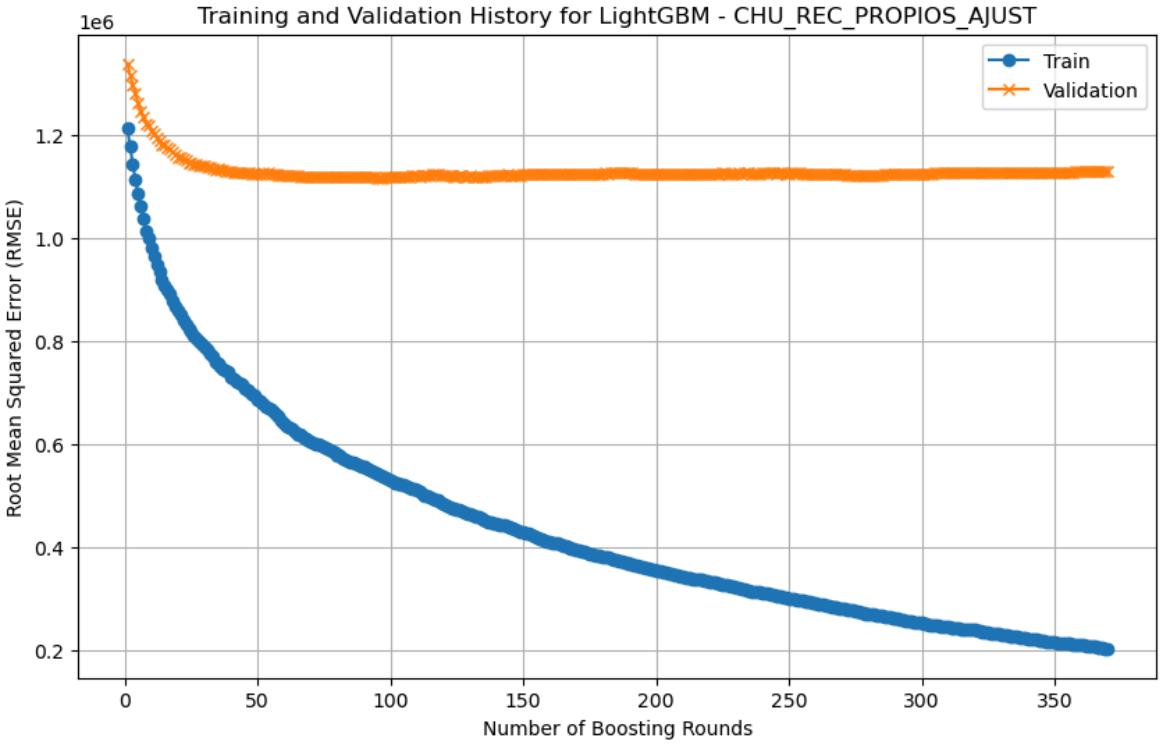
In [23]:
```
from sklearn.metrics import mean_absolute_error as mae

models = [xgb_copa, xgb_rec_propios, xgb_regalias]
X_test = [X_test_COPA, X_test_REC_PROPIOS, X_test_REGALIAS]
y_test = [y_test_COPA, y_test_REC_PROPIOS, y_test_REGALIAS]

for i in range(len(models)):
    rmse_score = np.sqrt(mean_squared_error(y_test[i], model.predict(X_test[i])))
    mae_score = mae(y_test[i], model.predict(X_test[i]))
    print(f'RMSE en conjunto de Test Modelo XGB: {rmse_score:0.2f}')
    print(f'MAE en conjunto de Test Modelo XGB: {mae_score:0.2f}')
    print('--------------')
```

