Anexo III. Código y resultados para Aprendizaje Automático

```
In [1]: import pandas as pd
        import numpy as np
        import matplotlib.pyplot as plt
        import seaborn as sns
        %matplotlib inline

        from datetime import datetime
        from math import sqrt, exp
        from statistics import mean

        from statsmodels.api import ProbPlot
        from statsmodels.graphics import tsaplots
        from statsmodels.stats.stattools import jarque_bera as jb
        from statsmodels.stats.diagnostic import acorr_ljungbox as lb
        from statsmodels.tsa.seasonal import seasonal_decompose

        from scipy.stats import kstest, boxcox, gaussian_kde, norm

        from pmdarima.arima import ndiffs
        from pmdarima.arima import nsdiffs

        from sklearn.neighbors import KNeighborsRegressor
        from sklearn.linear_model import ElasticNet
        from sklearn.tree import DecisionTreeRegressor
        from sklearn.ensemble import RandomForestRegressor

        from sklearn.metrics import mean_squared_error as mse
        from sklearn.metrics import mean_absolute_error as mae

        from tstoolbox import *

        import warnings
        warnings.filterwarnings("ignore")

In [2]: sns.set(rc = {"figure.figsize":(10,4), "axes.facecolor": "#eeeef4"})
        my_palette = sns.color_palette(sns.diverging_palette(255,
                                                             133,
                                                             l=40,
                                                             n=4,
```

```
                                                        center="dark"))
        sns.set_palette(my_palette)
```

```
In [3]: ts_df = pd.read_csv('wolf_river.csv', sep = ';')
        ts_df['index'] = pd.to_datetime(ts_df['month'])
        ts_df.set_index('index', inplace = True)
        ts_df.drop(["month"], axis = 1, inplace = True) # Serie como pd.DataFrame
        ts = ts_df.iloc[:,0] # Serie como pd.Series
```

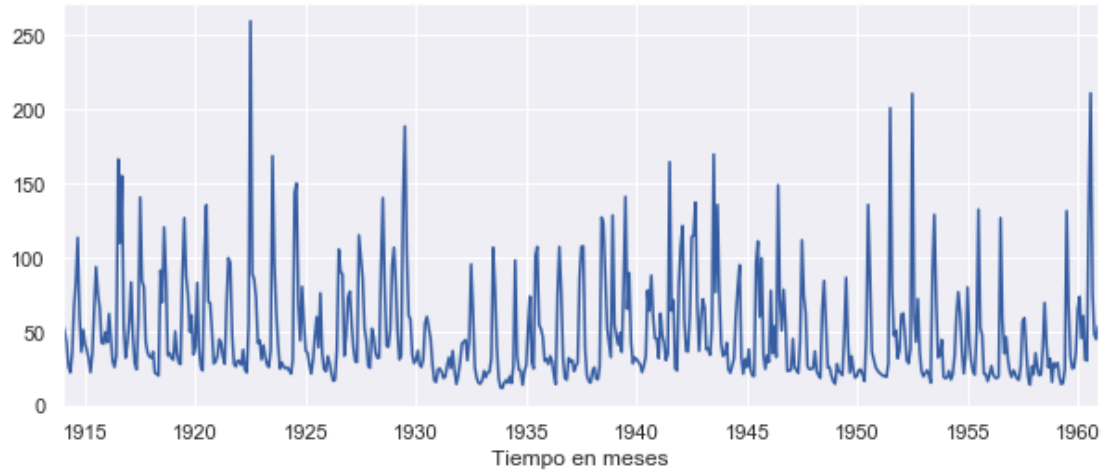
```
In [4]: type(ts_df)
```

```
Out[4]: pandas.core.frame.DataFrame
```

```
In [5]: type(ts)
```

```
Out[5]: pandas.core.series.Series
```

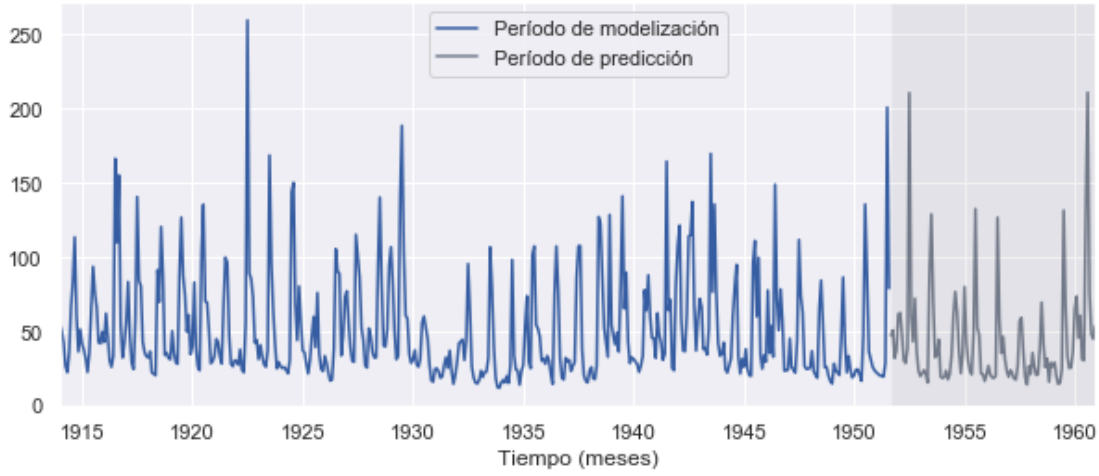
```
In [6]: tsplot(ts)
        plt.savefig("river.png", dpi = 400)
        plt.show()
```



División temporal en período de modelización y período de predicción

```
In [7]: train = ts_split(ts_df)[0] # Período de ajsute de modelos
        test  = ts_split(ts)[1]    # Período de generación de predicciones
```

```
In [8]: train_test_plot(train, test)
        plt.savefig("river_split.png", dpi = 400)
        plt.show()
```



Fechas destacables

```
In [9]: start_date = train.index[0]
        split_date = test.index[0]  # Primera observación a predecir
        end_date   = test.index[-1]
```

Preprocesamientos para la serie

```
In [10]: boxcox_trans = boxcox(train)
         bc_param = boxcox_trans[1][0]
         bc_train = ((train**bc_param)-1)/bc_param

In [11]: ts_components = seasonal_decompose(train, "add")
         seasonal = ts_components.seasonal
         deseas = train - seasonal

         seasonality_forecast = snaive(seasonal, test)

In [12]: diff_train = train.diff(1).iloc[1:]

In [13]: bc_ts_components = seasonal_decompose(bc_train, "add")
         bc_seasonal = bc_ts_components.seasonal
         bc_deseas = bc_train - bc_seasonal

         bc_seasonality_forecast = snaive(bc_seasonal, test)

In [14]: diff_bc_train = bc_train.diff(1).iloc[1:]

In [15]: diff_deseas = deseas.diff(1).iloc[1:]

In [16]: bc_diff_deseas = bc_deseas.diff(1).iloc[1:]
```

Fijación de semilla para reproducibilidad

```
In [17]: seed = 1
```

0.0.1 Serie temporal original

```
In [18]: lag_df = series_to_supervised(train, n_in=12)
         lag_df.head(5)
```

Out[18]:

index	var1(t-12)	var1(t-11)	var1(t-10)	var1(t-9)	var1(t-8)	\
1915-01-01	55.275	49.951	42.617	26.901	22.654	
1915-02-01	49.951	42.617	26.901	22.654	35.793	
1915-03-01	42.617	26.901	22.654	35.793	66.063	
1915-04-01	26.901	22.654	35.793	66.063	83.903	
1915-05-01	22.654	35.793	66.063	83.903	113.636	

index	var1(t-7)	var1(t-6)	var1(t-5)	var1(t-4)	var1(t-3)	var1(t-2)	\
1915-01-01	35.793	66.063	83.903	113.636	60.655	36.557	
1915-02-01	66.063	83.903	113.636	60.655	36.557	51.537	
1915-03-01	83.903	113.636	60.655	36.557	51.537	41.739	
1915-04-01	113.636	60.655	36.557	51.537	41.739	37.492	
1915-05-01	60.655	36.557	51.537	41.739	37.492	31.998	

index	var1(t-1)	var1(t)
1915-01-01	51.537	41.739
1915-02-01	41.739	37.492
1915-03-01	37.492	31.998
1915-04-01	31.998	22.823
1915-05-01	22.823	35.566

Definición de X (predictoras) e y (a predecir)

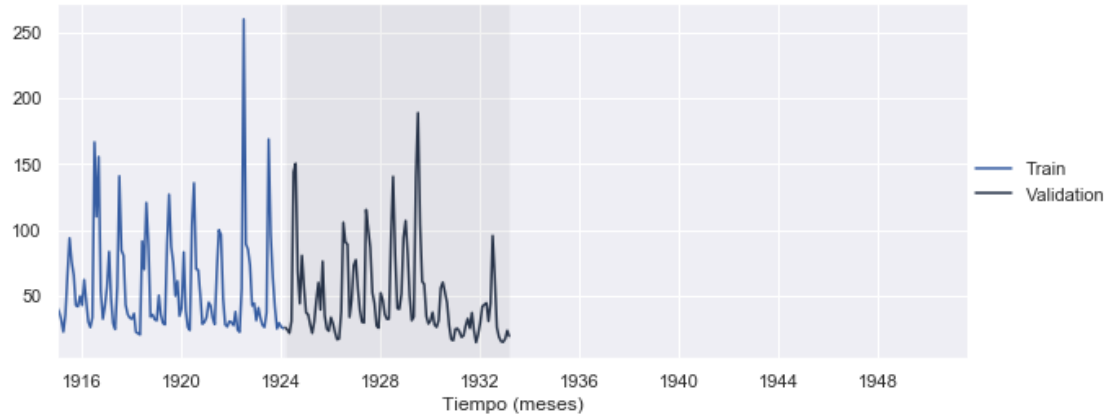
```
In [19]: X_train = lag_df.iloc[:,:-1]
         y_train = lag_df.iloc[:,-1]
```

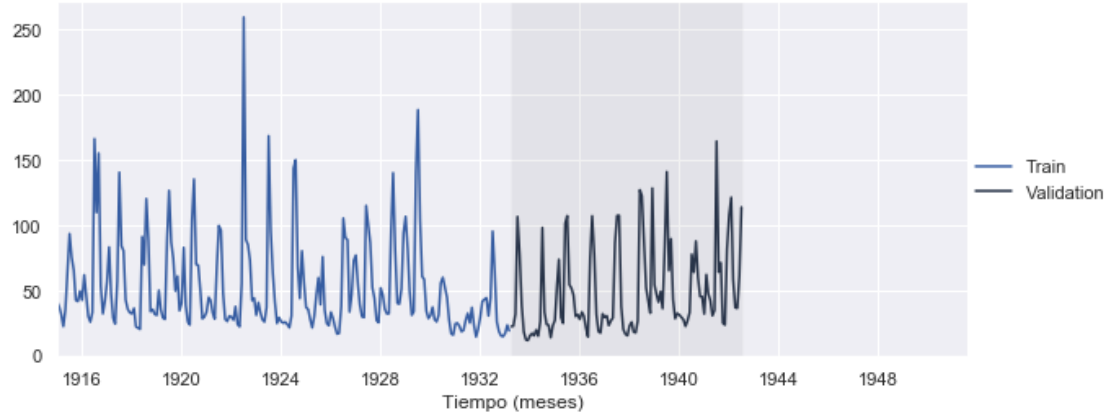
Validación cruzada temporal

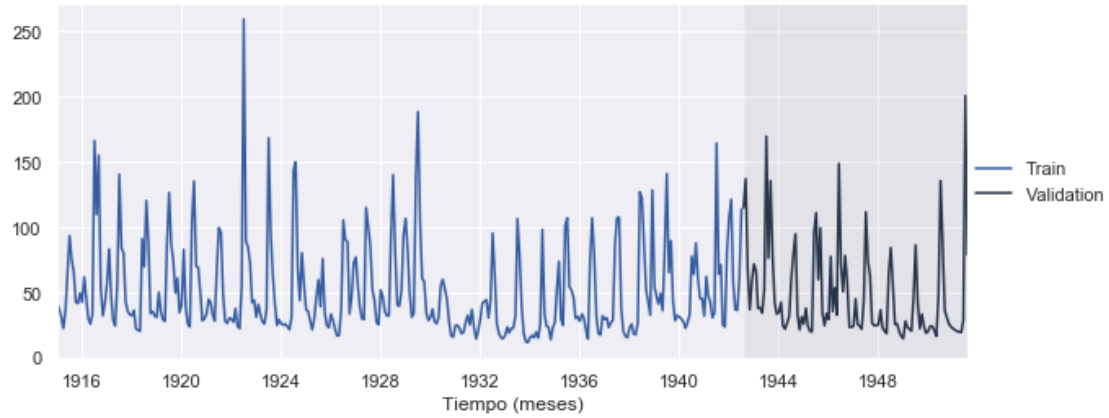
```
In [20]: train3, validation3 = ts_split(lag_df, train_size=0.75)
         X_train3 = train3.iloc[:,:-1]
         y_train3 = train3.iloc[:,-1]
         X_val3 = validation3.iloc[:,:-1]
         y_val3 = validation3.iloc[:,-1]

         train2, validation2 = ts_split(train3, train_size=0.66)
         X_train2 = train2.iloc[:,:-1]
         y_train2 = train2.iloc[:,-1]
```

```
X_val2 = validation2.iloc[:,:-1]
y_val2 = validation2.iloc[:,-1]

train1, validation1 = ts_split(train2, train_size=0.5)
X_train1 = train1.iloc[:,:-1]
y_train1 = train1.iloc[:,-1]
X_val1 = validation1.iloc[:,:-1]
y_val1 = validation1.iloc[:,-1]
```

In [21]:
```
tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
plt.show()
tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
plt.show()
tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
plt.show()
```





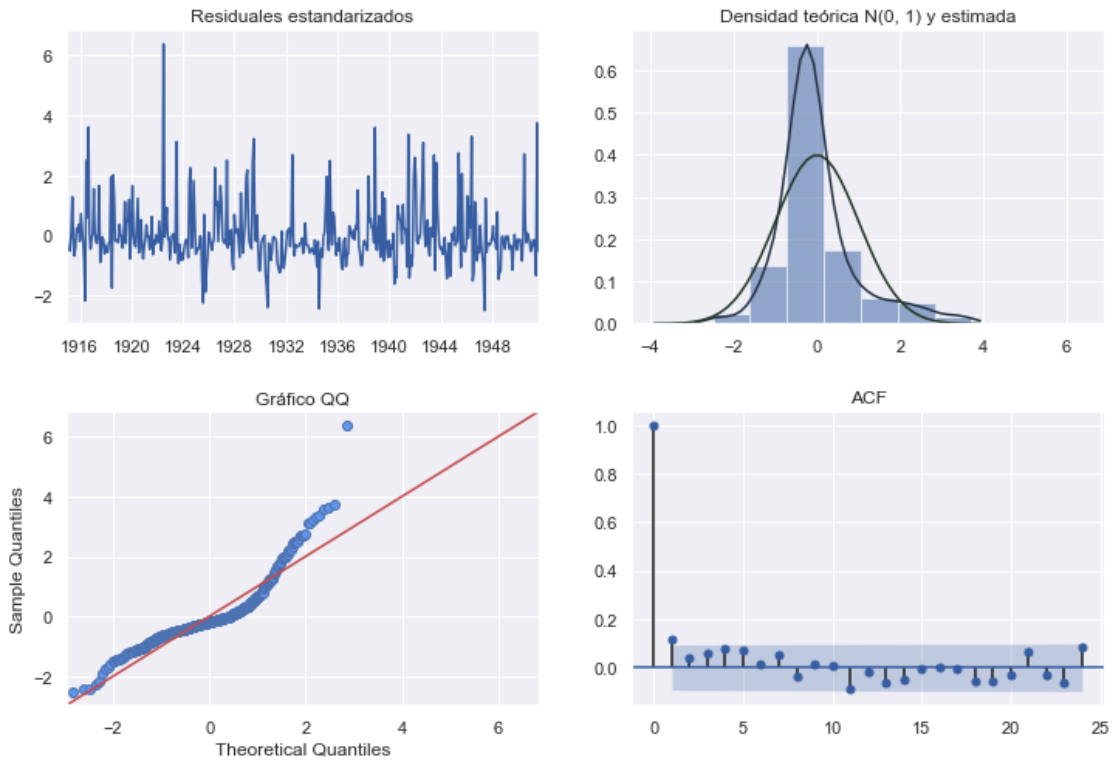


K-Nearest Neighbors

```
In [22]: neigb = list(np.arange(2, 41, 1))

In [23]: best_score, best_knn = float("inf"), None

         for k in neigb:
                 knn = KNeighborsRegressor(n_neighbors=k)

                 knn_model1 = knn.fit(X_train1, y_train1)
                 knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                 knn_model2 = knn.fit(X_val1, y_val1)
                 knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                 knn_model3 = knn.fit(X_val2, y_val2)
                 knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                 rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                 cvrmse = mean([rmse1, rmse2, rmse3])
                 if cvrmse < best_score:
                     best_score, best_knn = cvrmse, knn.get_params()

         print('Best KNN: k = %s | CVRMSE = %.3f' % (best_knn['n_neighbors'],
                                                     best_score))

Best KNN: k = 12 | CVRMSE = 30.586


In [24]: knn_hyp = {"k": 12}
```

In [25]:
```
knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
knn_model = knn.fit(X_train, y_train)
knn_fitted = pd.Series(knn_model.predict(X_train))
knn_fitted
knn_fitted.index = X_train.index
knn_resid = y_train - knn_fitted
knn_resid = (knn_resid -
             knn_resid.mean()) / knn_resid.std()

knn_jb_test = jb(knn_resid)
knn_lb_test = lb(knn_resid)

knn_forecast = iter_forecast(knn, y_train, 12, test)
```

In [26]:
```
resid_diag(knn_resid)
plt.show()
```

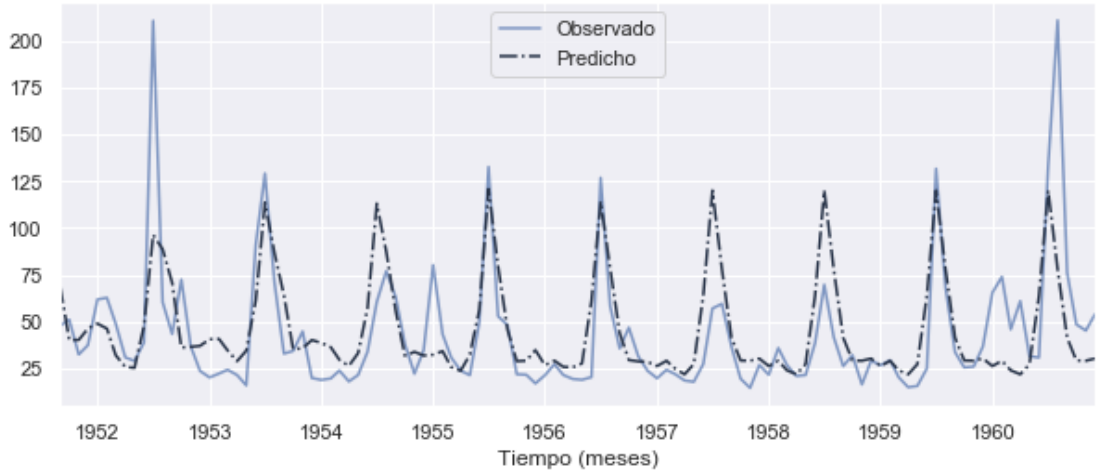


In [27]:
```
print("K-Nearest Neighbors")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
```

```
        print("Test de Ljung-Box para k =  6 (p-valor): " +
              str(knn_lb_test[1][6]))
        print("Test de Ljung-Box para k = 12 (p-valor): " +
              str(knn_lb_test[1][12]))
        print("")
        print("RMSE (test): " + str(sqrt(mse(test, knn_forecast))))
        print("MAE (test):  " + str(mae(test, knn_forecast)))
        print("sMAPE (test):  " + str(smape(test, knn_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 2.903200667052171e-168
Test de Ljung-Box para k =  6 (p-valor): 0.03932935347286502
Test de Ljung-Box para k = 12 (p-valor): 0.07230606434407635

RMSE (test): 25.57542279856696
MAE (test):  16.631637648809523
sMAPE (test):  35.39380649389102
```

