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))
```

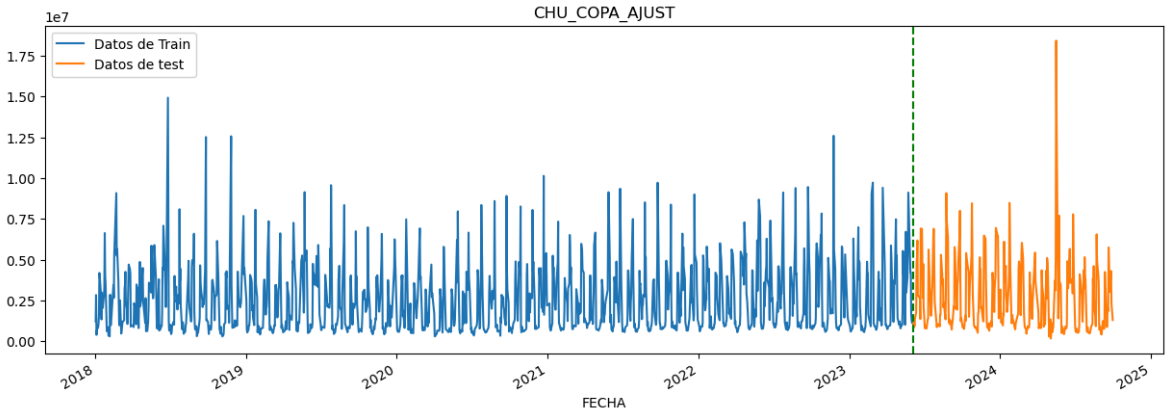
In [7]:
```
train_recursos.head()
```

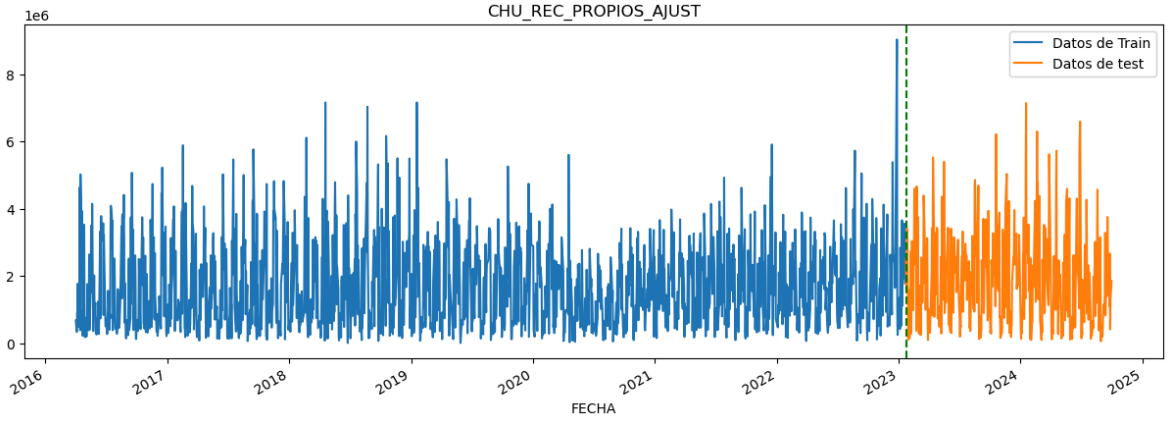
Out[7]:

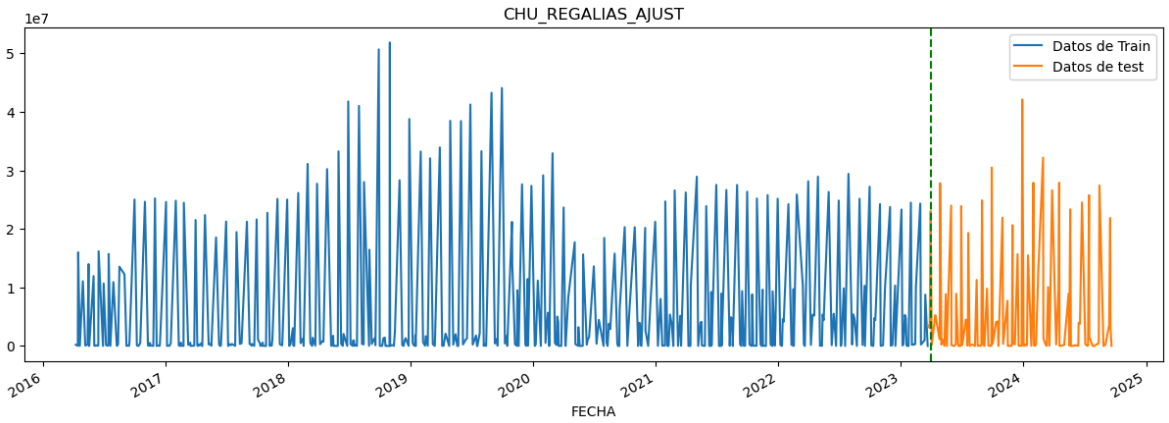
FECHA	CHU_REC_PROPIOS_AJUST	dayofweek	quarter	month	year	dayofyear	dayof