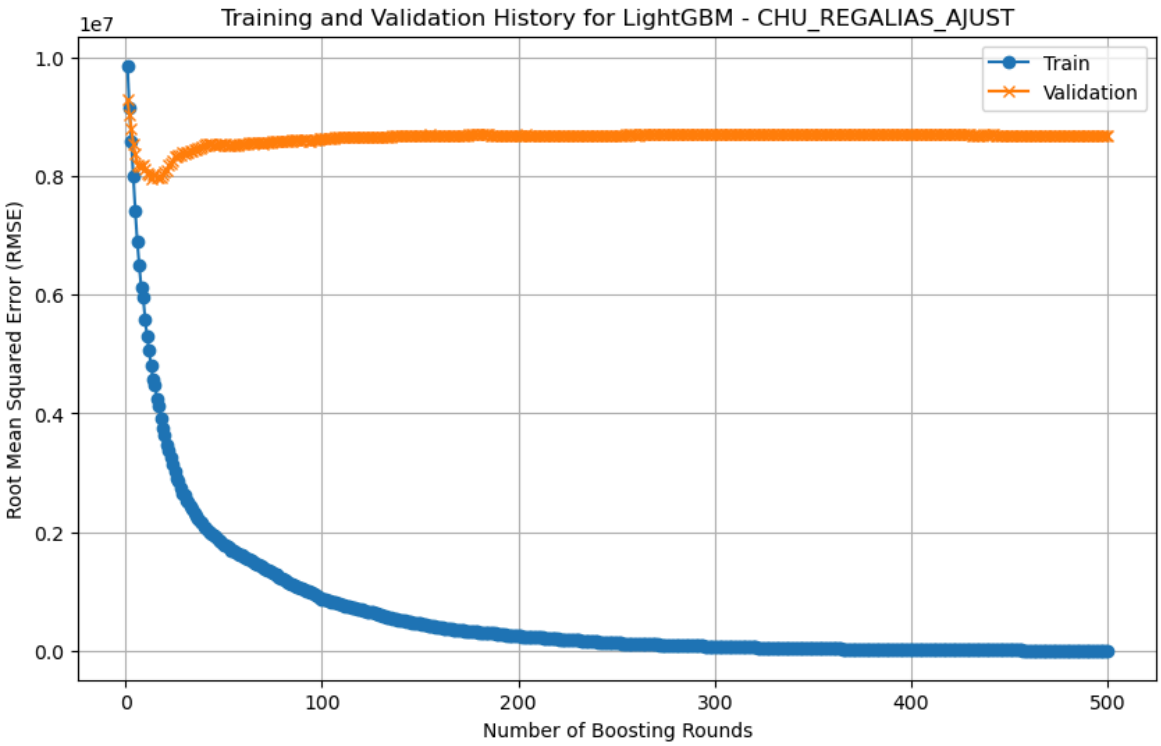
```
RMSE en conjunto de Test Modelo XGB: 6190399.85
MAE en conjunto de Test Modelo XGB: 3598181.03
--------------
RMSE en conjunto de Test Modelo XGB: 6773735.25
MAE en conjunto de Test Modelo XGB: 4069939.65
--------------
RMSE en conjunto de Test Modelo XGB: 8688363.20
MAE en conjunto de Test Modelo XGB: 5021455.02
--------------
```

In [24]:
```
models = [xgb_copa, xgb_rec_propios, xgb_regalias]

for i in range(len(models)):

    resultsXGB = models[i].evals_result()
    train_error = resultsXGB['validation_0']['rmse']
    val_error = resultsXGB['validation_1']['rmse']

    # Número de rondas de boosting
    epoch = range(1, len(train_error) + 1)

    # Crear el gráfico
    plt.figure(figsize=(10, 6))
    plt.plot(epoch, train_error, label='Train', marker='o')
```

```
    plt.plot(epoch, val_error, label='Validation', marker='x')
    plt.xlabel('Number of Boosting Rounds')
    plt.ylabel('Root Mean Squared Error (RMSE)')
    plt.title(f'Training and Validation History for LightGBM - {titulos[i]}')
    plt.legend()
    plt.grid()
    plt.show()
```