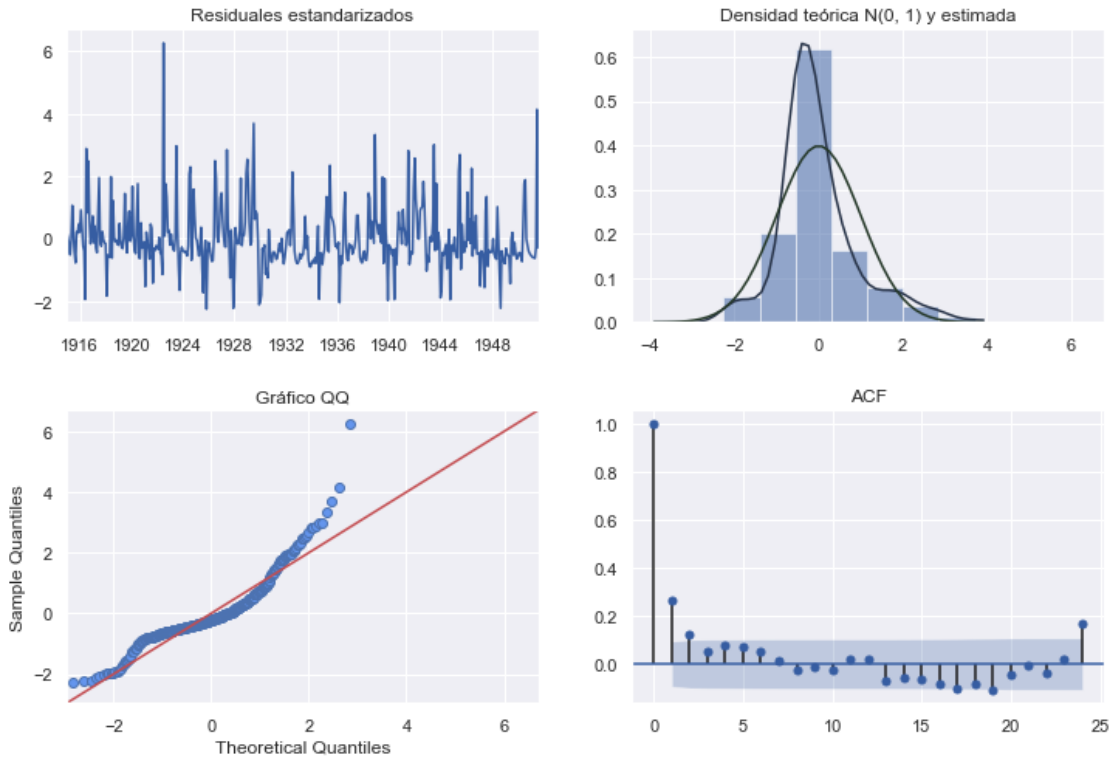
```
In [28]: forecast_plot(test, knn_forecast)
         plt.show()
```



Regresion tree

```
In [29]: depths = list(np.arange(1, 21, 1))
```

```
In [30]: best_score, best_tree = float("inf"), None

         for depth in depths:
                 tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                 tree_model1 = tree.fit(X_train1, y_train1)
                 tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                 tree_model2 = tree.fit(X_val1, y_val1)
                 tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                 tree_model3 = tree.fit(X_val2, y_val2)
                 tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                 rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))

                 cvrmse = mean([rmse1, rmse2, rmse3])
                 if cvrmse < best_score:
                     best_score, best_tree = cvrmse, tree.get_params()

         print('Best Tree: depth: %s | CV RMSE = %.3f' % (best_tree['max_depth'],
                                                          best_score))

Best Tree: depth: 1 | CV RMSE = 34.312


In [31]: tree_hyp = {"depth": 1}

In [32]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"], random_state=seed)
         tree_model = tree.fit(X_train, y_train)
         tree_fitted = pd.Series(tree_model.predict(X_train))
         tree_fitted
         tree_fitted.index = X_train.index
         tree_resid = y_train - tree_fitted
         tree_resid = (tree_resid -
                       tree_resid.mean()) / tree_resid.std()

         tree_jb_test = jb(tree_resid)
         tree_lb_test = lb(tree_resid)

         tree_forecast = iter_forecast(tree, y_train, 12, test)

In [33]: resid_diag(tree_resid)
         plt.show()
```

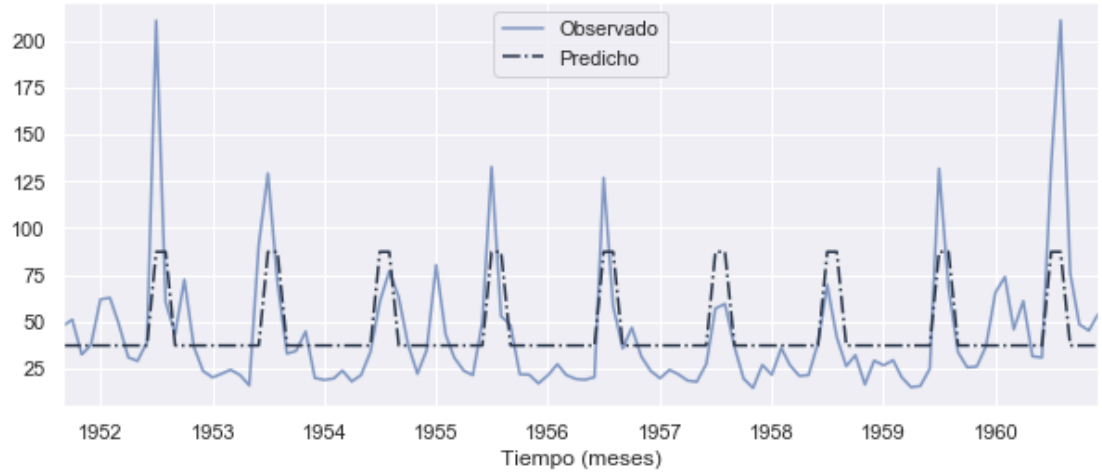



```
In [34]: print("Decision Tree")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(tree_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(tree_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, tree_forecast))))
         print("MAE (test):  " + str(mae(test, tree_forecast)))
         print("sMAPE (test):  " + str(smape(test, tree_forecast)))
```

```
Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 2.3423838676505707e-129
Test de Ljung-Box para k =  6 (p-valor): 2.0285871463335237e-07
Test de Ljung-Box para k = 12 (p-valor): 8.268260440498782e-06
```

```
RMSE (test): 25.83950361433136
MAE (test):  18.321662961679994
sMAPE (test):  40.46374917218229
```

```
In [35]: forecast_plot(test, tree_forecast)
         plt.show()
```



Random Forest

```
In [37]: best_score, best_tree = float("inf"), None

         n_estimators = [50, 100, 200, 500]
         depths = np.linspace(1, 61, 20)
         max_features = [0.8, 1]


         for n in n_estimators:
             for depth in depths:
                 for features in max_features:
                     rf = RandomForestRegressor(n_estimators=n,
                                                max_depth=depth,
                                                max_features=features,
                                                random_state=seed)

                     rf_model1 = rf.fit(X_train1, y_train1)
                     rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                     rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))
```

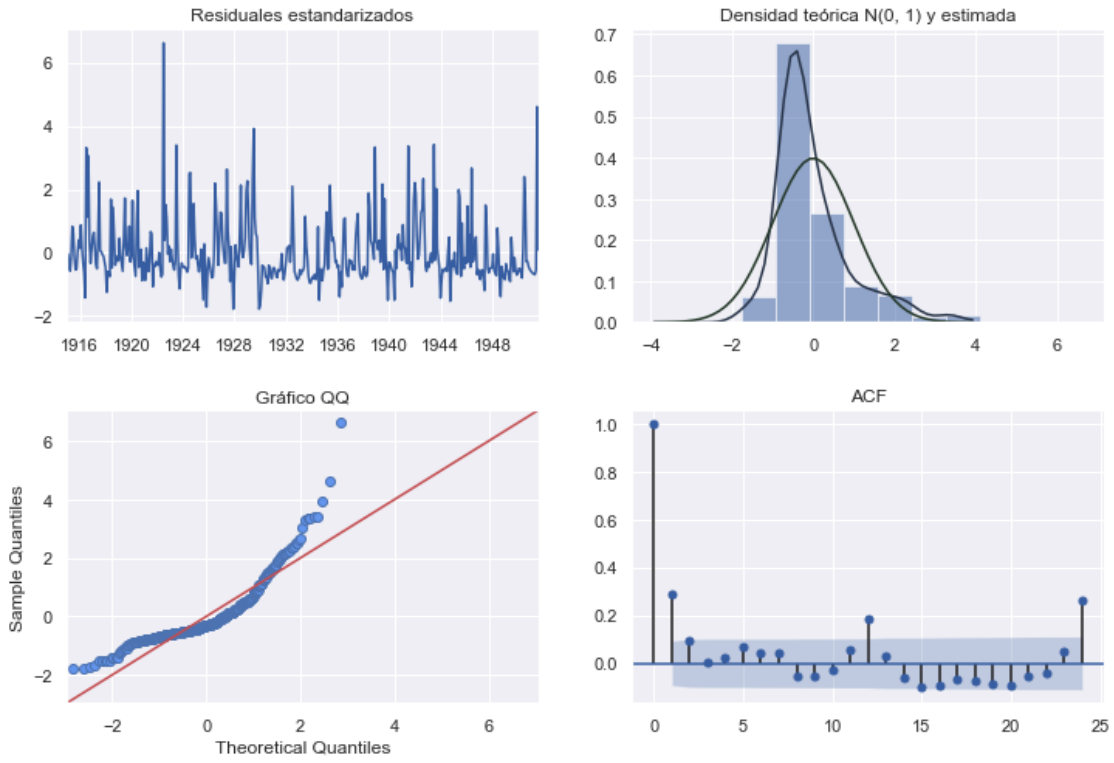
```
                    rf_model2 = rf.fit(X_val1, y_val1)
                    rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                    rf_model3 = rf.fit(X_val2, y_val2)
                    rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_rf = cvrmse, rf.get_params()

        print('Best RF: n_estimators: %s max_depth: %s max_features : %s | CV RMSE = %.3f' %
              (best_rf['n_estimators'], best_rf['max_depth'],
               best_rf['max_features'], best_score))
```

```
Best RF: n_estimators: 50 max_depth: 1.0 max_features : 0.8 | CV RMSE = 32.379
```

```
In [38]: rf_hyp = {"max_depth": 1,
                   "n_estimators": 50,
                   "max_features": 0.8}
```

```
In [39]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"], n_estimators=rf_hyp["n_estima
                                    max_features=rf_hyp["max_features"], random_state=seed)

         rf_model = rf.fit(X_train, y_train)
         rf_fitted = pd.Series(rf_model.predict(X_train))
         rf_fitted
         rf_fitted.index = X_train.index
         rf_resid = y_train - rf_fitted
         rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

         rf_jb_test = jb(rf_resid)
         rf_lb_test = lb(rf_resid)

         rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [40]: resid_diag(rf_resid)
         plt.show()
```

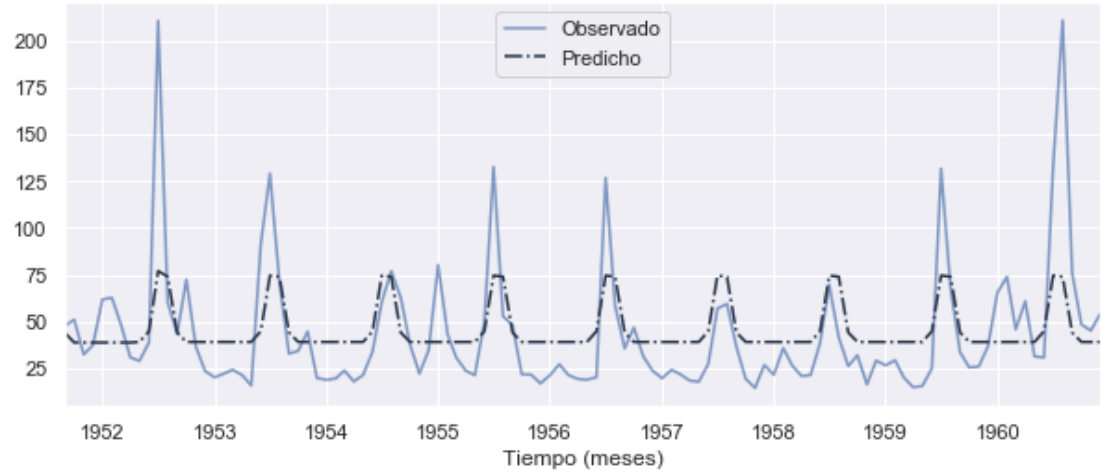



```
In [41]: print("Random Forest")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(rf_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(rf_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, rf_forecast))))
         print("MAE (test):  " + str(mae(test, rf_forecast)))
         print("sMAPE (test):  " + str(smape(test, rf_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.7713368672108015e-226
Test de Ljung-Box para k =  6 (p-valor): 1.3674098923847824e-07
Test de Ljung-Box para k = 12 (p-valor): 4.580087633609218e-09
```

```
RMSE (test): 27.274163651871557
MAE (test):  18.873514748356094
sMAPE (test):  42.28556263637247
```

```
In [42]: forecast_plot(test, rf_forecast)
         plt.show()
```



ElasticNet

```
In [43]: best_score, best_tree = float("inf"), None

         ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
         alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


         for rat in ratio:
             for alp in alpha:
                 en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                 en_model1 = en.fit(X_train1, y_train1)
                 en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                 en_model2 = en.fit(X_val1, y_val1)
                 en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                 en_model3 = en.fit(X_val2, y_val2)
```

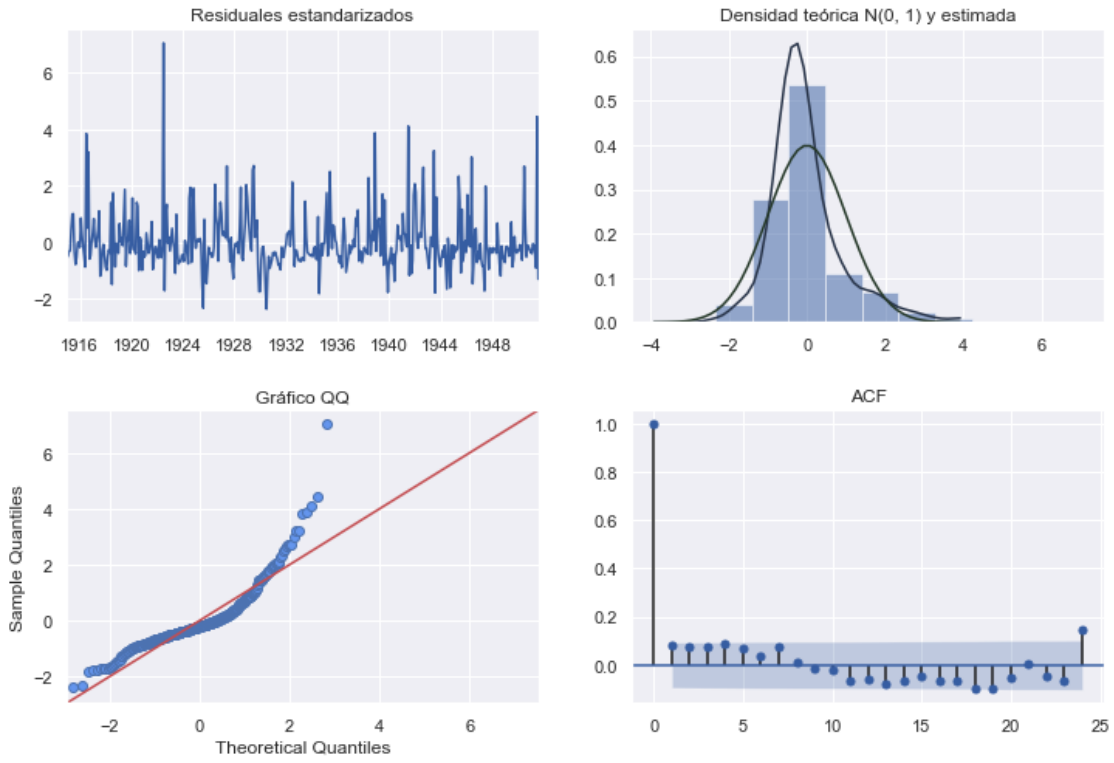
```
                en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_en = cvrmse, en.get_params()

        print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
              (best_en['l1_ratio'], best_en['alpha'], best_score))
```

```
Best EN: ratio: 0.1 alpha: 100 | CV RMSE = 31.974
```

```
In [44]: en_hyp = {"l1_ratio": 0.1,
                   "alpha": 100}
```

```
In [45]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                         random_state=seed)
         en_model = en.fit(X_train, y_train)
         en_fitted = pd.Series(en_model.predict(X_train))
         en_fitted
         en_fitted.index = X_train.index
         en_resid = y_train - en_fitted
         en_resid = (en_resid - en_resid.mean()) / en_resid.std()

         en_jb_test = jb(en_resid)
         en_lb_test = lb(en_resid)

         en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [46]: resid_diag(en_resid)
         plt.show()
```

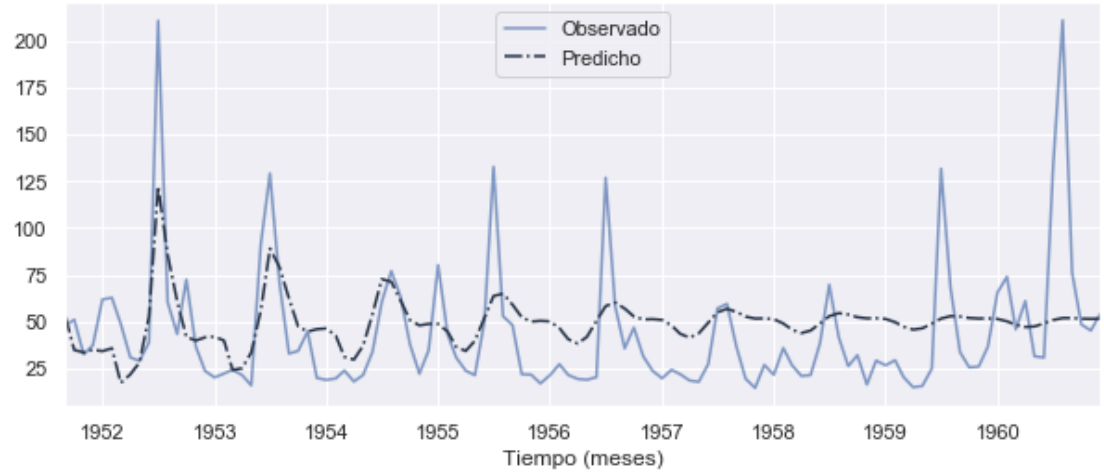



```
In [47]: print("ElasticNet")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(en_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(en_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, en_forecast))))
         print("MAE (test):  " + str(mae(test, en_forecast)))
         print("sMAPE (test):  " + str(smape(test, en_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 3.034582288460461e-305
Test de Ljung-Box para k =  6 (p-valor): 0.018580289030905108
Test de Ljung-Box para k = 12 (p-valor): 0.0377027495242834
```

```
RMSE (test): 30.11545109033476
MAE (test):  22.0843920027641
sMAPE (test):  48.59639886725879
```

```
In [48]: forecast_plot(test, en_forecast)
         plt.show()
```



Serie temporal transformada con Box-Cox como estructura de DataFrame

```
In [49]: lag_df = series_to_supervised(bc_train, n_in=12)
         lag_df.head(5)
```

Out[49]:

index	var1(t-12)	var1(t-11)	var1(t-10)	var1(t-9)	var1(t-8)	var1(t-7)	var1(t-6)	var1(t-5)	var1(t-4)	var1(t-3)	var1(t-2)
1915-01-01	2.056547	2.034131	1.997200	1.876680	1.825973	1.953956	2.093966	2.140314	2.193369	2.076357	1.959344
1915-02-01	2.034131	1.997200	1.876680	1.825973	1.953956	2.093966	2.140314	2.193369	2.076357	1.959344	2.041142
1915-03-01	1.997200	1.876680	1.825973	1.953956	2.093966	2.140314	2.193369	2.076357	1.959344	2.041142	1.992191
1915-04-01	1.876680	1.825973	1.953956	2.093966	2.140314	2.193369	2.076357	1.959344	2.041142	1.992191	1.965730
1915-05-01	1.825973	1.953956	2.093966	2.140314	2.193369	2.076357	1.959344	2.041142	1.992191	1.965730	1.924627