2016-04-01	679233	4	2	4	2016	92	
2016-04-04	339379	0	2	4	2016	95	
2016-04-05	903634	1	2	4	2016	96	
2016-04-06	858197	2	2	4	2016	97	
2016-04-07	1774956	3	2	4	2016	98	

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]
```

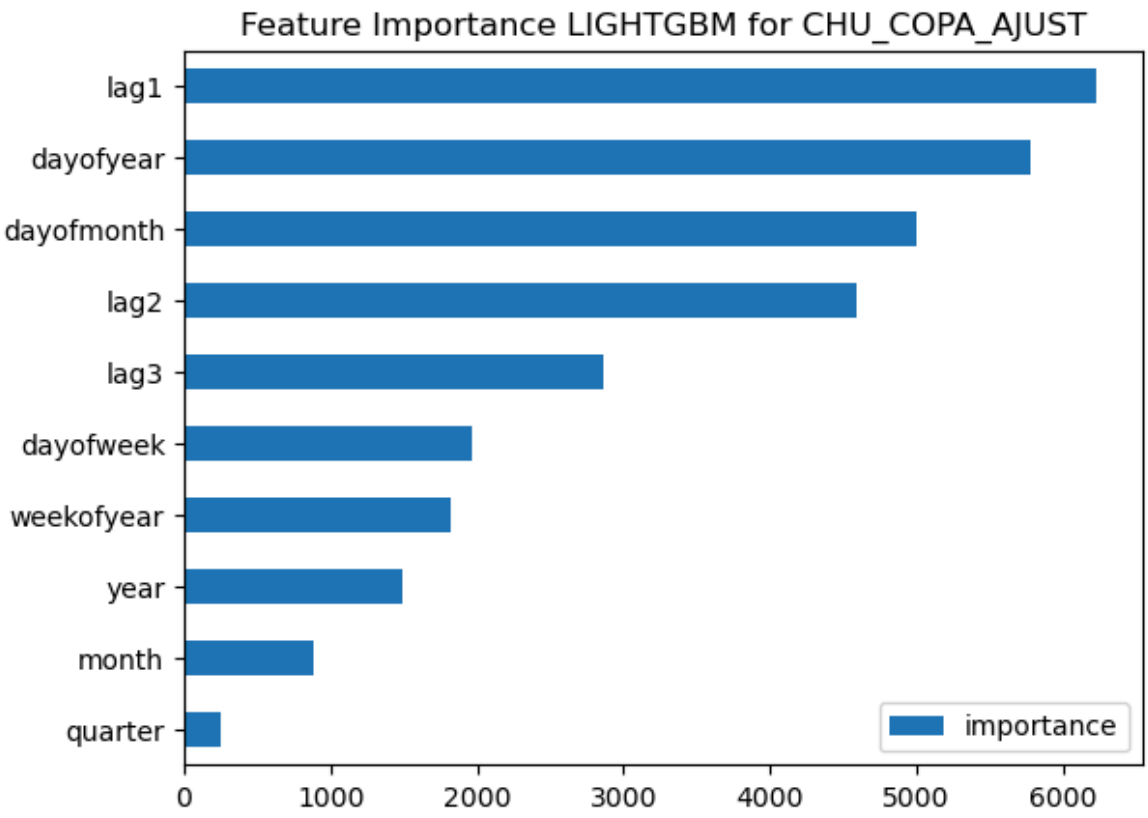
```
y_test_REC_PROPIOS = dataframes_test[1][TARGET[1]]