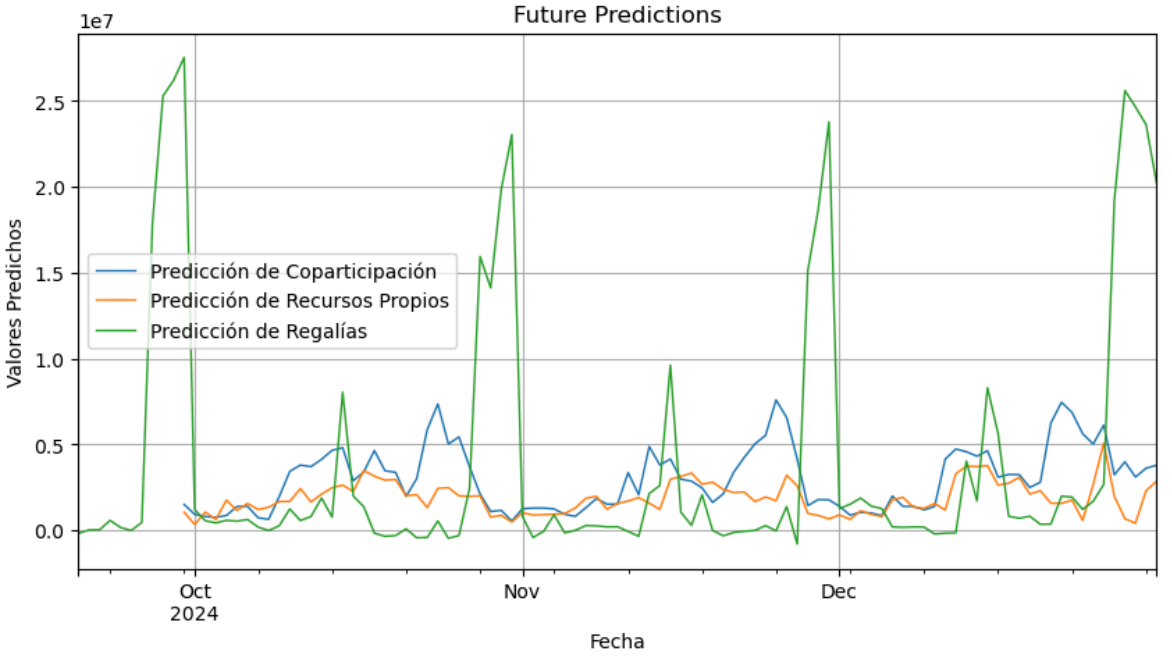




In [38]:

```python
import matplotlib.pyplot as plt

models = [xgb_copa, xgb_rec_propios, xgb_regalias]
titles = ["Predicción de Coparticipación", "Predicción de Recursos Propios", "Pr

plt.figure(figsize=(10, 5))  # Crear una figura para graficar

for i in range(len(models)):
    df_aux = dataframes[i].copy()
    df_aux.drop(columns=['dayofweek', 'quarter', 'month', 'year', 'dayofyear',
                         'dayofmonth', 'weekofyear', 'lag1', 'lag2', 'lag3'], in

    # Generar datos futuros
    future = pd.date_range(dataframes[i].index.max(), '2024-12-31', freq='1d')
    future_df = pd.DataFrame(index=future)
    future_df['isFuture'] = True
    df_aux['isFuture'] = False
    df_and_future = pd.concat([df_aux, future_df])

    # Agregar características de tiempo y lags
    time_features = df_and_future.index.to_series().apply(extract_time_features)
    df_and_future = pd.concat([df_and_future, time_features], axis=1)
    df_and_future = add_lags(df_and_future, titulos[i])

    # Predicciones futuras
    future_w_features = df_and_future.query('isFuture').copy()
    future_w_features['pred'] = models[i].predict(future_w_features[FEATURES])

    # Graficar las predicciones
    future_w_features['pred'].plot(
        ms=1,
        lw=1,
        label=titles[i]  # Etiqueta para la leyenda
    )

# Personalizar el gráfico
```

```
plt.title("Future Predictions")
plt.xlabel("Fecha")
plt.ylabel("Valores Predichos")
plt.legend()  # Mostrar leyenda
plt.grid(True)
plt.show()
```



In [ ]:
```
param_grid = {
    'n_estimators': [100, 500], # Numero de arboles a incluir en el modelo
    'max_depth': [3, 5, 10],   # Profundidad maxima de cada arbol
    'learning_rate': [0.01, 0.1]
}

# Lags used as predictors
lags_grid = [48, 72]

results_grid = grid_search_forecaster(
                    forecaster         = forecaster,    # Se pasa el objeto Forec
                    y                  = data.loc[:end_validation, 'users'], #  s
                    param_grid         = param_grid,
                    lags_grid          = lags_grid,
                    steps              = 36,  # numero de pasos en el futuro que
                    refit              = False, # no se ajustara el modelo con lo
                    metric             = 'mean_squared_error',
                    initial_train_size = len(data_train), # se utilizara todos lo
                    fixed_train_size   = False, # en cada iteracion de la busqued
                    return_best        = True, # la función devolvera el mejor mo
                    verbose            = False
                )
```