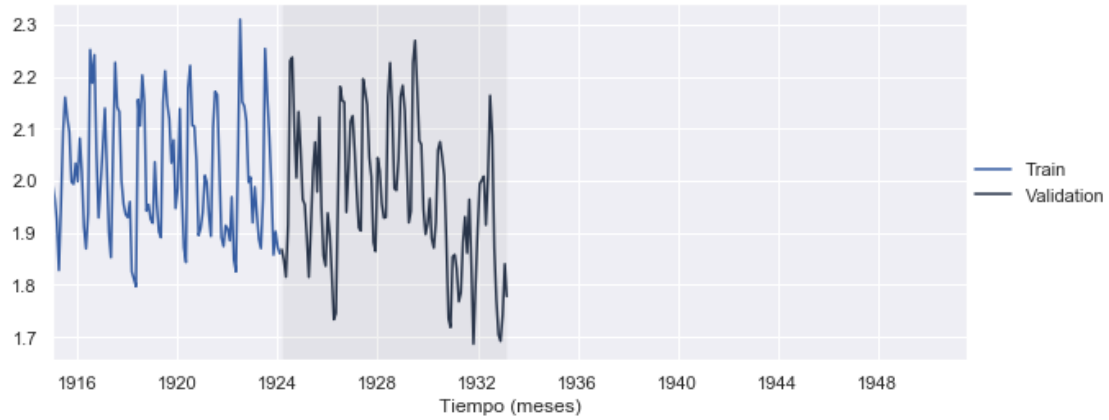
```
            var1(t-1)   var1(t)
index
1915-01-01   2.041142  1.992191
1915-02-01   1.992191  1.965730
1915-03-01   1.965730  1.924627
1915-04-01   1.924627  1.828236
1915-05-01   1.828236  1.952324
```

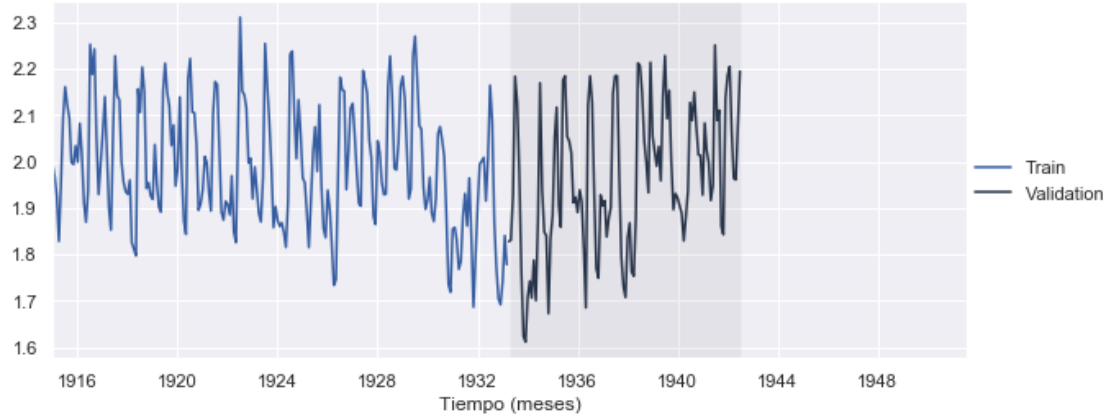
Definición de X (predictoras) e y (a predecir)

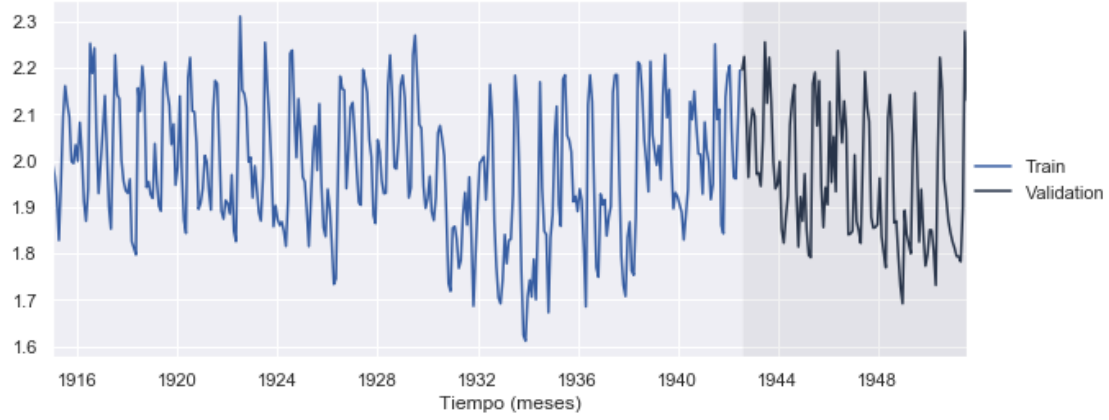
```
In [50]: X_train = lag_df.iloc[:,:-1]
         y_train = lag_df.iloc[:,-1]
```

Validación cruzada temporal

```
In [51]: train3, validation3 = ts_split(lag_df, train_size=0.75)
         X_train3 = train3.iloc[:,:-1]
         y_train3 = train3.iloc[:,-1]
         X_val3 = validation3.iloc[:,:-1]
         y_val3 = validation3.iloc[:,-1]

         train2, validation2 = ts_split(train3, train_size=0.66)
         X_train2 = train2.iloc[:,:-1]
         y_train2 = train2.iloc[:,-1]
         X_val2 = validation2.iloc[:,:-1]
         y_val2 = validation2.iloc[:,-1]

         train1, validation1 = ts_split(train2, train_size=0.5)
         X_train1 = train1.iloc[:,:-1]
         y_train1 = train1.iloc[:,-1]
         X_val1 = validation1.iloc[:,:-1]
         y_val1 = validation1.iloc[:,-1]

In [52]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
         plt.show()
         tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
         plt.show()
         tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
         plt.show()
```

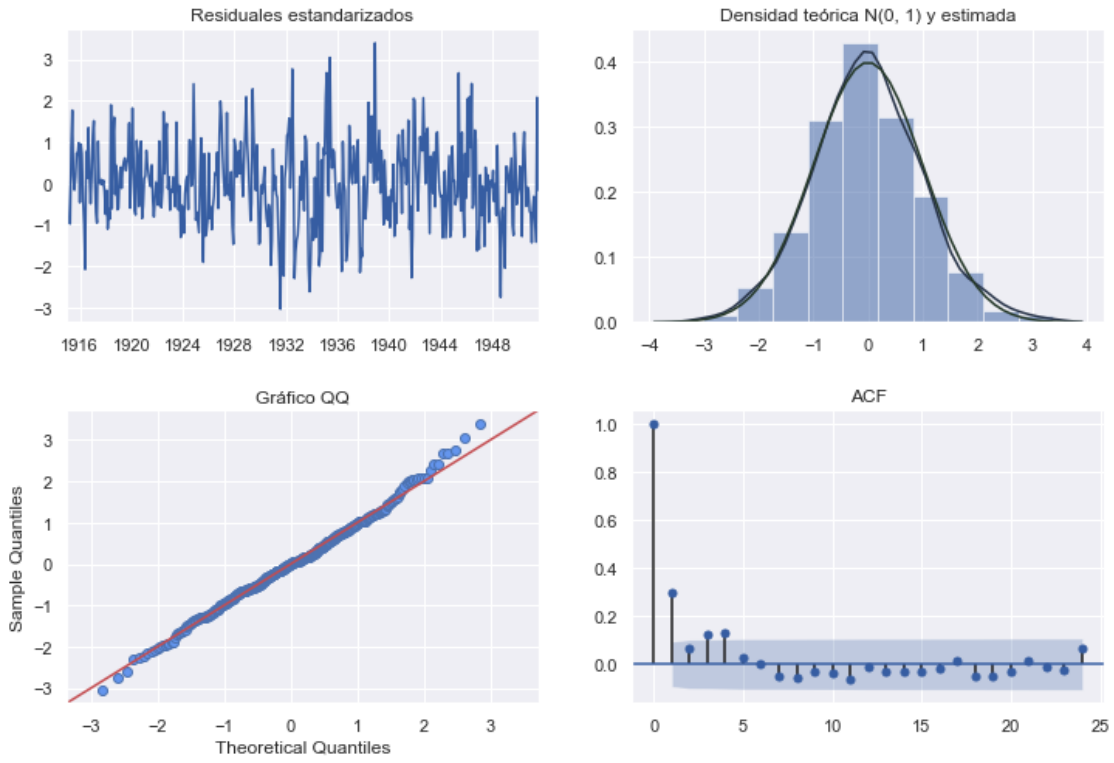

2.3
2.2
2.1
2.0
1.9
1.8
1.7
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

K-Nearest Neighbors

```
In [53]: neigb = list(np.arange(2, 41, 1))

In [54]: best_score, best_knn = float("inf"), None

         for k in neigb:
                 knn = KNeighborsRegressor(n_neighbors=k)

                 knn_model1 = knn.fit(X_train1, y_train1)
                 knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                 knn_model2 = knn.fit(X_val1, y_val1)
                 knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                 knn_model3 = knn.fit(X_val2, y_val2)
                 knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                 rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                 cvrmse = mean([rmse1, rmse2, rmse3])
                 if cvrmse < best_score:
                     best_score, best_knn = cvrmse, knn.get_params()

         print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))

Best KNN 10 CVRMSE = 0.136


In [55]: knn_hyp = {"k": 10}

In [56]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
         knn_model = knn.fit(X_train, y_train)
         knn_fitted = pd.Series(knn_model.predict(X_train))
         knn_fitted
         knn_fitted.index = X_train.index
         knn_resid = y_train - knn_fitted
         knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

         knn_jb_test = jb(knn_resid)
         knn_lb_test = lb(knn_resid)

         knn_forecast = iter_forecast(knn, y_train, 12, test)

In [57]: knn_box_forecast = (bc_param * knn_forecast + 1) ** (1 / bc_param)

In [58]: resid_diag(knn_resid)
         plt.show()
```

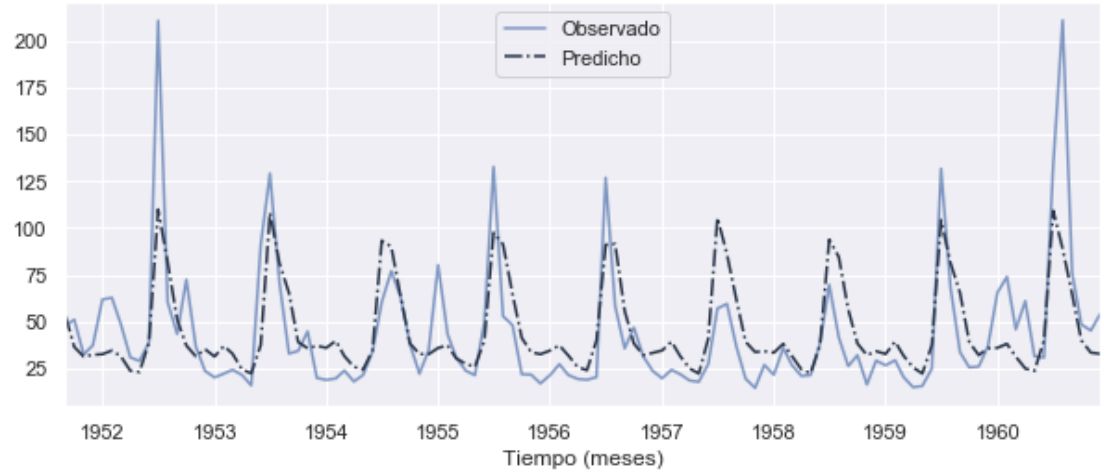



```
In [59]: print("K-Nearest Neighbors")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(knn_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(knn_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, knn_box_forecast))))
         print("MAE (test):  " + str(mae(test, knn_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, knn_box_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.14929158900292663
Test de Ljung-Box para k =  6 (p-valor): 6.173994051775582e-10
Test de Ljung-Box para k = 12 (p-valor): 2.2780049116050887e-08
```

```
RMSE (test): 23.826827407781153
MAE (test):  16.289851321109712
sMAPE (test):  35.04950163941397
```

```
In [60]: forecast_plot(test, knn_box_forecast)
         plt.show()
```



Regresion tree

```
In [61]: depths = list(np.arange(1, 21, 1))
```

```
In [62]: best_score, best_tree = float("inf"), None

         for depth in depths:
                 tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                 tree_model1 = tree.fit(X_train1, y_train1)
                 tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                 tree_model2 = tree.fit(X_val1, y_val1)
                 tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                 tree_model3 = tree.fit(X_val2, y_val2)
                 tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                 rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))
```

```
                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

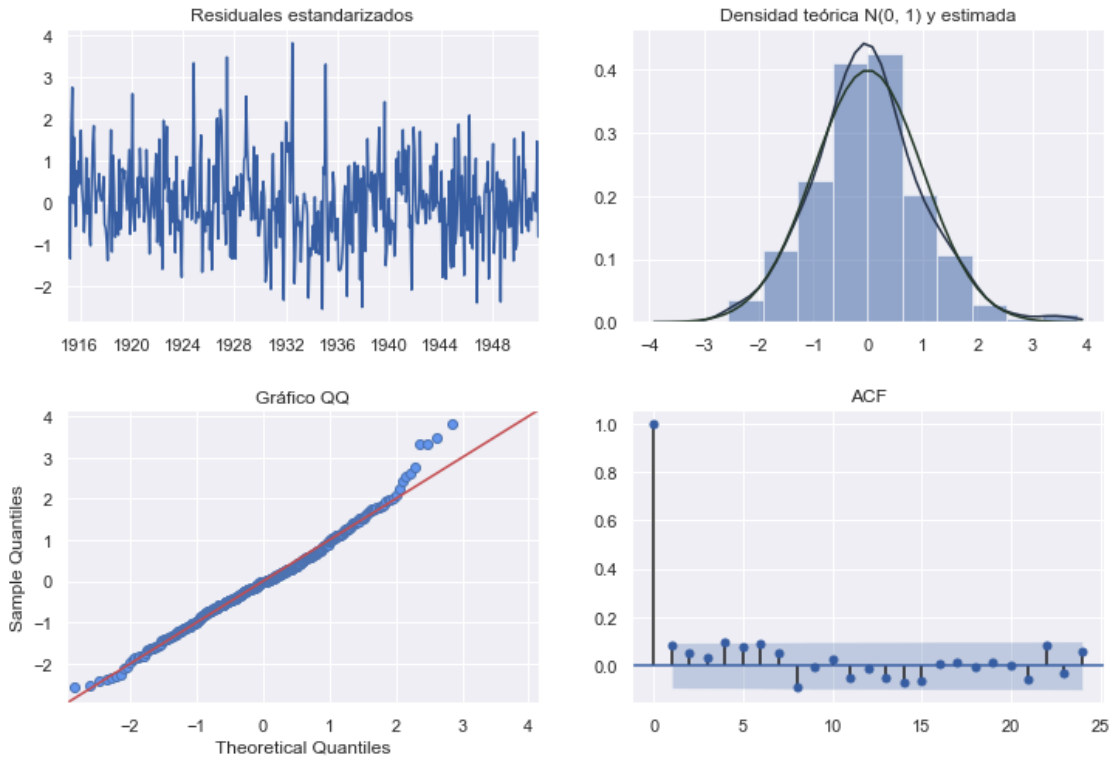
```
Best Tree 5 CV RMSE = 0.152
```

```
In [63]: tree_hyp = {"depth": 5}
```

```
In [64]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                      random_state=seed)
         tree_model = tree.fit(X_train, y_train)
         tree_fitted = pd.Series(tree_model.predict(X_train))
         tree_fitted
         tree_fitted.index = X_train.index
         tree_resid = y_train - tree_fitted
         tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

         tree_jb_test = jb(tree_resid)
         tree_lb_test = lb(tree_resid)

         tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [65]: tree_box_forecast = (bc_param * tree_forecast + 1) ** (1 / bc_param)
```

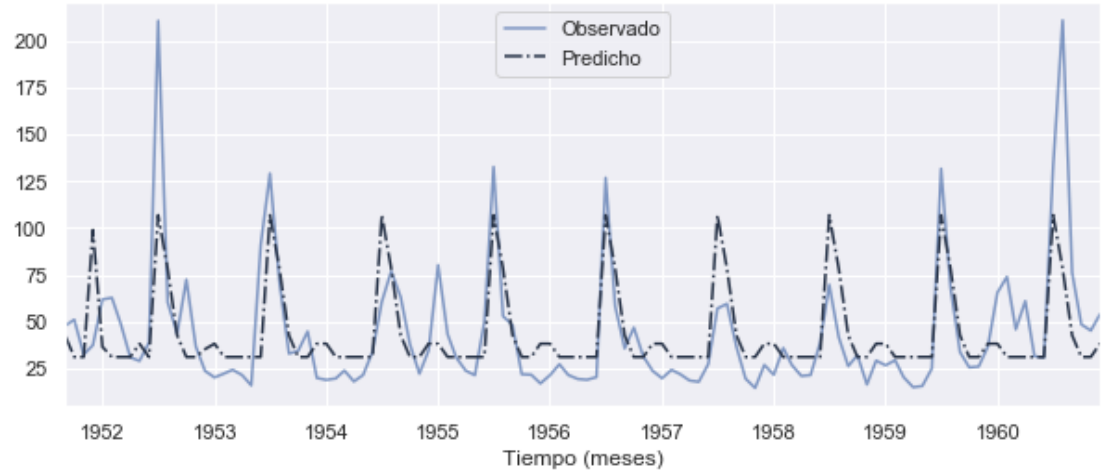
```
In [66]: resid_diag(tree_resid)
         plt.show()
```




```
In [67]: print("Decision Tree")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(tree_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(tree_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, tree_box_forecast))))
         print("MAE (test):  " + str(mae(test, tree_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, tree_box_forecast)))

Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.566066446696135e-05
Test de Ljung-Box para k =  6 (p-valor): 0.020923869379414626
Test de Ljung-Box para k = 12 (p-valor): 0.0421623493635886
```

```
RMSE (test): 24.744712241704015
MAE (test):  16.56474204351321
sMAPE (test):  36.708903576558605
```

```
In [68]: forecast_plot(test, tree_box_forecast)
         plt.show()
```



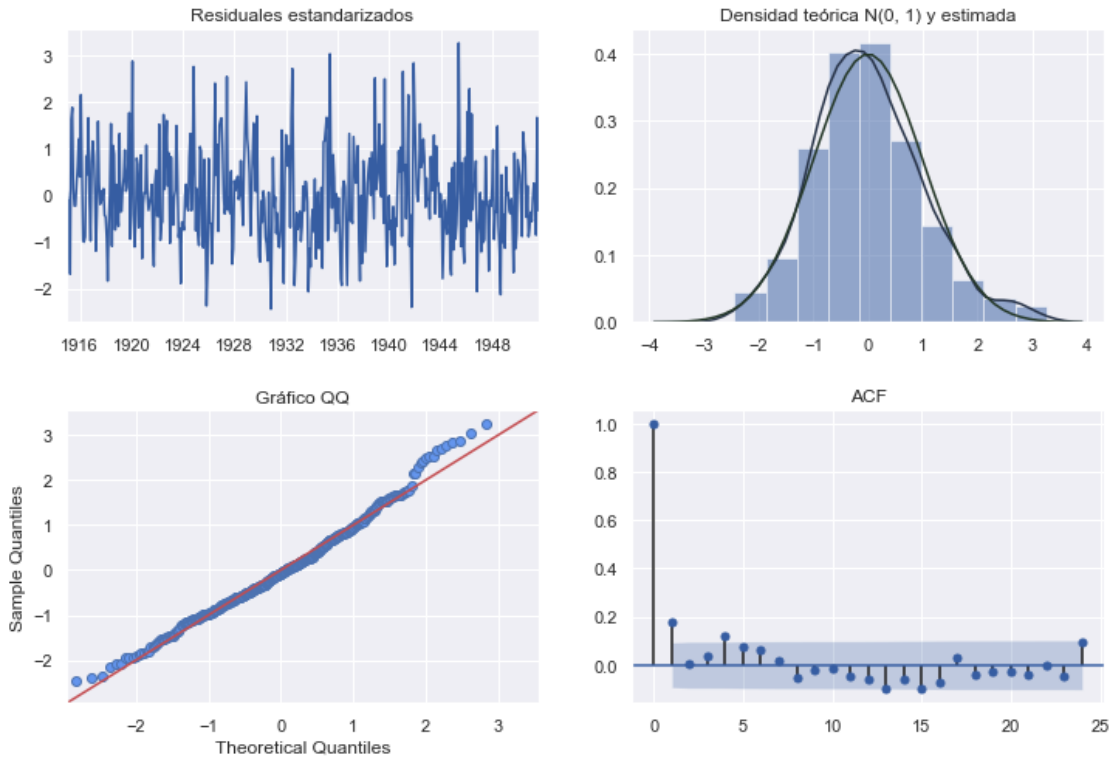
Random Forest