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]]
```

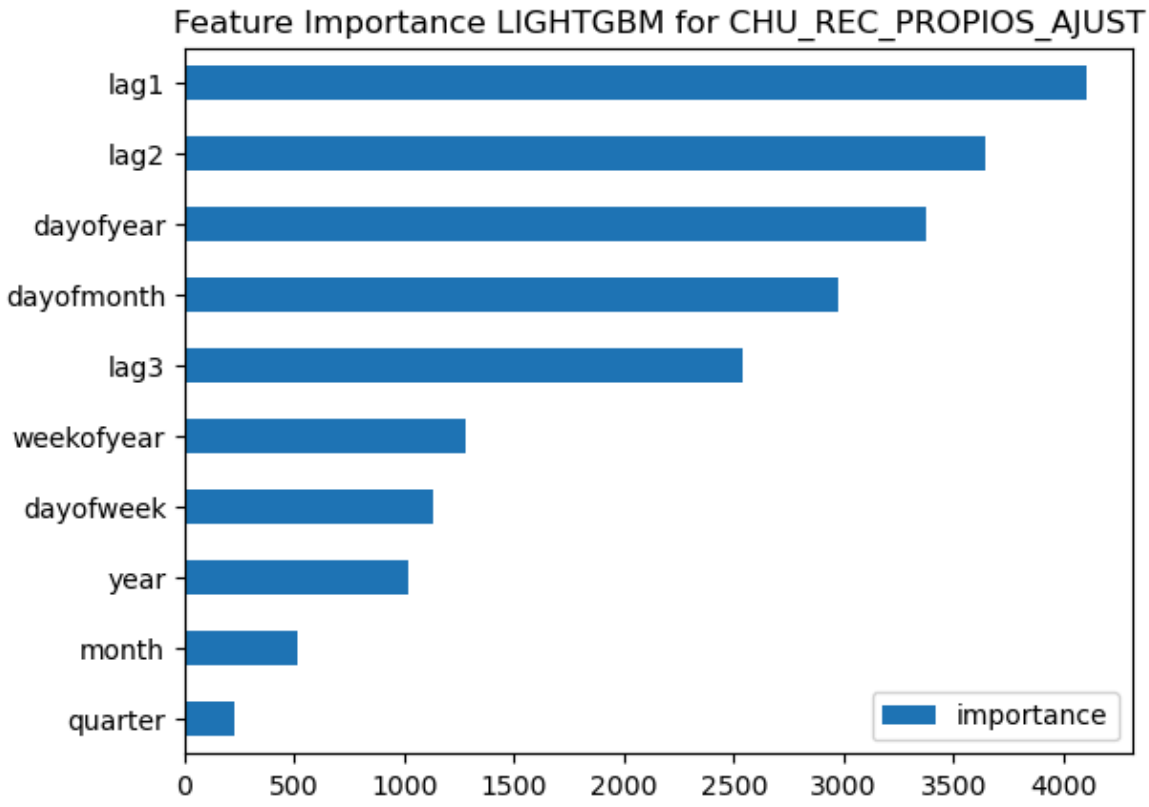
In [ ]:
```
lgb_copa = lgb.LGBMRegressor(**copa_best_params )
lgb_copa.fit(X_train_COPA, y_train_COPA,
        eval_set=[(X_train_COPA, y_train_COPA), (X_test_COPA, y_test_COPA)], eva
```

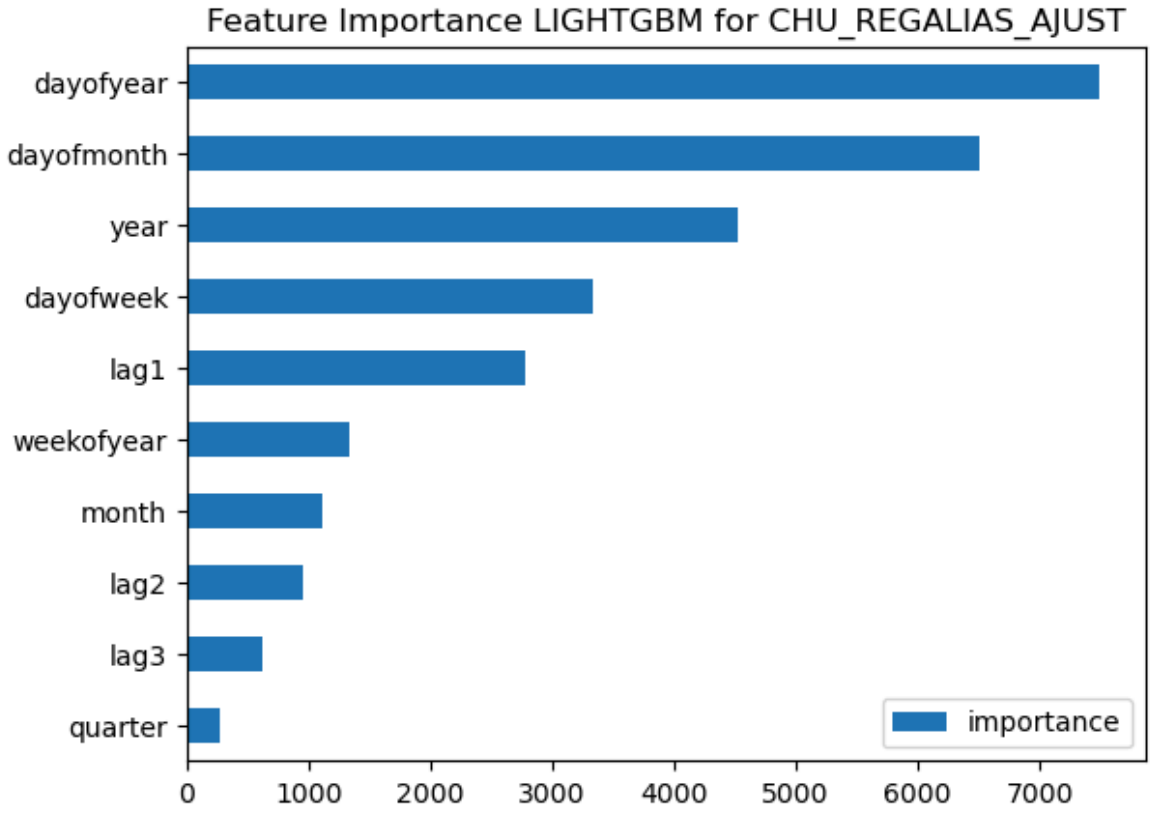
In [ ]:
```
lgb_rec_propios = lgb.LGBMRegressor(**rec_propios_best_params )
lgb_rec_propios.fit(X_train_REC_PROPIOS, y_train_REC_PROPIOS,
        eval_set=[(X_train_REC_PROPIOS, y_train_REC_PROPIOS), (X_test_REC_PROPIO
```

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()