```
In [69]: best_score, best_tree = float("inf"), None

         n_estimators = [50, 100, 200, 500]
         depths = np.linspace(1, 61, 20)
         max_features = [0.8, 1]


         for n in n_estimators:
             for depth in depths:
                 for features in max_features:
                     rf = RandomForestRegressor(n_estimators=n,
                                                max_depth=depth,
                                                max_features=features,
                                                random_state=seed)

                     rf_model1 = rf.fit(X_train1, y_train1)
                     rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                     rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))
```

```
                    rf_model2 = rf.fit(X_val1, y_val1)
                    rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                    rf_model3 = rf.fit(X_val2, y_val2)
                    rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_rf = cvrmse, rf.get_params()

        print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f' %
              (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_sco
```

```
Best RF: n_estimators: 50 max_depth: 7.315789473684211 max_features :0.8 | CV RMSE = 0.140
```

```
In [70]: rf_hyp = {"max_depth": 7.32,
                   "n_estimators": 50,
                   "max_features": 0.8}

In [71]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                    n_estimators=rf_hyp["n_estimators"],
                                    max_features=rf_hyp["max_features"],
                                    random_state=seed)

         rf_model = rf.fit(X_train, y_train)
         rf_fitted = pd.Series(rf_model.predict(X_train))
         rf_fitted
         rf_fitted.index = X_train.index
         rf_resid = y_train - rf_fitted
         rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

         rf_jb_test = jb(rf_resid)
         rf_lb_test = lb(rf_resid)

         rf_forecast = iter_forecast(rf, y_train, 12, test)

In [72]: rf_box_forecast = (bc_param * rf_forecast + 1) ** (1 / bc_param)

In [73]: resid_diag(rf_resid)
         plt.show()
```

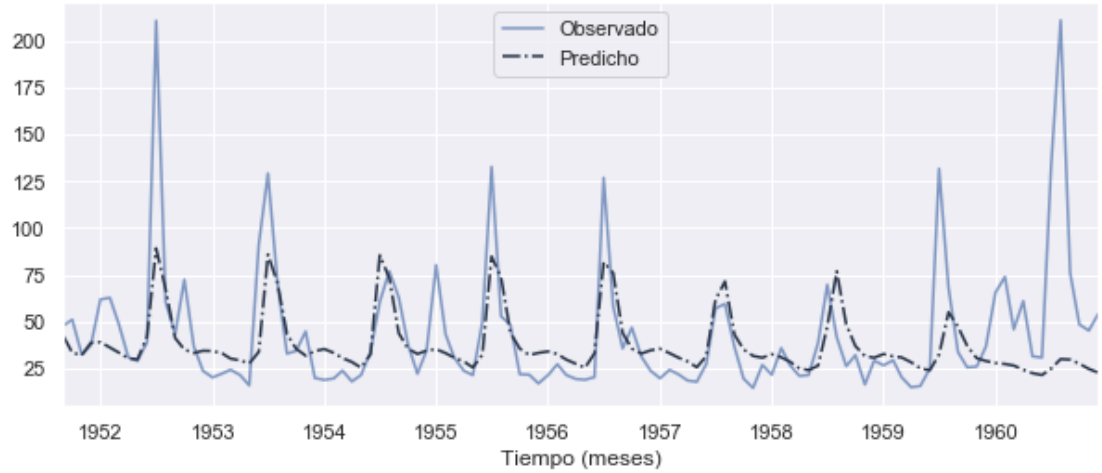



```
In [74]: print("Random Forest")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(rf_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(rf_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, rf_box_forecast))))
         print("MAE (test):  " + str(mae(test, rf_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, rf_box_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.0009343986727170103
Test de Ljung-Box para k =  6 (p-valor): 0.0007964689182289883
Test de Ljung-Box para k = 12 (p-valor): 0.0016563699647625693
```

```
RMSE (test): 30.496564708279912
MAE (test):  17.28236557049287
sMAPE (test):  37.02239483180497
```

```
In [75]: forecast_plot(test, rf_box_forecast)
         plt.show()
```



ElasticNet

```
In [76]: best_score, best_tree = float("inf"), None

         ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
         alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


         for rat in ratio:
             for alp in alpha:
                 en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                 en_model1 = en.fit(X_train1, y_train1)
                 en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                 en_model2 = en.fit(X_val1, y_val1)
                 en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                 en_model3 = en.fit(X_val2, y_val2)
```

```
                en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_en = cvrmse, en.get_params()

        print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
              (best_en['l1_ratio'], best_en['alpha'], best_score))
```

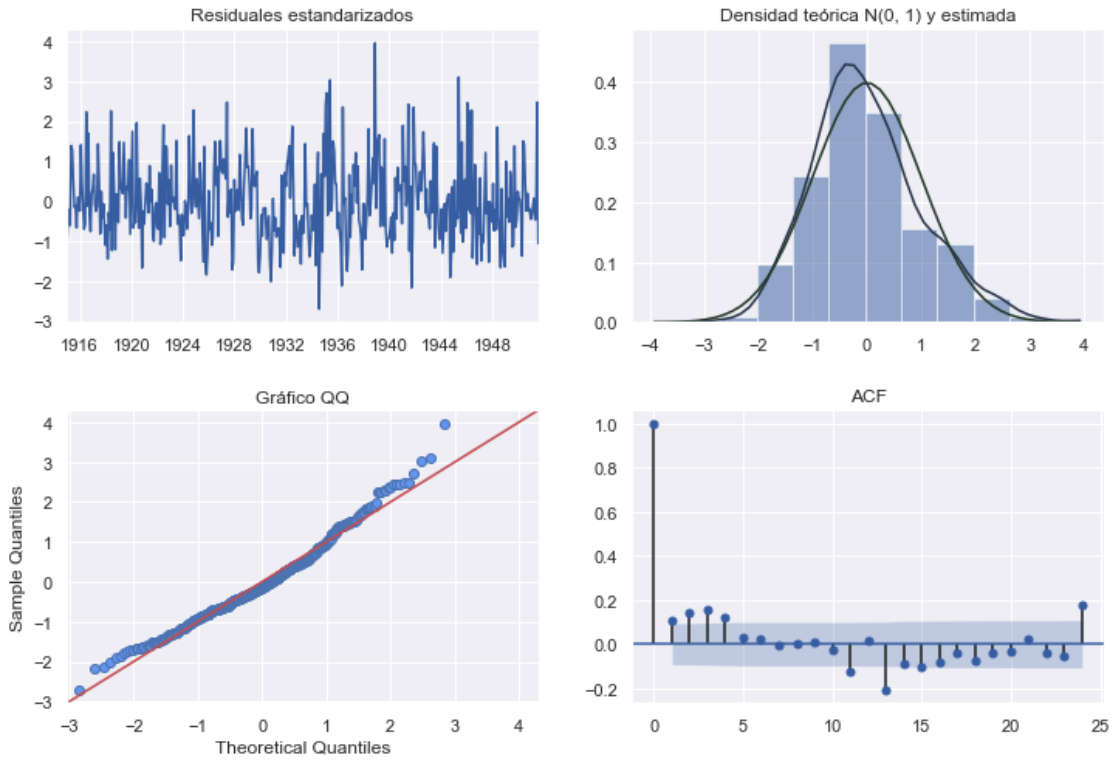
```
Best EN: ratio: 0.1 alpha: 0 | CV RMSE = 0.140
```

```
In [77]: en_hyp = {"l1_ratio": 0.1,
                   "alpha": 0}
```

```
In [78]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                         random_state=seed)
         en_model = en.fit(X_train, y_train)
         en_fitted = pd.Series(en_model.predict(X_train))
         en_fitted
         en_fitted.index = X_train.index
         en_resid = y_train - en_fitted
         en_resid = (en_resid - en_resid.mean()) / en_resid.std()

         en_jb_test = jb(en_resid)
         en_lb_test = lb(en_resid)

         en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [79]: en_box_forecast = (bc_param * en_forecast + 1) ** (1 / bc_param)
```

```
In [80]: resid_diag(en_resid)
         plt.show()
```

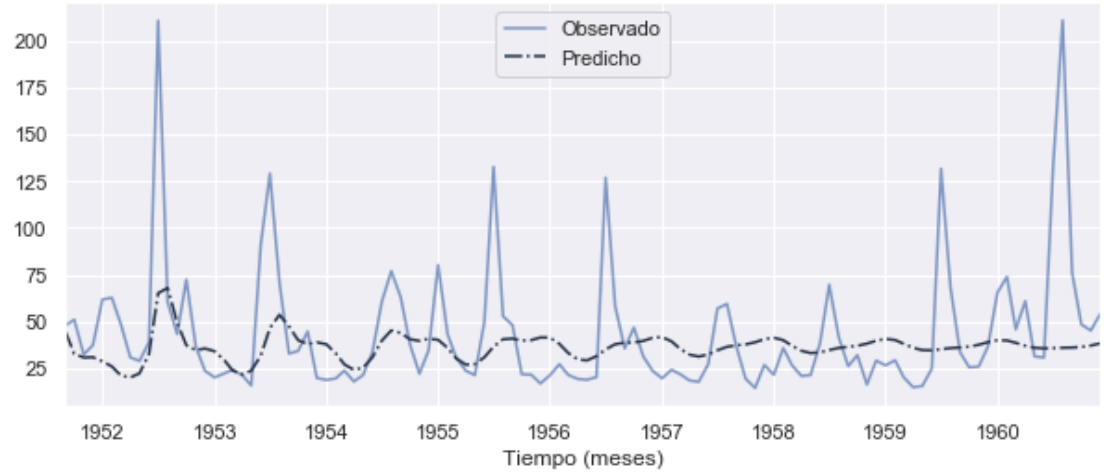



```
In [81]: print("ElasticNet")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(en_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(en_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, en_box_forecast))))
         print("MAE (test):  " + str(mae(test, en_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, en_box_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 6.76771127119615e-07
Test de Ljung-Box para k =  6 (p-valor): 4.748066502114843e-05
Test de Ljung-Box para k = 12 (p-valor): 1.0413255691897458e-07
```

```
RMSE (test): 33.682465160124686
MAE (test):  20.119056207537295
sMAPE (test):  42.9938082467703
```

```
In [82]: forecast_plot(test, en_box_forecast)
         plt.show()
```



Serie temporal desestacionalizada como estructura de DataFrame

```
In [83]: lag_df = series_to_supervised(deseas, n_in=12)
         lag_df.head(5)
```

Out[83]:

index	var1(t-12)	var1(t-11)	var1(t-10)	var1(t-9)	var1(t-8)	\
1915-01-01	68.056741	55.487990	59.745262	49.642875	47.097132	
1915-02-01	55.487990	59.745262	49.642875	47.097132	19.921335	
1915-03-01	59.745262	49.642875	47.097132	19.921335	2.252072	
1915-04-01	49.642875	47.097132	19.921335	2.252072	56.538266	
1915-05-01	47.097132	19.921335	2.252072	56.538266	96.012723	

index	var1(t-7)	var1(t-6)	var1(t-5)	var1(t-4)	var1(t-3)	var1(t-2)	\
1915-01-01	19.921335	2.252072	56.538266	96.012723	70.726177	55.973661	
1915-02-01	2.252072	56.538266	96.012723	70.726177	55.973661	64.087769	
1915-03-01	56.538266	96.012723	70.726177	55.973661	64.087769	54.520741	
1915-04-01	96.012723	70.726177	55.973661	64.087769	54.520741	43.028990	
1915-05-01	70.726177	55.973661	64.087769	54.520741	43.028990	49.126262	

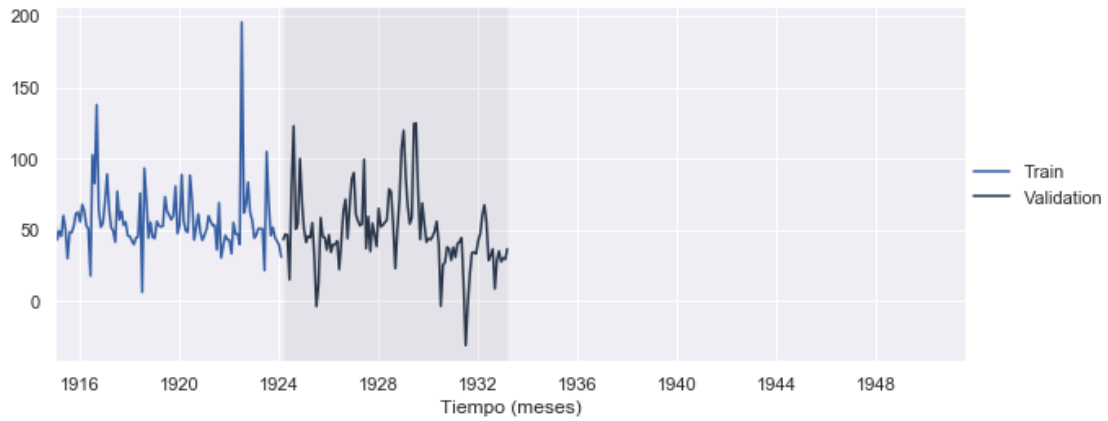
```
            var1(t-1)    var1(t)
index
1915-01-01  64.087769  54.520741
1915-02-01  54.520741  43.028990
1915-03-01  43.028990  49.126262
1915-04-01  49.126262  45.564875
1915-05-01  45.564875  60.009132
```

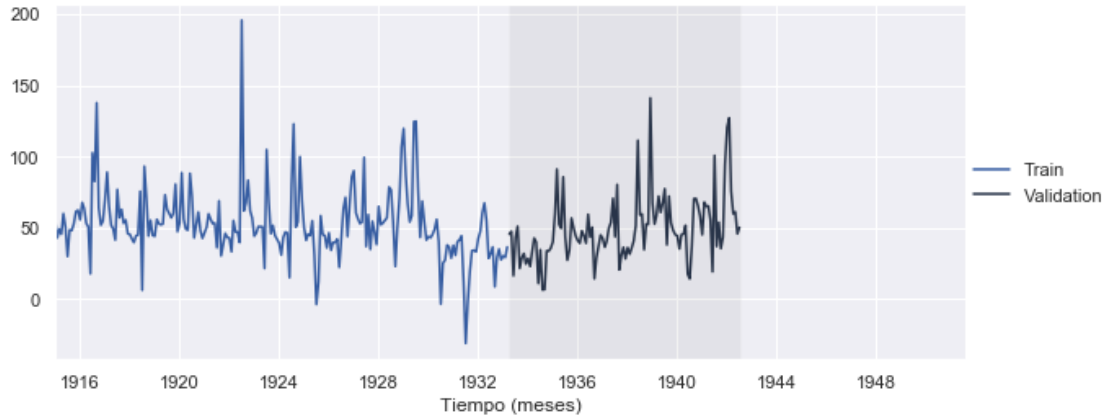
Definición de X (predictoras) e y (a predecir)

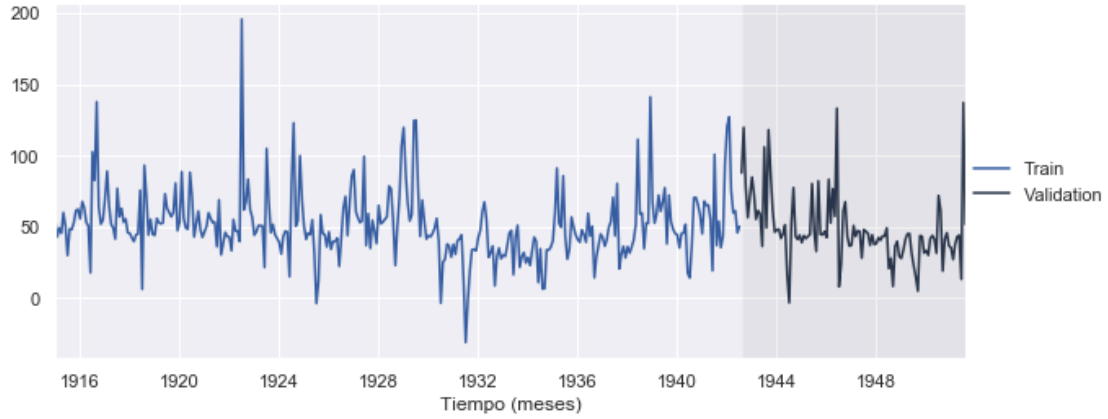
```
In [84]: X_train = lag_df.iloc[:,:-1]
         y_train = lag_df.iloc[:,-1]
```

Validación cruzada temporal

```
In [85]: train3, validation3 = ts_split(lag_df, train_size=0.75)
         X_train3 = train3.iloc[:,:-1]
         y_train3 = train3.iloc[:,-1]
         X_val3 = validation3.iloc[:,:-1]
         y_val3 = validation3.iloc[:,-1]

         train2, validation2 = ts_split(train3, train_size=0.66)
         X_train2 = train2.iloc[:,:-1]
         y_train2 = train2.iloc[:,-1]
         X_val2 = validation2.iloc[:,:-1]
         y_val2 = validation2.iloc[:,-1]

         train1, validation1 = ts_split(train2, train_size=0.5)
         X_train1 = train1.iloc[:,:-1]
         y_train1 = train1.iloc[:,-1]
         X_val1 = validation1.iloc[:,:-1]
         y_val1 = validation1.iloc[:,-1]

In [86]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
         plt.show()
         tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
         plt.show()
         tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
         plt.show()
```

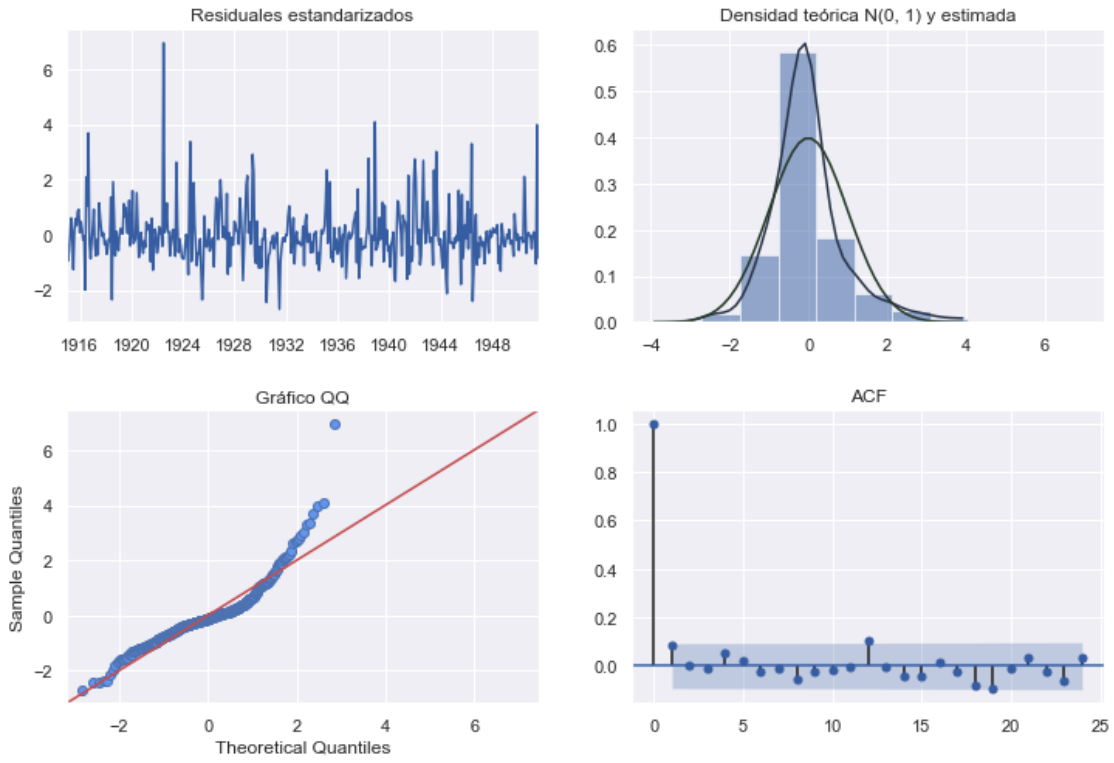

200
150
100
50
0
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


200
150
100
50
0
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


200
150
100
50
0
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

K-Nearest Neighbors

```
In [87]: neigb = list(np.arange(2, 41, 1))

In [88]: best_score, best_knn = float("inf"), None

         for k in neigb:
                 knn = KNeighborsRegressor(n_neighbors=k)

                 knn_model1 = knn.fit(X_train1, y_train1)
                 knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                 knn_model2 = knn.fit(X_val1, y_val1)
                 knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                 knn_model3 = knn.fit(X_val2, y_val2)
                 knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                 rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                 cvrmse = mean([rmse1, rmse2, rmse3])
                 if cvrmse < best_score:
                     best_score, best_knn = cvrmse, knn.get_params()

         print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))