```





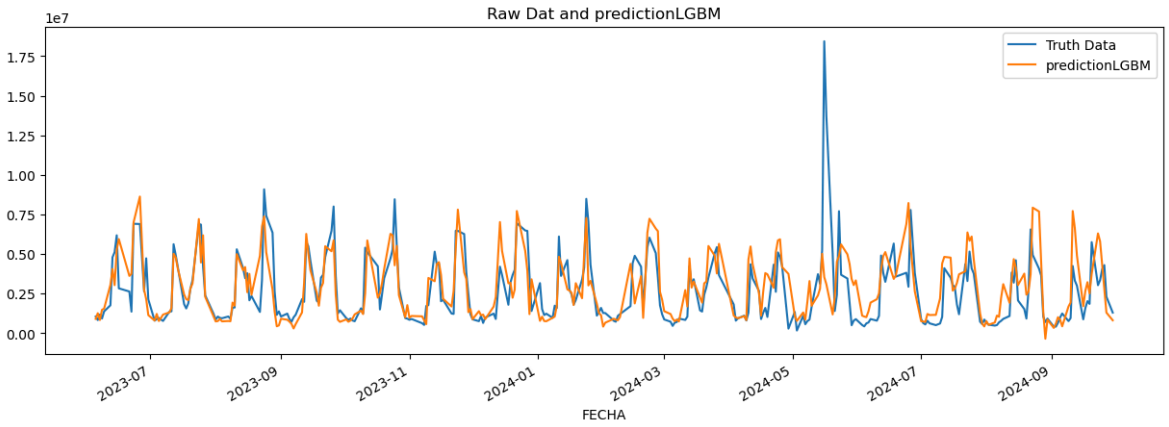


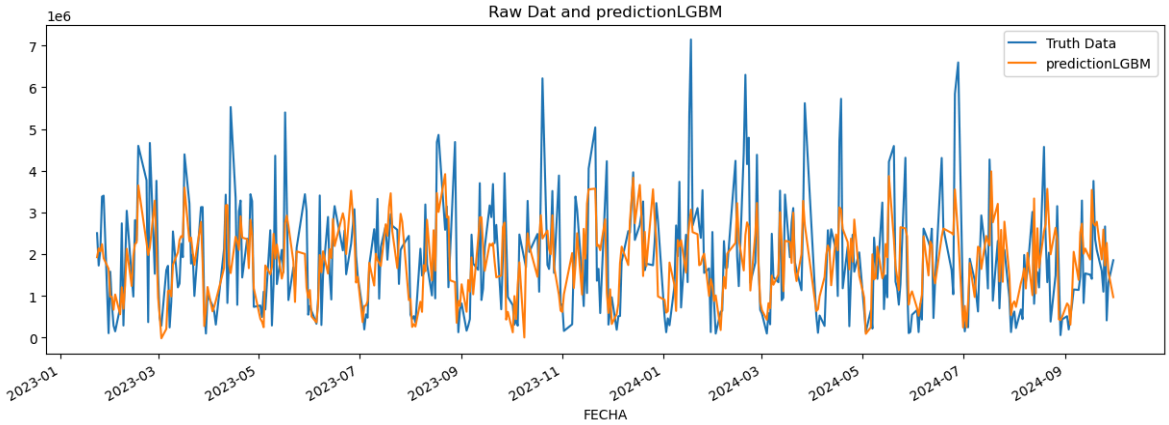
In [58]:

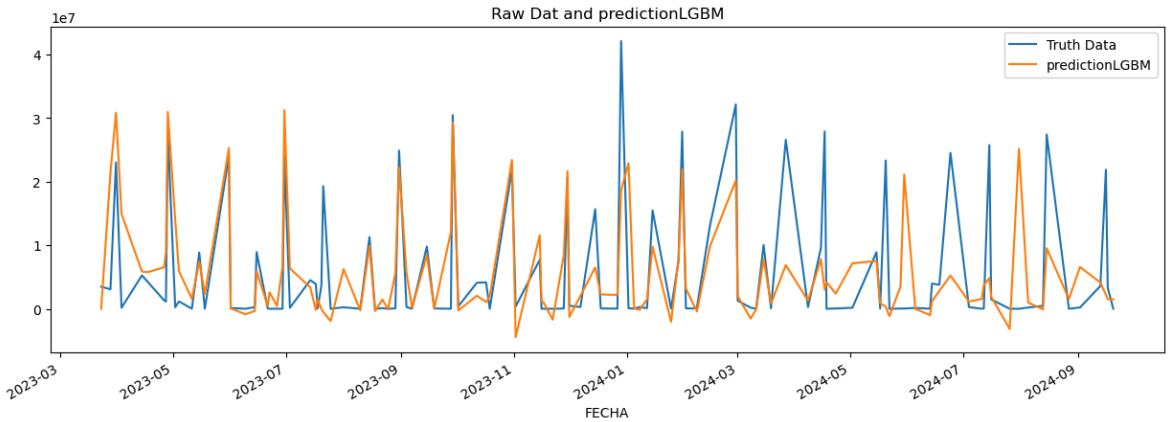
```
def plotear_predicciones(df_aux, model, X_test):
    df = df_aux.copy()
    test = df.copy()
    test['predictionLGBM'] = model.predict(X_test)
    df = df.merge(test[['predictionLGBM']], how='left', left_index=True, right_i
    ax = df[df.columns[0]].plot(figsize=(15, 5))
    df['predictionLGBM'].plot(ax=ax)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

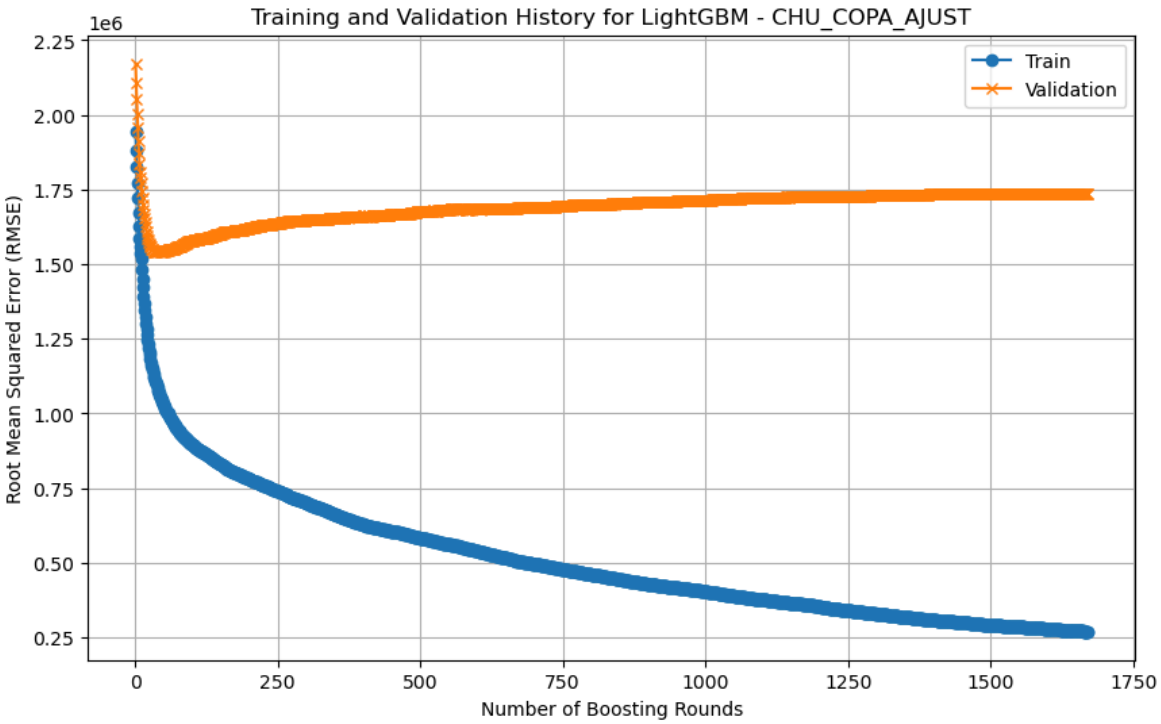
```
import matplotlib.pyplot as plt
import seaborn as sns