Best KNN 10 CVRMSE = 24.538


In [ ]: knn_hyp = {"k": 10}

In [89]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
         knn_model = knn.fit(X_train, y_train)
         knn_fitted = pd.Series(knn_model.predict(X_train))
         knn_fitted
         knn_fitted.index = X_train.index
         knn_resid = y_train - knn_fitted
         knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

         knn_jb_test = jb(knn_resid)
         knn_lb_test = lb(knn_resid)

         knn_forecast = iter_forecast(knn, y_train, 12, test)

In [90]: knn_seas_forecast = knn_forecast + seasonality_forecast

In [91]: resid_diag(knn_resid)
         plt.show()
```

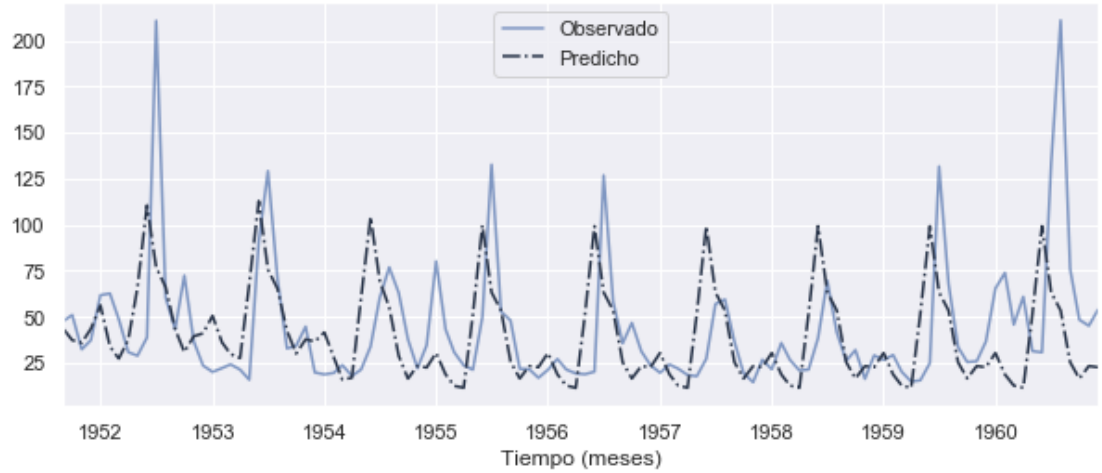



```
In [92]: print("K-Nearest Neighbors")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(knn_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(knn_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, knn_seas_forecast))))
         print("MAE (test):  " + str(mae(test, knn_seas_forecast)))
         print("sMAPE (test):  " + str(smape(test, knn_seas_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 3.221140212318335e-238
Test de Ljung-Box para k =  6 (p-valor): 0.6861542427252421
Test de Ljung-Box para k = 12 (p-valor): 0.5852275392995411
```

```
RMSE (test): 35.73070318812319
MAE (test):  23.860184319978462
sMAPE (test):  52.04783996158255
```

```
In [93]: forecast_plot(test, knn_seas_forecast)
         plt.show()
```



Regresion tree

```
In [94]: depths = list(np.arange(1, 21, 1))
```

```
In [95]: best_score, best_tree = float("inf"), None

         for depth in depths:
                 tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                 tree_model1 = tree.fit(X_train1, y_train1)
                 tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                 rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                 tree_model2 = tree.fit(X_val1, y_val1)
                 tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                 rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                 tree_model3 = tree.fit(X_val2, y_val2)
                 tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                 rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))
```

```
                cvrmse = mean([rmse1, rmse2, rmse3])

                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

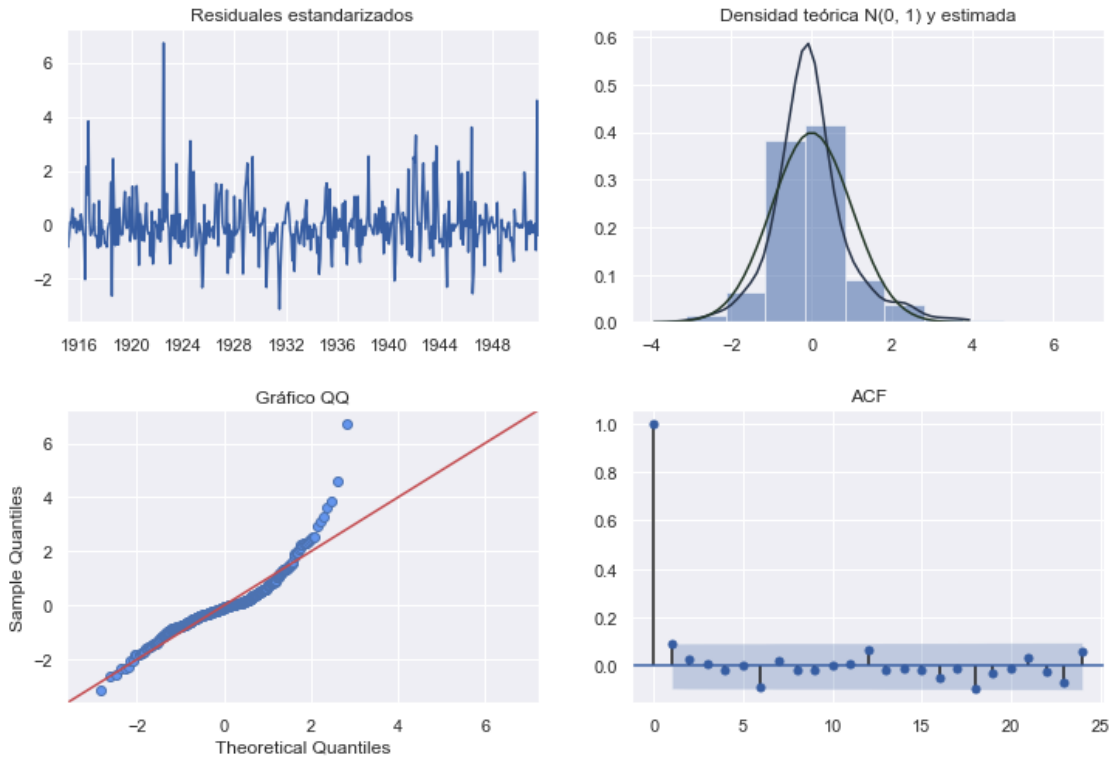
```
Best Tree 3 CV RMSE = 24.941
```

```
In [96]: tree_hyp = {"depth": 3}
```

```
In [97]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                      random_state=seed)
         tree_model = tree.fit(X_train, y_train)
         tree_fitted = pd.Series(tree_model.predict(X_train))
         tree_fitted
         tree_fitted.index = X_train.index
         tree_resid = y_train - tree_fitted
         tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

         tree_jb_test = jb(tree_resid)
         tree_lb_test = lb(tree_resid)

         tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [98]: tree_seas_forecast = tree_forecast + seasonality_forecast
```

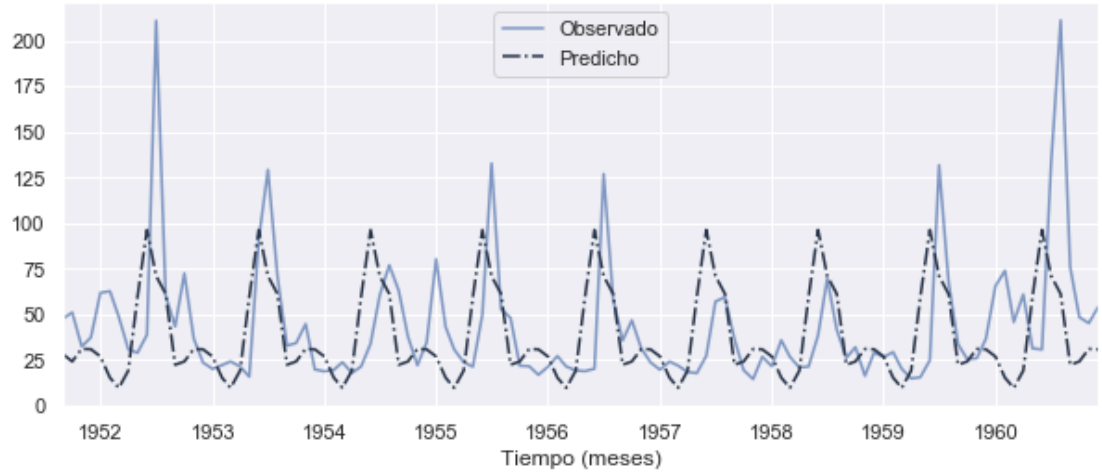
```
In [99]: resid_diag(tree_resid)
         plt.show()
```




```
In [100]: print("Decision Tree")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(tree_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(tree_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, tree_seas_forecast))))
          print("MAE (test):  " + str(mae(test, tree_seas_forecast)))
          print("sMAPE (test):  " + str(smape(test, tree_seas_forecast)))

Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 2.3249335220687302e-200
Test de Ljung-Box para k =  6 (p-valor): 0.32816725368366206
Test de Ljung-Box para k = 12 (p-valor): 0.648859080395447
```

```
RMSE (test): 35.32047965264542
MAE (test):  23.998700669257506
sMAPE (test):  54.28693445110659
```

```
In [101]: forecast_plot(test, tree_seas_forecast)
          plt.show()
```



Random Forest

```
In [102]: best_score, best_tree = float("inf"), None

          n_estimators = [50, 100, 200, 500]
          depths = np.linspace(1, 61, 20)
          max_features = [0.8, 1]


          for n in n_estimators:
              for depth in depths:
                  for features in max_features:
                      rf = RandomForestRegressor(n_estimators=n,
                                                 max_depth=depth,
                                                 max_features=features,
                                                 random_state=seed)

                      rf_model1 = rf.fit(X_train1, y_train1)
                      rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                      rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))
```

```
                    rf_model2 = rf.fit(X_val1, y_val1)
                    rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                    rf_model3 = rf.fit(X_val2, y_val2)
                    rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_rf = cvrmse, rf.get_params()

        print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f'
              % (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_
```

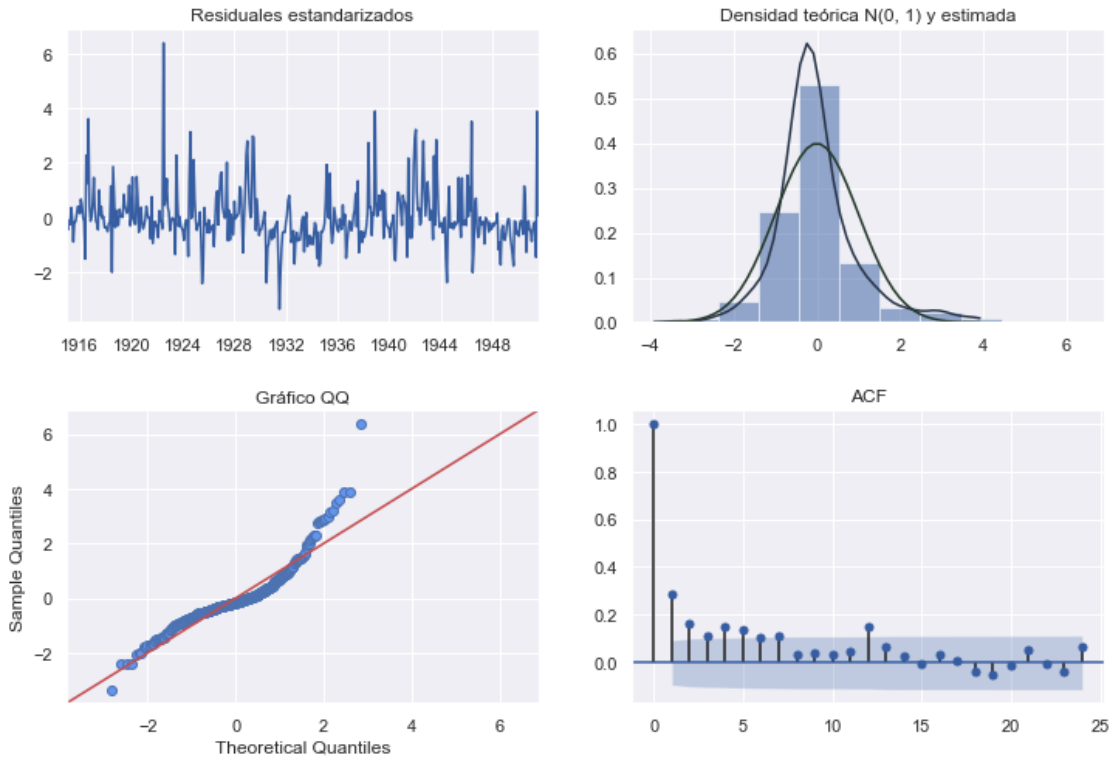
```
Best RF: n_estimators: 50 max_depth: 1.0 max_features :1 | CV RMSE = 24.151
```

```
In [103]: rf_hyp = {"max_depth": 1,
                    "n_estimators": 50,
                    "max_features": 1}
```

```
In [104]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                     n_estimators=rf_hyp["n_estimators"],
                                     max_features=rf_hyp["max_features"])

          rf_model = rf.fit(X_train, y_train)
          rf_fitted = pd.Series(rf_model.predict(X_train))
          rf_fitted
          rf_fitted.index = X_train.index
          rf_resid = y_train - rf_fitted
          rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

          rf_jb_test = jb(rf_resid)
          rf_lb_test = lb(rf_resid)

          rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [105]: rf_seas_forecast = rf_forecast + seasonality_forecast
```

```
In [106]: resid_diag(rf_resid)
          plt.show()
```

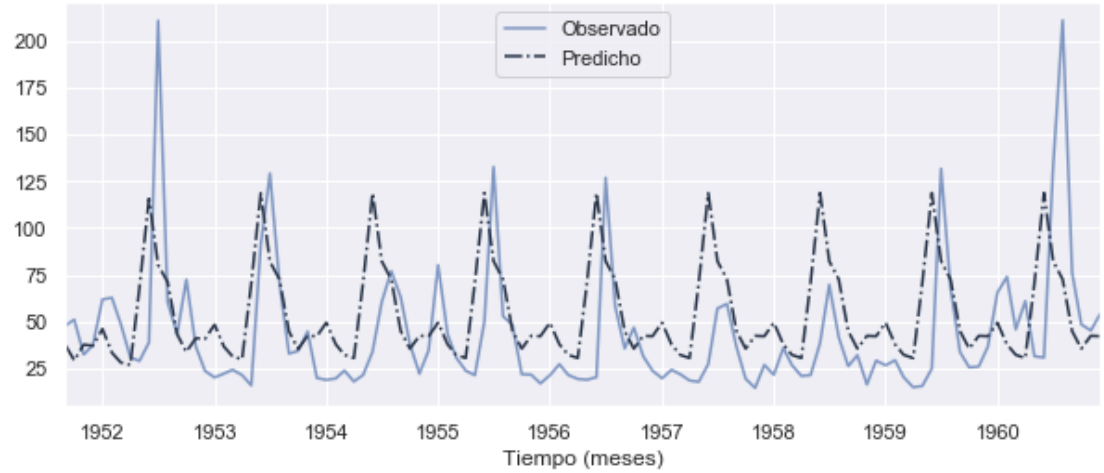



```
In [107]: print("Random Forest")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(rf_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(rf_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, rf_seas_forecast))))
          print("MAE (test):  " + str(mae(test, rf_seas_forecast)))
          print("sMAPE (test):  " + str(smape(test, rf_seas_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.3404599347819535e-167
Test de Ljung-Box para k =  6 (p-valor): 3.8209202885056384e-15
Test de Ljung-Box para k = 12 (p-valor): 3.08333506870211e-15
```

```
RMSE (test): 37.221632138684946
MAE (test):  26.05070483344991
sMAPE (test):  50.40460863038776
```

```
In [108]: forecast_plot(test, rf_seas_forecast)
          plt.show()
```



ElasticNet

```
In [109]: best_score, best_tree = float("inf"), None

          ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
          alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


          for rat in ratio:
              for alp in alpha:
                  en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                  en_model1 = en.fit(X_train1, y_train1)
                  en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                  en_model2 = en.fit(X_val1, y_val1)
                  en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                  en_model3 = en.fit(X_val2, y_val2)
```

```
                    en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_en = cvrmse, en.get_params()

            print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
                  (best_en['l1_ratio'], best_en['alpha'], best_score))
```

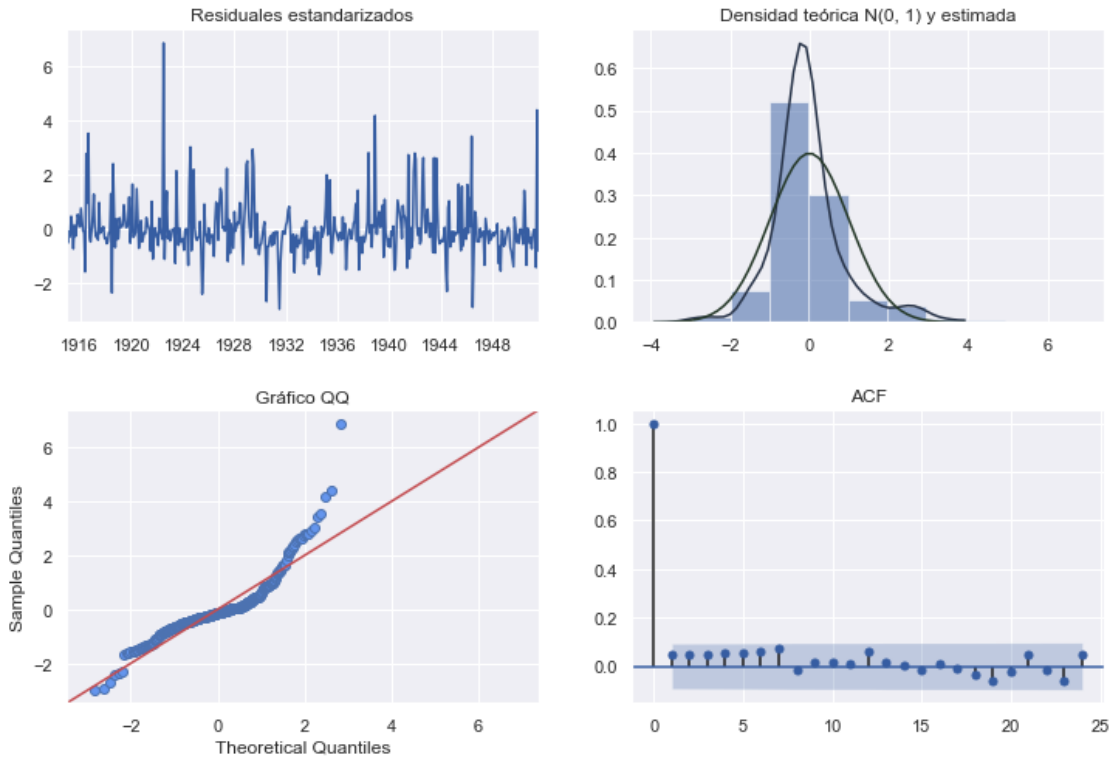
```
Best EN: ratio: 0.7 alpha: 50 | CV RMSE = 24.458
```

```
In [110]: en_hyp = {"l1_ratio": 0.7,
                    "alpha": 50}
```

```
In [111]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                          random_state=seed)
          en_model = en.fit(X_train, y_train)
          en_fitted = pd.Series(en_model.predict(X_train))
          en_fitted
          en_fitted.index = X_train.index
          en_resid = y_train - en_fitted
          en_resid = (en_resid - en_resid.mean()) / en_resid.std()

          en_jb_test = jb(en_resid)
          en_lb_test = lb(en_resid)

          en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [112]: en_seas_forecast = en_forecast + seasonality_forecast
```

```
In [113]: resid_diag(en_resid)
          plt.show()
```

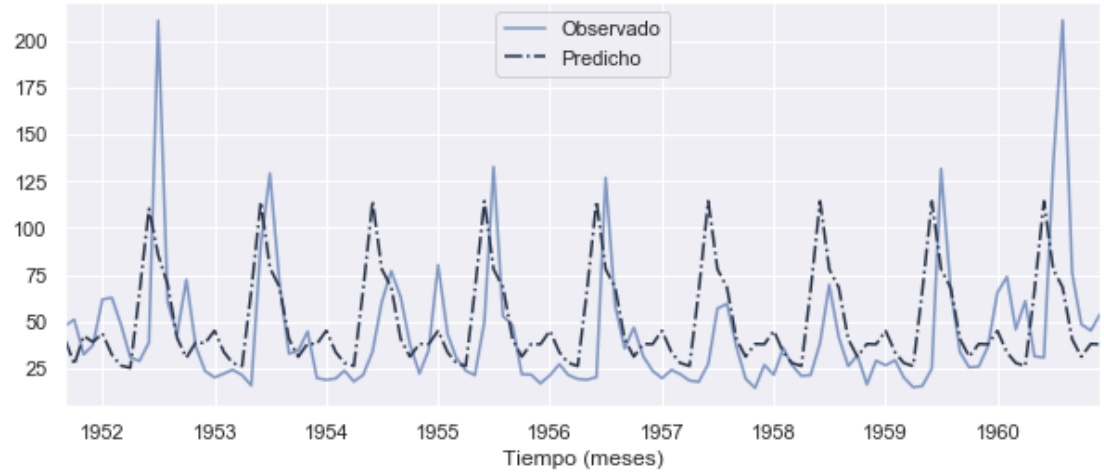



```
In [114]: print("ElasticNet")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(en_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(en_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, en_seas_forecast))))
          print("MAE (test):  " + str(mae(test, en_seas_forecast)))
          print("sMAPE (test):  " + str(smape(test, en_seas_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.8221992633454572e-265
Test de Ljung-Box para k =  6 (p-valor): 0.2116590961603848
Test de Ljung-Box para k = 12 (p-valor): 0.5484740779269146
```

```
RMSE (test): 35.879726444295535
MAE (test):  24.27506662692949
sMAPE (test):  47.12662561864641
```

```
In [115]: forecast_plot(test, en_seas_forecast)
          plt.show()
```



Serie temporal diferenciada como estructura de DataFrame

```
In [116]: lag_df = series_to_supervised(diff_train, n_in=12)
          lag_df.head(5)
```

Out[116]:

index	var1(t-12)	var1(t-11)	var1(t-10)	var1(t-9)	var1(t-8)	\
1915-02-01	-5.324	-7.334	-15.716	-4.247	13.139	
1915-03-01	-7.334	-15.716	-4.247	13.139	30.270	
1915-04-01	-15.716	-4.247	13.139	30.270	17.840	
1915-05-01	-4.247	13.139	30.270	17.840	29.733	
1915-06-01	13.139	30.270	17.840	29.733	-52.981	

index	var1(t-7)	var1(t-6)	var1(t-5)	var1(t-4)	var1(t-3)	var1(t-2)	\
1915-02-01	30.270	17.840	29.733	-52.981	-24.098	14.980	
1915-03-01	17.840	29.733	-52.981	-24.098	14.980	-9.798	
1915-04-01	29.733	-52.981	-24.098	14.980	-9.798	-4.247	
1915-05-01	-52.981	-24.098	14.980	-9.798	-4.247	-5.494	
1915-06-01	-24.098	14.980	-9.798	-4.247	-5.494	-9.175	

```
            var1(t-1)  var1(t)
index
1915-02-01     -9.798   -4.247
1915-03-01     -4.247   -5.494
1915-04-01     -5.494   -9.175
1915-05-01     -9.175   12.743
1915-06-01     12.743   30.724
```

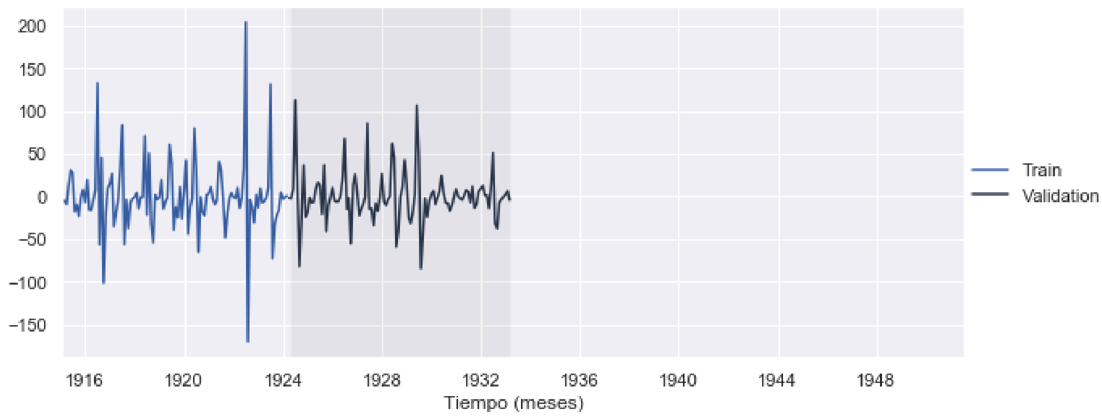
Definición de X (predictoras) e y (a predecir)

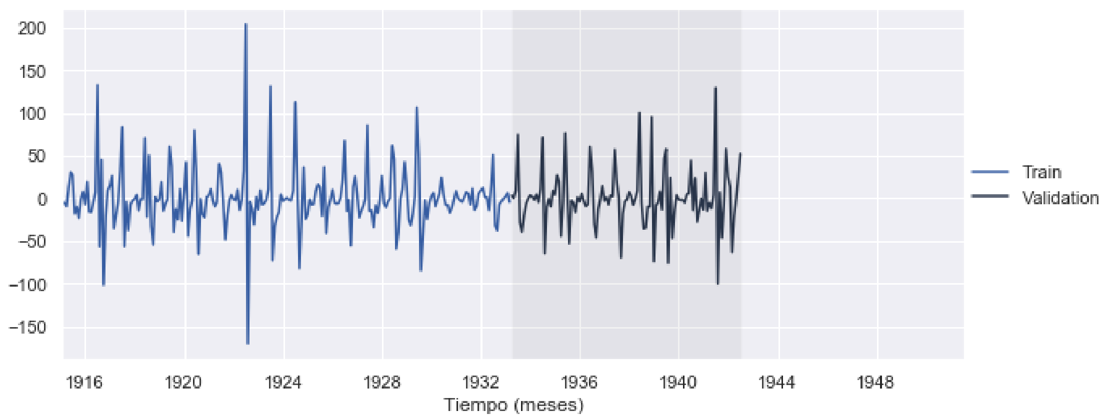
```
In [117]: X_train = lag_df.iloc[:,:-1]
          y_train = lag_df.iloc[:,-1]
```

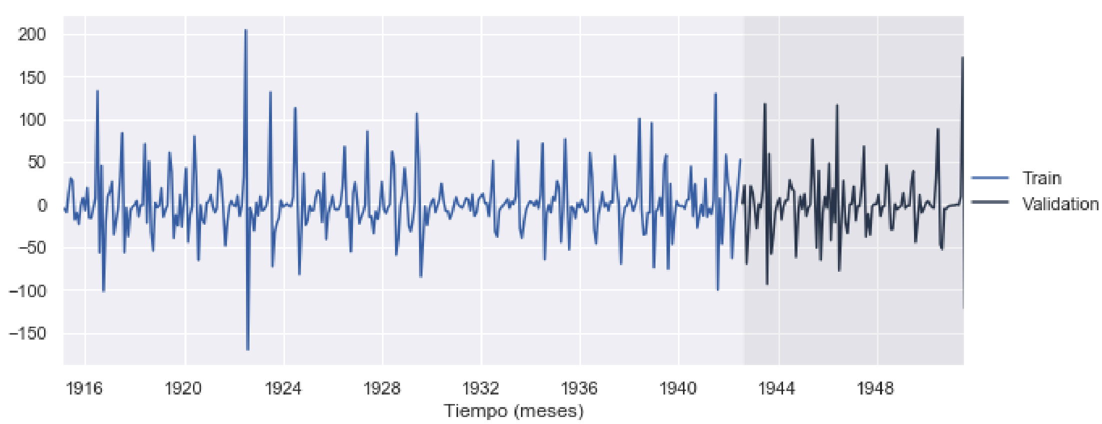
Validación cruzada temporal

```
In [118]: train3, validation3 = ts_split(lag_df, train_size=0.75)
          X_train3 = train3.iloc[:,:-1]
          y_train3 = train3.iloc[:,-1]
          X_val3 = validation3.iloc[:,:-1]
          y_val3 = validation3.iloc[:,-1]

          train2, validation2 = ts_split(train3, train_size=0.66)
          X_train2 = train2.iloc[:,:-1]
          y_train2 = train2.iloc[:,-1]
          X_val2 = validation2.iloc[:,:-1]
          y_val2 = validation2.iloc[:,-1]

          train1, validation1 = ts_split(train2, train_size=0.5)
          X_train1 = train1.iloc[:,:-1]
          y_train1 = train1.iloc[:,-1]
          X_val1 = validation1.iloc[:,:-1]
          y_val1 = validation1.iloc[:,-1]
```

```
In [119]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
          plt.show()
```


200
150
100
50
0
−50
−100
−150
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


200
150
100
50
0
−50
−100
−150
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

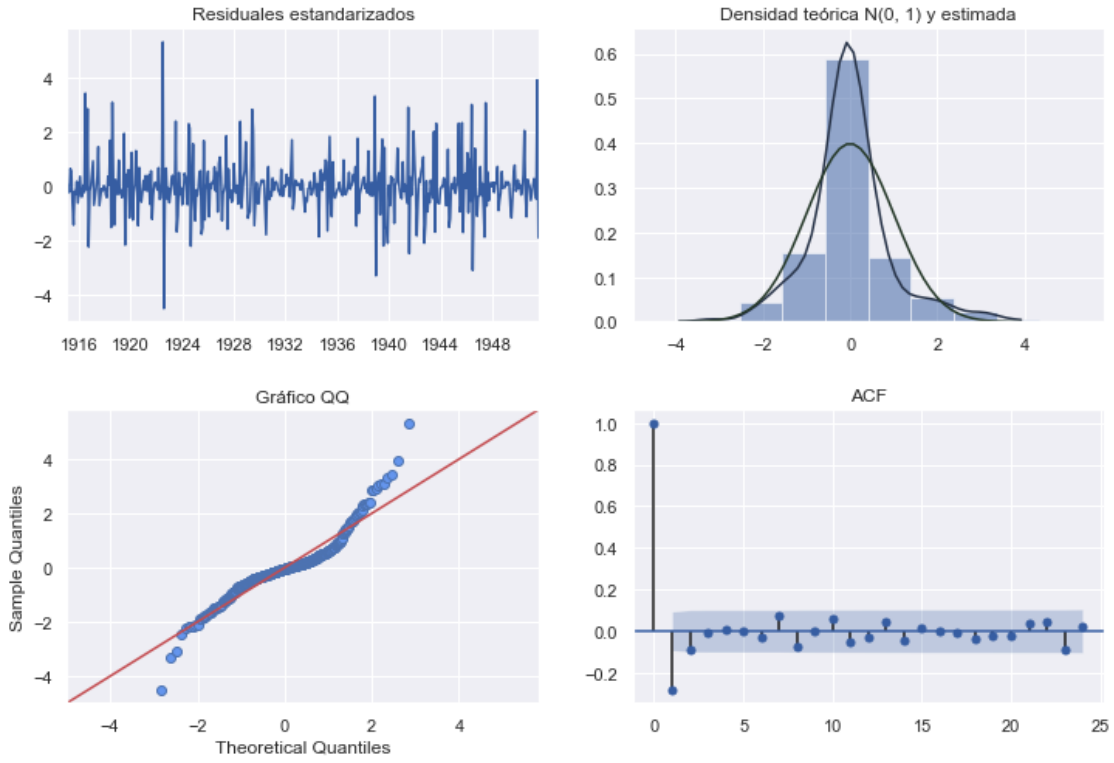

200
150
100
50
0
−50
−100
−150
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

K-Nearest Neighbors

```
In [120]: neigb = list(np.arange(2, 41, 1))

In [121]: best_score, best_knn = float("inf"), None

          for k in neigb:
                  knn = KNeighborsRegressor(n_neighbors=k)

                  knn_model1 = knn.fit(X_train1, y_train1)
                  knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                  knn_model2 = knn.fit(X_val1, y_val1)
                  knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                  knn_model3 = knn.fit(X_val2, y_val2)
                  knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                  rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                  cvrmse = mean([rmse1, rmse2, rmse3])
                  if cvrmse < best_score:
                      best_score, best_knn = cvrmse, knn.get_params()

          print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))

Best KNN 8 CVRMSE = 33.097


In [123]: knn_hyp = {"k": 8}

In [124]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
          knn_model = knn.fit(X_train, y_train)
          knn_fitted = pd.Series(knn_model.predict(X_train))
          knn_fitted
          knn_fitted.index = X_train.index
          knn_resid = y_train - knn_fitted
          knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

          knn_jb_test = jb(knn_resid)
          knn_lb_test = lb(knn_resid)

          knn_forecast = iter_forecast(knn, y_train, 12, test)

In [125]: knn_undiff_forecast = []
          last_obser = train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + knn_forecast[i]
```

```
        knn_undiff_forecast.append(yhat)
        last_obser = yhat

    knn_undiff_forecast = pd.Series(knn_undiff_forecast)
    knn_undiff_forecast.index = test.index
```

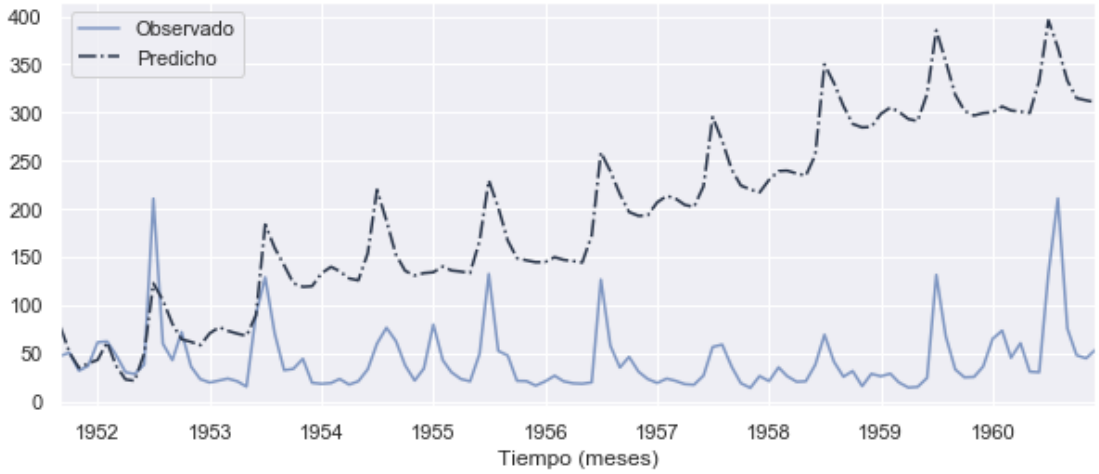
In [126]:
```
resid_diag(knn_resid)
plt.show()
```



In [127]:
```
print("K-Nearest Neighbors")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(knn_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(knn_lb_test[1][12]))
print("")
print("RMSE (test): " + str(sqrt(mse(test, knn_undiff_forecast))))
print("MAE (test):  " + str(mae(test, knn_undiff_forecast)))
print("sMAPE (test):  " + str(smape(test, knn_undiff_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.917901228467001e-79
Test de Ljung-Box para k =  6 (p-valor): 5.776945665723931e-07
Test de Ljung-Box para k = 12 (p-valor): 5.455386637939246e-06

RMSE (test): 177.22695016002845
MAE (test):  153.15659709821418
sMAPE (test):  121.110202320245
```

```
In [128]: forecast_plot(test, knn_undiff_forecast)
          plt.show()
```



Regresion tree

```
In [129]: depths = list(np.arange(1, 21, 1))

In [130]: best_score, best_tree = float("inf"), None

          for depth in depths:
                  tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                  tree_model1 = tree.fit(X_train1, y_train1)
                  tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))
```

```
                tree_model2 = tree.fit(X_val1, y_val1)
                tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                tree_model3 = tree.fit(X_val2, y_val2)
                tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

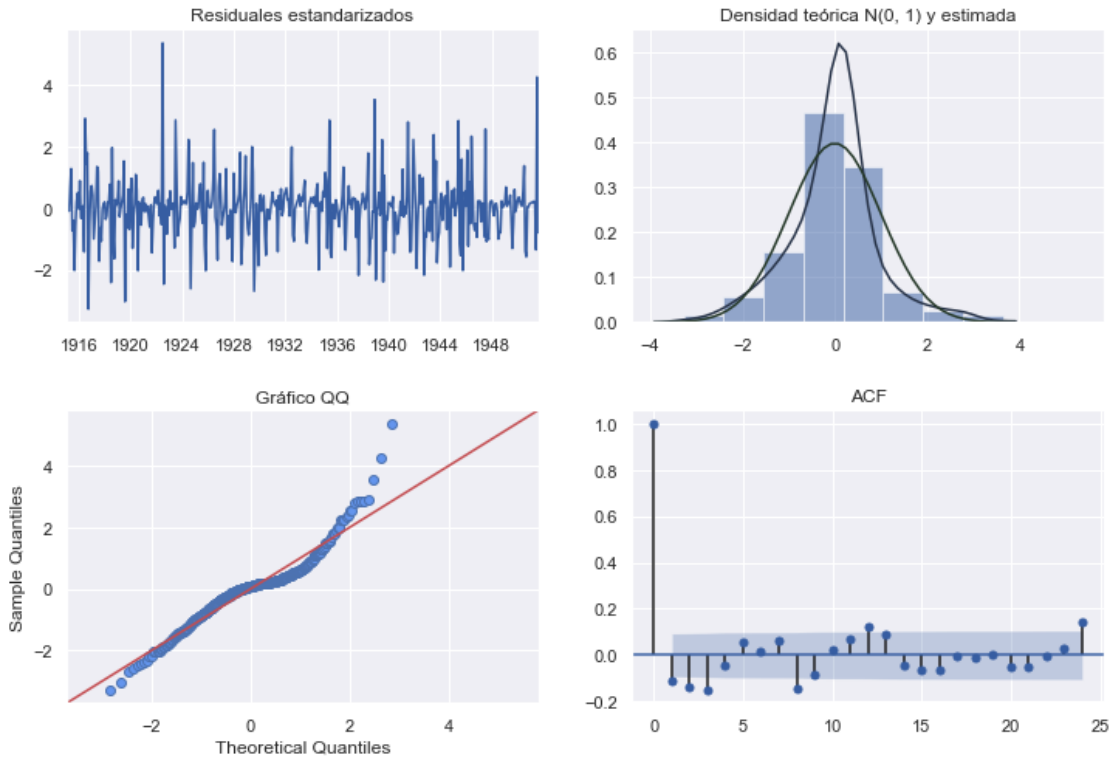
```
Best Tree 2 CV RMSE = 30.315
```

```
In [131]: tree_hyp = {"depth": 2}
```

```
In [132]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                       random_state=seed)
          tree_model = tree.fit(X_train, y_train)
          tree_fitted = pd.Series(tree_model.predict(X_train))
          tree_fitted
          tree_fitted.index = X_train.index
          tree_resid = y_train - tree_fitted
          tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

          tree_jb_test = jb(tree_resid)
          tree_lb_test = lb(tree_resid)

          tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [133]: tree_undiff_forecast = []
          last_obser = train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + tree_forecast[i]
              tree_undiff_forecast.append(yhat)
              last_obser = yhat

          tree_undiff_forecast = pd.Series(tree_undiff_forecast)
          tree_undiff_forecast.index = test.index
```

```
In [134]: resid_diag(tree_resid)
          plt.show()
```

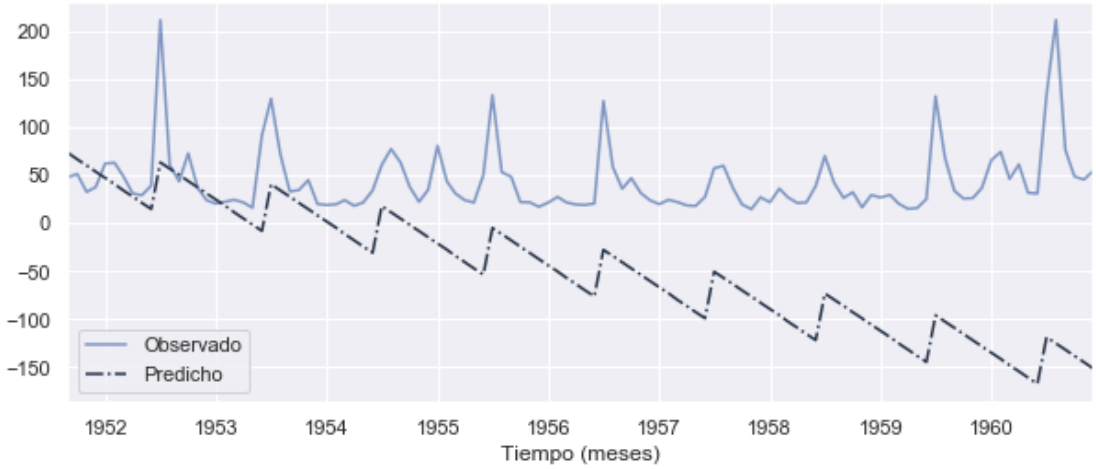