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)
```

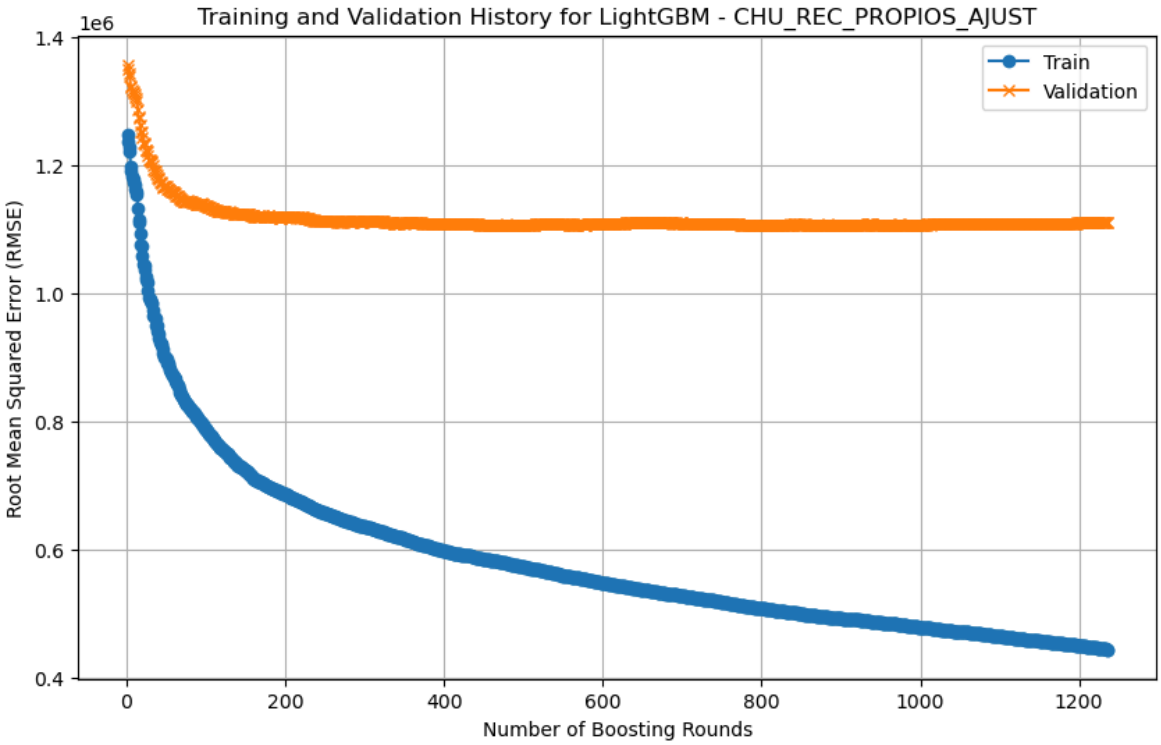
```
    plt.tight_layout()
    plt.show()
```

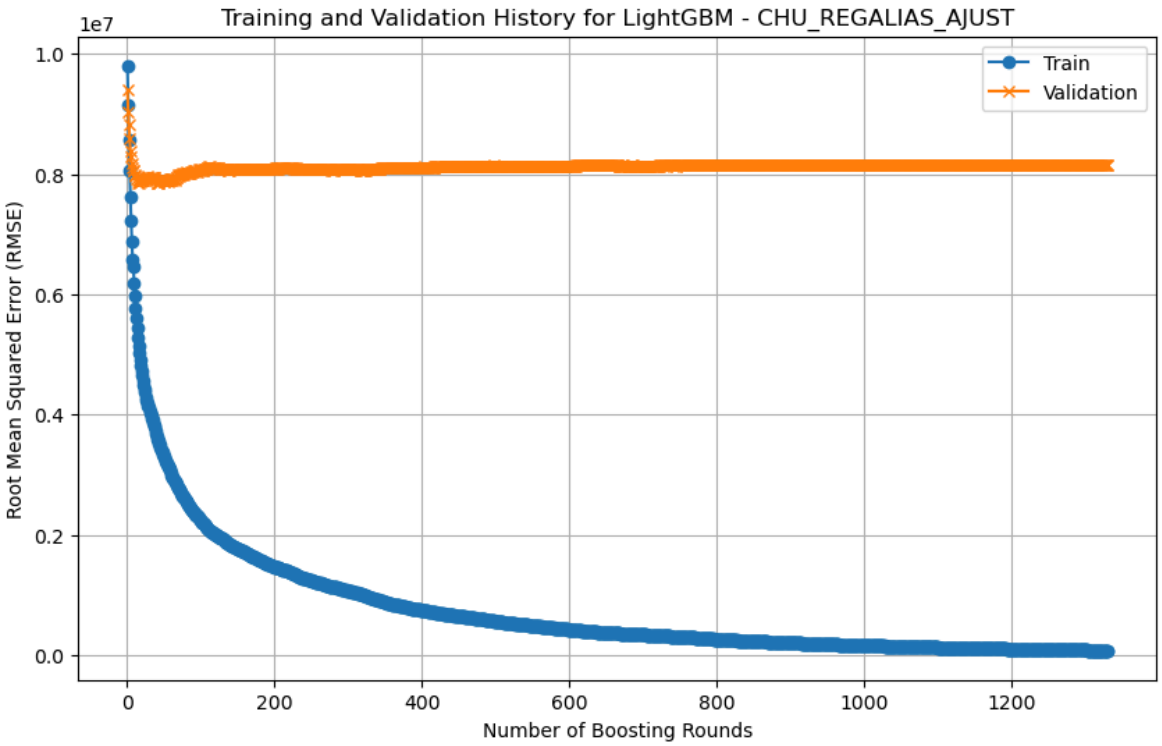
In [66]:
```
from sklearn.metrics import mean_absolute_error as mae

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()
```