```
In [135]: print("Decision Tree")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(tree_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(tree_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, tree_undiff_forecast))))
          print("MAE (test):  " + str(mae(test, tree_undiff_forecast)))
          print("sMAPE (test):  " + str(smape(test, tree_undiff_forecast)))
```

```
Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.2372416779099734e-51
Test de Ljung-Box para k =  6 (p-valor): 0.00023462568230369247
Test de Ljung-Box para k = 12 (p-valor): 6.963358532075138e-07
```

```
RMSE (test): 114.28259407187224
MAE (test):  93.38271343999499
sMAPE (test):  163.26939411832194
```

```
In [136]: forecast_plot(test, tree_undiff_forecast)
          plt.show()
```



Random Forest

```
In [137]: best_score, best_tree = float("inf"), None

          n_estimators = [50, 100, 200, 500]
          depths = np.linspace(1, 61, 20)
          max_features = [0.8, 1]


          for n in n_estimators:
              for depth in depths:
                  for features in max_features:
                      rf = RandomForestRegressor(n_estimators=n,
                                                 max_depth=depth,
                                                 max_features=features,
                                                 random_state=seed)

                      rf_model1 = rf.fit(X_train1, y_train1)
                      rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                      rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))
```

```
                    rf_model2 = rf.fit(X_val1, y_val1)
                    rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                    rf_model3 = rf.fit(X_val2, y_val2)
                    rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_rf = cvrmse, rf.get_params()

        print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f'
              % (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_
```

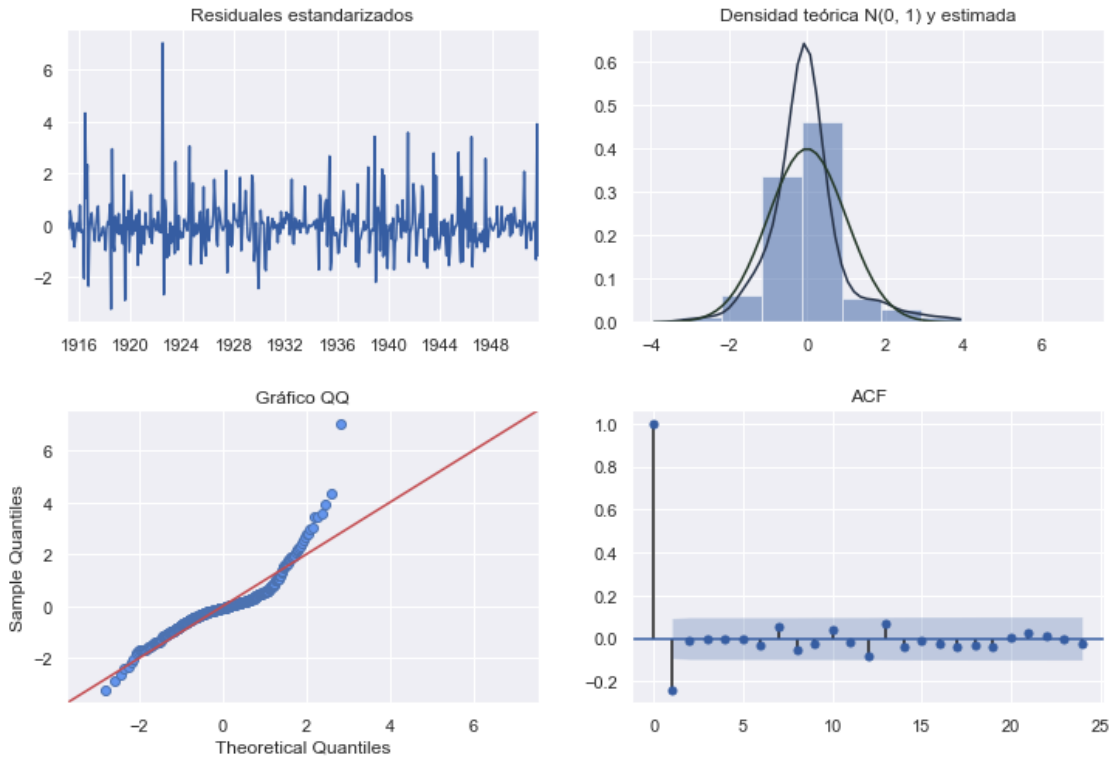
```
Best RF: n_estimators: 200 max_depth: 19.94736842105263 max_features :0.8 | CV RMSE = 28.999
```

```
In [138]: rf_hyp = {"max_depth": 19.95,
                    "n_estimators": 200,
                    "max_features": 0.8}
```

```
In [139]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                     n_estimators=rf_hyp["n_estimators"],
                                     max_features=rf_hyp["max_features"])
          rf_model = rf.fit(X_train, y_train)
          rf_fitted = pd.Series(rf_model.predict(X_train))
          rf_fitted
          rf_fitted.index = X_train.index
          rf_resid = y_train - rf_fitted
          rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

          rf_jb_test = jb(rf_resid)
          rf_lb_test = lb(rf_resid)

          rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [140]: rf_undiff_forecast = []
          last_obser = train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + rf_forecast[i]
              rf_undiff_forecast.append(yhat)
              last_obser = yhat

          rf_undiff_forecast = pd.Series(rf_undiff_forecast)
          rf_undiff_forecast.index = test.index
```

```
In [141]: resid_diag(rf_resid)
          plt.show()
```

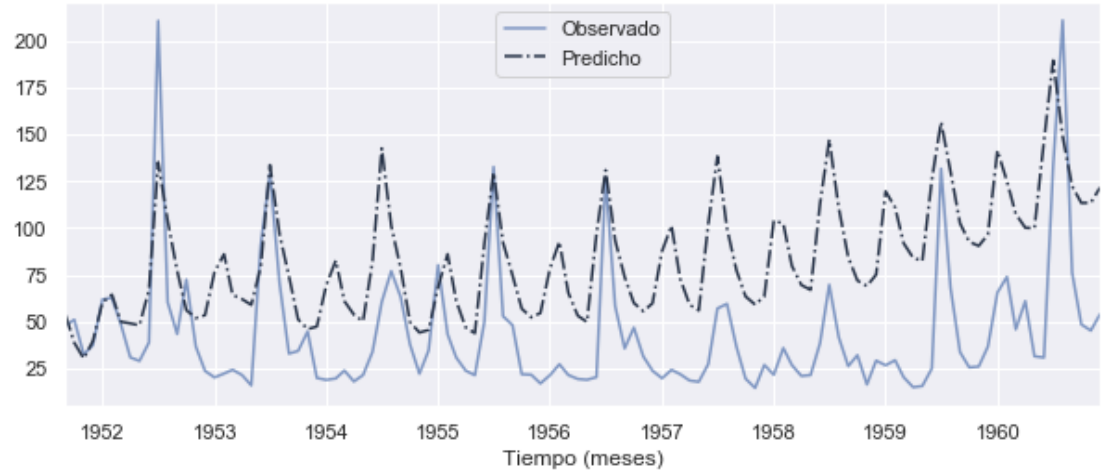



```
In [142]: print("Random Forest")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(rf_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(rf_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, rf_undiff_forecast))))
          print("MAE (test):  " + str(mae(test, rf_undiff_forecast)))
          print("sMAPE (test):  " + str(smape(test, rf_undiff_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 1.2628792392400582e-276
Test de Ljung-Box para k =  6 (p-valor): 0.000340694012737027
Test de Ljung-Box para k = 12 (p-valor): 0.0007856372962224352
```

```
RMSE (test): 49.99219208276194
MAE (test):  43.52829952097113
sMAPE (test):  74.06849193480416
```

```
In [143]: forecast_plot(test, rf_undiff_forecast)
          plt.show()
```



ElasticNet

```
In [144]: best_score, best_tree = float("inf"), None

          ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
          alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


          for rat in ratio:
              for alp in alpha:
                  en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                  en_model1 = en.fit(X_train1, y_train1)
                  en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                  en_model2 = en.fit(X_val1, y_val1)
                  en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                  en_model3 = en.fit(X_val2, y_val2)
```

```
                    en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_en = cvrmse, en.get_params()

            print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
                  (best_en['l1_ratio'], best_en['alpha'], best_score))
```

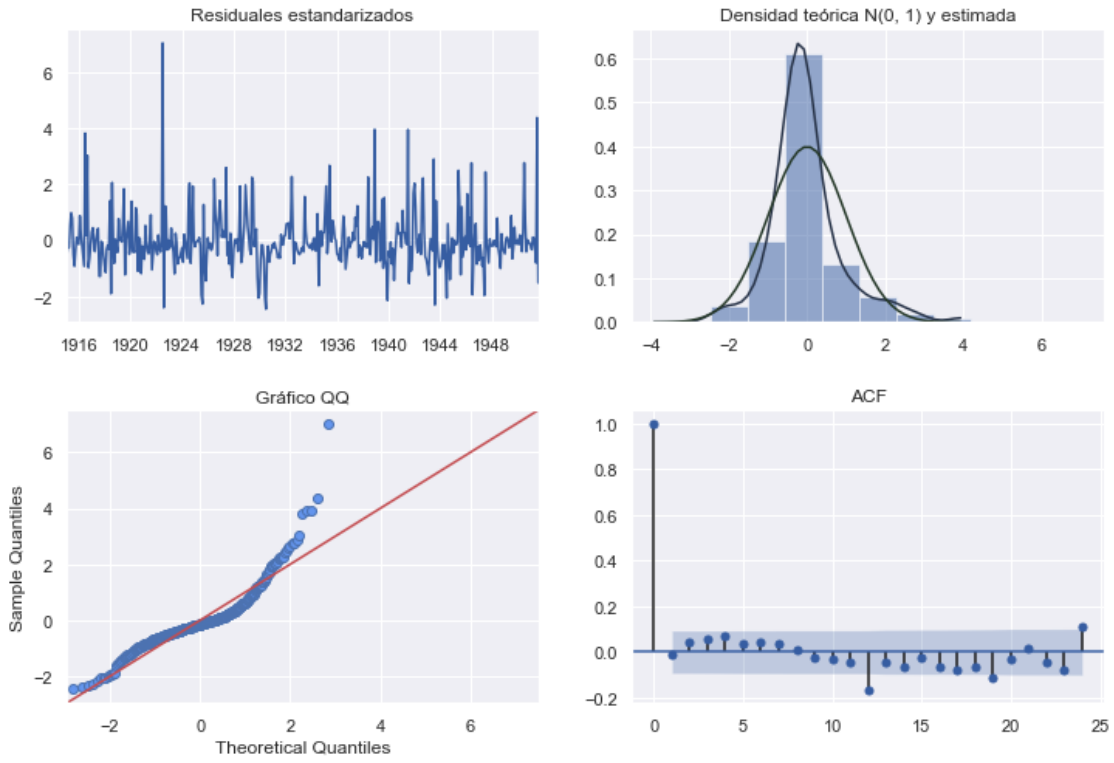
```
Best EN: ratio: 0.1 alpha: 0 | CV RMSE = 31.409
```

```
In [145]: en_hyp = {"l1_ratio": 0.1,
                    "alpha": 0}
```

```
In [146]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                          random_state=seed)
          en_model = en.fit(X_train, y_train)
          en_fitted = pd.Series(en_model.predict(X_train))
          en_fitted
          en_fitted.index = X_train.index
          en_resid = y_train - en_fitted
          en_resid = (en_resid - en_resid.mean()) / en_resid.std()

          en_jb_test = jb(en_resid)
          en_lb_test = lb(en_resid)

          en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [147]: en_undiff_forecast = []
          last_obser = train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + en_forecast[i]
              en_undiff_forecast.append(yhat)
              last_obser = yhat

          en_undiff_forecast = pd.Series(en_undiff_forecast)
          en_undiff_forecast.index = test.index
```

```
In [148]: resid_diag(en_resid)
          plt.show()
```

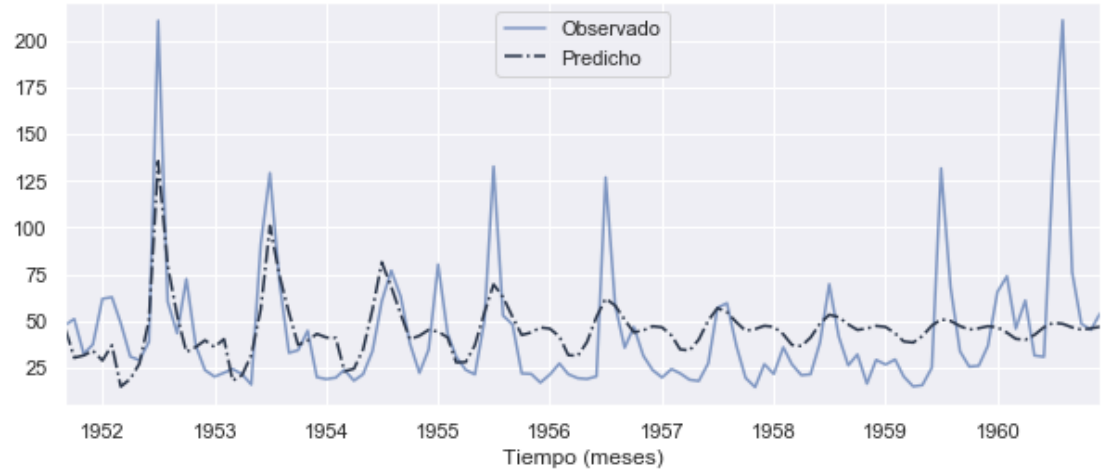



```
In [149]: print("ElasticNet")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(en_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(en_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, en_undiff_forecast))))
          print("MAE (test):  " + str(mae(test, en_undiff_forecast)))
          print("sMAPE (test):  " + str(smape(test, en_undiff_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Ljung-Box para k =  6 (p-valor): 0.49673055638329544
Test de Ljung-Box para k = 12 (p-valor): 0.07128341852182685

RMSE (test): 28.20851419327389
```

```
MAE (test):  19.41713375186481
sMAPE (test):  43.647066496865655
```

```
In [150]: forecast_plot(test, en_undiff_forecast)
          plt.show()
```



Serie temporal con Box-Cox y desestacionalizada como estructura de DataFrame

```
In [151]: lag_df = series_to_supervised(bc_deseas, n_in=12)
          lag_df.head(5)
```

```
Out[151]:             var1(t-12)  var1(t-11)  var1(t-10)  var1(t-9)  var1(t-8)  \
          index
          1915-01-01    2.104823    2.032305    2.058984   1.982896   1.945772
          1915-02-01    2.032305    2.058984    1.982896   1.945772   1.870234
          1915-03-01    2.058984    1.982896    1.945772   1.870234   1.894937
          1915-04-01    1.982896    1.945772    1.870234   1.894937   2.008061
          1915-05-01    1.945772    1.870234    1.894937   2.008061   2.104107

                      var1(t-7)  var1(t-6)  var1(t-5)  var1(t-4)  var1(t-3)  var1(t-2)  \
          index
          1915-01-01   1.870234   1.894937   2.008061   2.104107   2.094243   2.052516
          1915-02-01   1.894937   2.008061   2.104107   2.094243   2.052516   2.100102
          1915-03-01   2.008061   2.104107   2.094243   2.052516   2.100102   2.040468
          1915-04-01   2.104107   2.094243   2.052516   2.100102   2.040468   1.963905
          1915-05-01   2.094243   2.052516   2.100102   2.040468   1.963905   1.986410

                      var1(t-1)   var1(t)
          index
```

```
1915-01-01   2.100102  2.040468
1915-02-01   2.040468  1.963905
1915-03-01   1.963905  1.986410
1915-04-01   1.986410  1.934452
1915-05-01   1.934452  2.072123
```

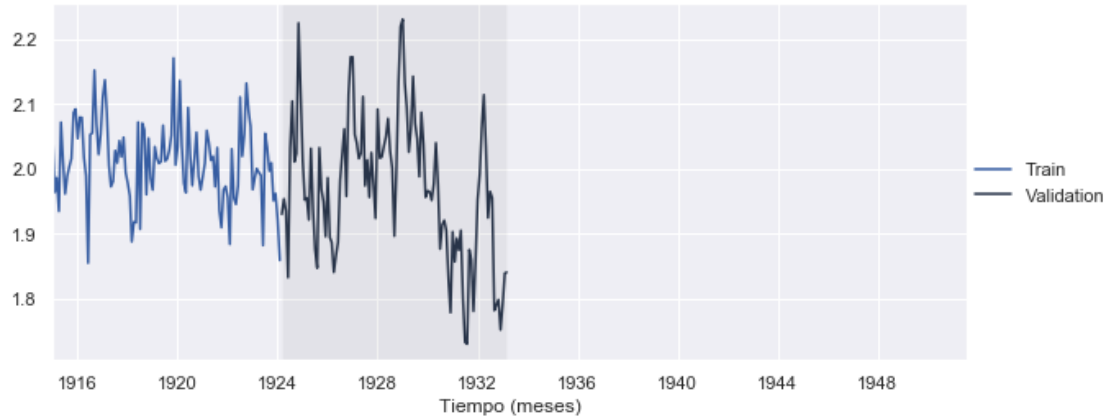
Definición de X (predictoras) e y (a predecir)

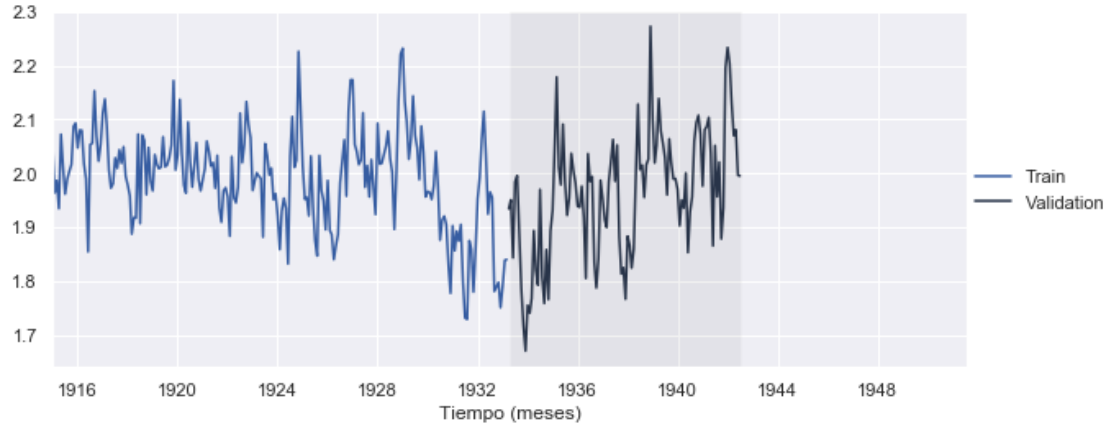
```
In [152]: X_train = lag_df.iloc[:,:-1]
          y_train = lag_df.iloc[:,-1]
```

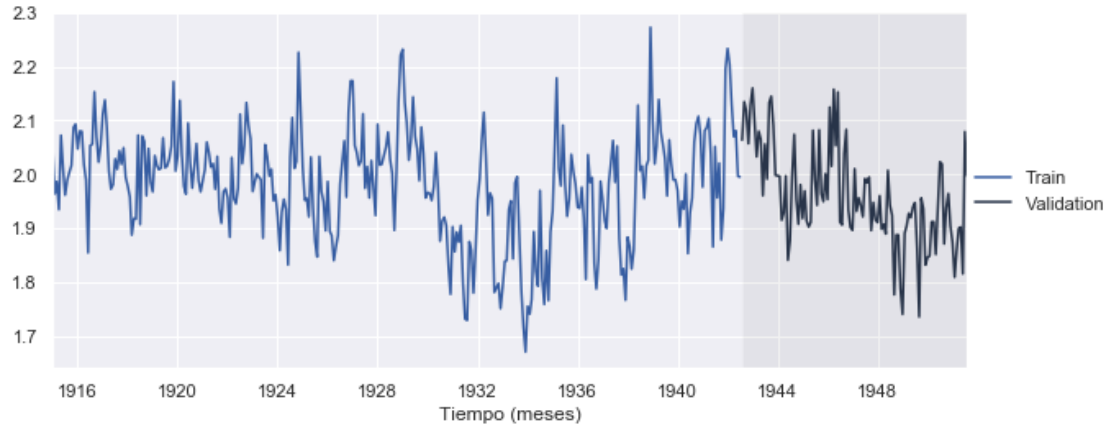
Validación cruzada temporal

```
In [153]: train3, validation3 = ts_split(lag_df, train_size=0.75)
          X_train3 = train3.iloc[:,:-1]
          y_train3 = train3.iloc[:,-1]
          X_val3 = validation3.iloc[:,:-1]
          y_val3 = validation3.iloc[:,-1]

          train2, validation2 = ts_split(train3, train_size=0.66)
          X_train2 = train2.iloc[:,:-1]
          y_train2 = train2.iloc[:,-1]
          X_val2 = validation2.iloc[:,:-1]
          y_val2 = validation2.iloc[:,-1]

          train1, validation1 = ts_split(train2, train_size=0.5)
          X_train1 = train1.iloc[:,:-1]
          y_train1 = train1.iloc[:,-1]
          X_val1 = validation1.iloc[:,:-1]
          y_val1 = validation1.iloc[:,-1]
```

```
In [154]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
          plt.show()
```


2.2
2.1
2.0
1.9
1.8
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


2.3
2.2
2.1
2.0
1.9
1.8
1.7
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

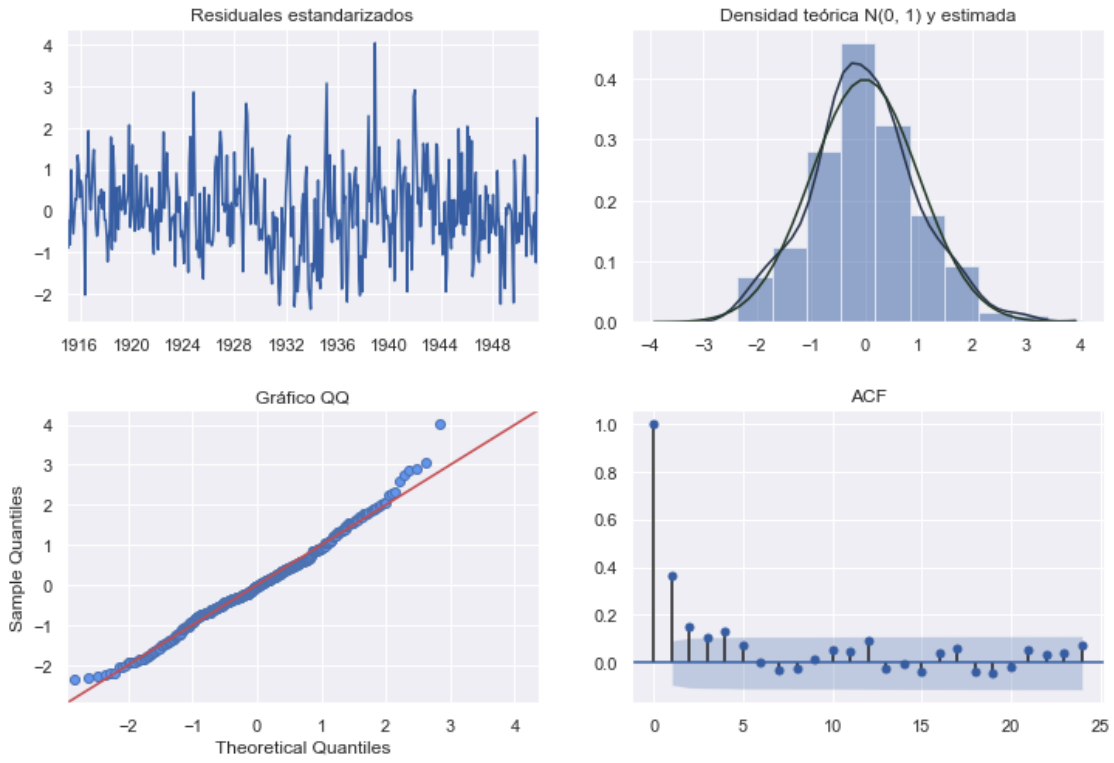

2.3
2.2
2.1
2.0
1.9
1.8
1.7
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

K-Nearest Neighbors

```
In [155]: neigb = list(np.arange(2, 41, 1))

In [156]: best_score, best_knn = float("inf"), None

          for k in neigb:
                  knn = KNeighborsRegressor(n_neighbors=k)

                  knn_model1 = knn.fit(X_train1, y_train1)
                  knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                  knn_model2 = knn.fit(X_val1, y_val1)
                  knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                  knn_model3 = knn.fit(X_val2, y_val2)
                  knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                  rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                  cvrmse = mean([rmse1, rmse2, rmse3])
                  if cvrmse < best_score:
                      best_score, best_knn = cvrmse, knn.get_params()

          print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))
```

```
Best KNN 39 CVRMSE = 0.101
```

```
In [157]: knn_hyp = {"k": 39}

In [158]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
          knn_model = knn.fit(X_train, y_train)
          knn_fitted = pd.Series(knn_model.predict(X_train))
          knn_fitted
          knn_fitted.index = X_train.index
          knn_resid = y_train - knn_fitted
          knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

          knn_jb_test = jb(knn_resid)
          knn_lb_test = lb(knn_resid)

          knn_forecast = iter_forecast(knn, y_train, 12, test)

In [159]: knn_seas_forecast = knn_forecast + bc_seasonality_forecast
          knn_box_forecast = (bc_param * knn_seas_forecast + 1) ** (1 / bc_param)

In [160]: resid_diag(knn_resid)
          plt.show()
```

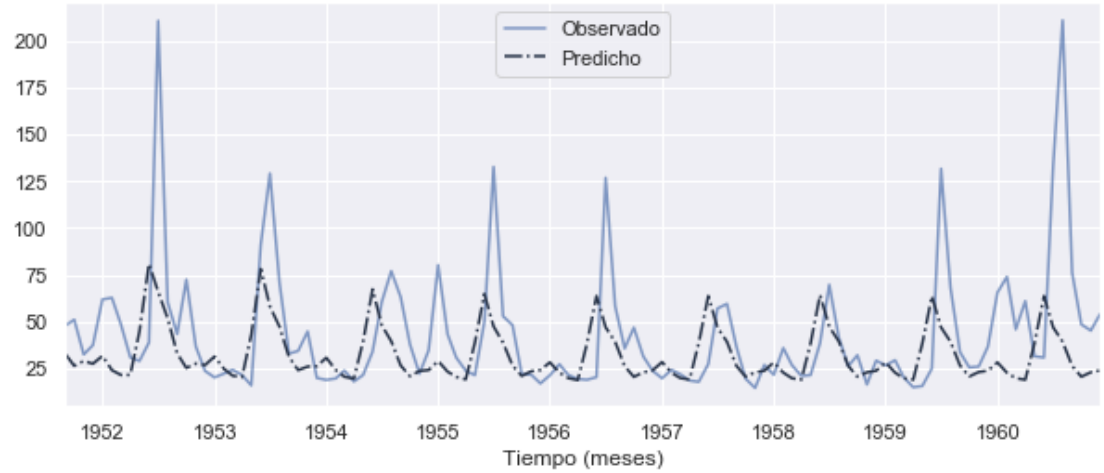



```
In [161]: print("K-Nearest Neighbors")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(knn_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(knn_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, knn_box_forecast))))
          print("MAE (test):  " + str(mae(test, knn_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, knn_box_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.0024537980554560092
Test de Ljung-Box para k =  6 (p-valor): 1.7902764790943185e-15
Test de Ljung-Box para k = 12 (p-valor): 7.567142794696897e-14
```

```
RMSE (test): 33.74267918581206
MAE (test):  20.81188937226639
sMAPE (test):  44.40053551108947
```

```
In [162]: forecast_plot(test, knn_box_forecast)
          plt.show()
```



Regresion tree

```
In [163]: depths = list(np.arange(1, 21, 1))
```

```
In [164]: best_score, best_tree = float("inf"), None

          for depth in depths:
                  tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                  tree_model1 = tree.fit(X_train1, y_train1)
                  tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                  tree_model2 = tree.fit(X_val1, y_val1)
                  tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                  tree_model3 = tree.fit(X_val2, y_val2)
                  tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                  rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))
```

```
                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

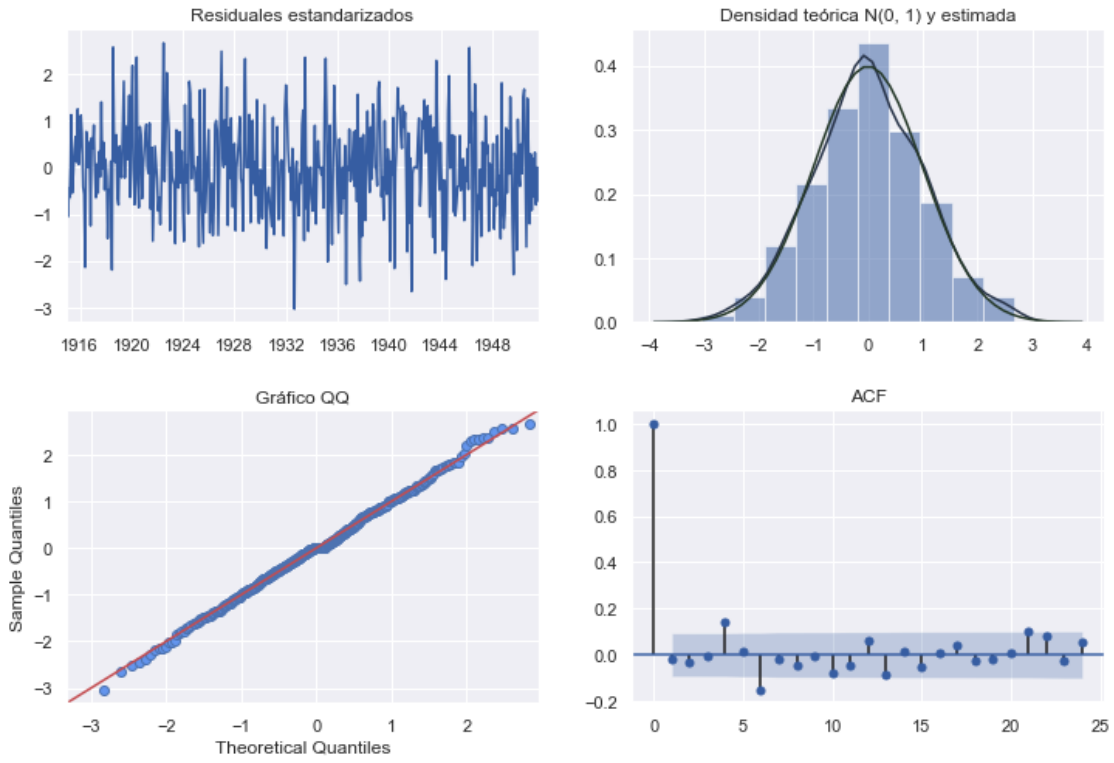
```
Best Tree 6 CV RMSE = 0.116
```

```
In [165]: tree_hyp = {"depth": 6}
```

```
In [166]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                       random_state=seed)
          tree_model = tree.fit(X_train, y_train)
          tree_fitted = pd.Series(tree_model.predict(X_train))
          tree_fitted
          tree_fitted.index = X_train.index
          tree_resid = y_train - tree_fitted
          tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

          tree_jb_test = jb(tree_resid)
          tree_lb_test = lb(tree_resid)

          tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [167]: tree_seas_forecast = tree_forecast + bc_seasonality_forecast
          tree_box_forecast = (bc_param * tree_seas_forecast + 1) ** (1 / bc_param)
```

```
In [168]: resid_diag(tree_resid)
          plt.show()
```

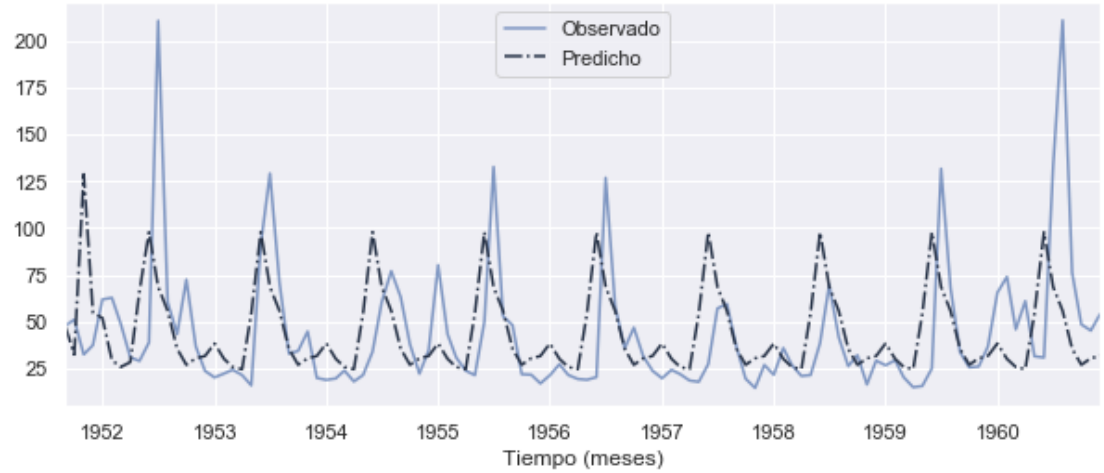



```
In [169]: print("Decision Tree")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(tree_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(tree_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, tree_box_forecast))))
          print("MAE (test):  " + str(mae(test, tree_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, tree_box_forecast)))
```

```
Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.9929874413510592
Test de Ljung-Box para k =  6 (p-valor): 0.00618239070831623
Test de Ljung-Box para k = 12 (p-valor): 0.005802475974333508
```

```
RMSE (test): 35.1622944094888
MAE (test):  22.43908436319708
sMAPE (test):  44.0630152274956
```

```
In [170]: forecast_plot(test, tree_box_forecast)
          plt.show()
```



Random Forest

```
In [172]: depths = np.linspace(1, 61, 21)
```

```
In [173]: best_score, best_tree = float("inf"), None

          n_estimators = [50, 100, 200, 500]
          depths = np.linspace(1, 61, 20)
          max_features = [0.8, 1]


          for n in n_estimators:
              for depth in depths:
                  for features in max_features:
                      rf = RandomForestRegressor(n_estimators=n,
                                                 max_depth=depth,
                                                 max_features=features,
                                                 random_state=seed)

                      rf_model1 = rf.fit(X_train1, y_train1)
                      rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
```

```
                        rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))

                        rf_model2 = rf.fit(X_val1, y_val1)
                        rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                        rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                        rf_model3 = rf.fit(X_val2, y_val2)
                        rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                        rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                        cvrmse = mean([rmse1, rmse2, rmse3])
                        if cvrmse < best_score:
                            best_score, best_rf = cvrmse, rf.get_params()

            print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f' %
                  (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_sc
```

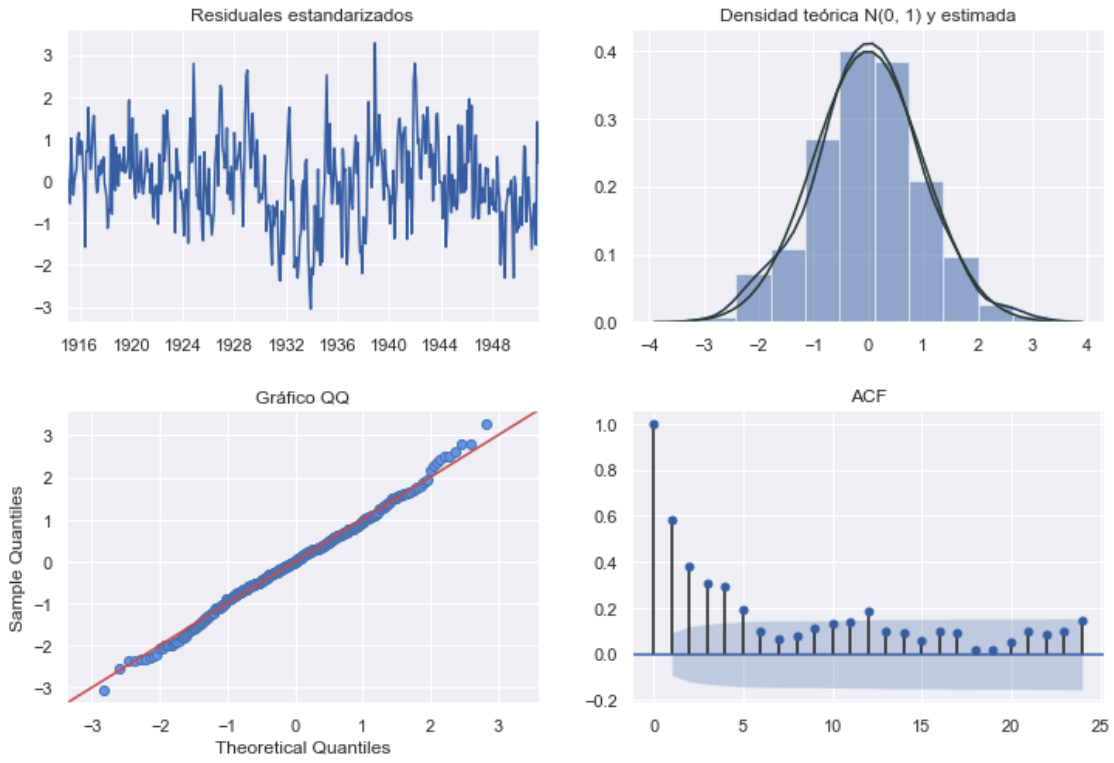
```
Best RF: n_estimators: 500 max_depth: 1.0 max_features :1 | CV RMSE = 0.107
```

```
In [174]: rf_hyp = {"max_depth": 1,
                    "n_estimators": 500,
                    "max_features": 1}
```

```
In [175]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                     n_estimators=rf_hyp["n_estimators"],
                                     max_features=rf_hyp["max_features"],
                                     random_state=seed)

          rf_model = rf.fit(X_train, y_train)
          rf_fitted = pd.Series(rf_model.predict(X_train))
          rf_fitted
          rf_fitted.index = X_train.index
          rf_resid = y_train - rf_fitted
          rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

          rf_jb_test = jb(rf_resid)
          rf_lb_test = lb(rf_resid)

          rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [176]: rf_seas_forecast = rf_forecast + bc_seasonality_forecast
          rf_box_forecast = (bc_param * rf_seas_forecast + 1) ** (1 / bc_param)
```

```
In [177]: resid_diag(rf_resid)
          plt.show()
```

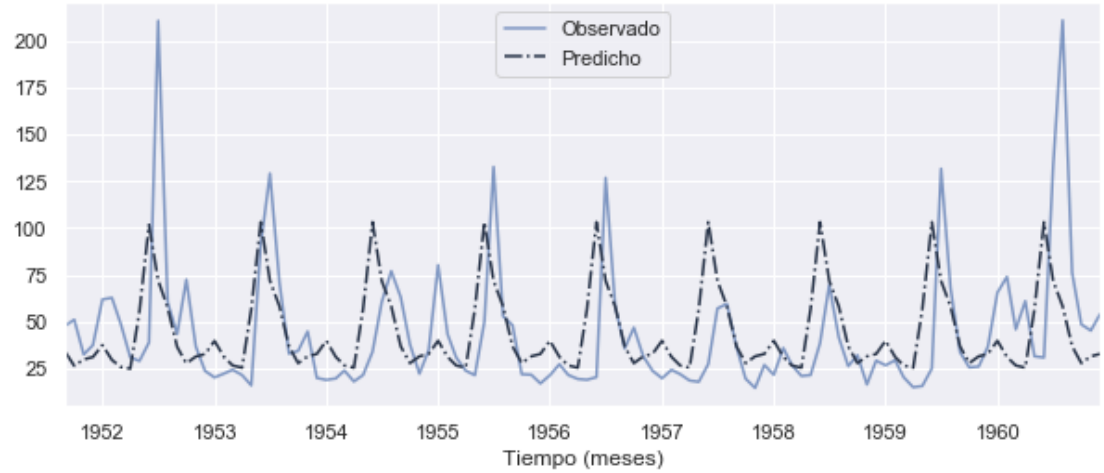



```
In [178]: print("Random Forest")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(rf_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(rf_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, rf_box_forecast))))
          print("MAE (test):  " + str(mae(test, rf_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, rf_box_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.4770988921732303
Test de Ljung-Box para k =  6 (p-valor): 4.8204864865797315e-65
Test de Ljung-Box para k = 12 (p-valor): 7.749578074539412e-70
```

```
RMSE (test): 34.36997958512307
MAE (test):  22.24758706621245
sMAPE (test):  44.313099901978816
```

```
In [179]: forecast_plot(test, rf_box_forecast)
          plt.show()
```



ElasticNet

```
In [180]: best_score, best_tree = float("inf"), None

          ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
          alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


          for rat in ratio:
              for alp in alpha:
                  en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                  en_model1 = en.fit(X_train1, y_train1)
                  en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                  en_model2 = en.fit(X_val1, y_val1)
                  en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                  en_model3 = en.fit(X_val2, y_val2)
```

```
                en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_en = cvrmse, en.get_params()

        print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
              (best_en['l1_ratio'], best_en['alpha'], best_score))
```

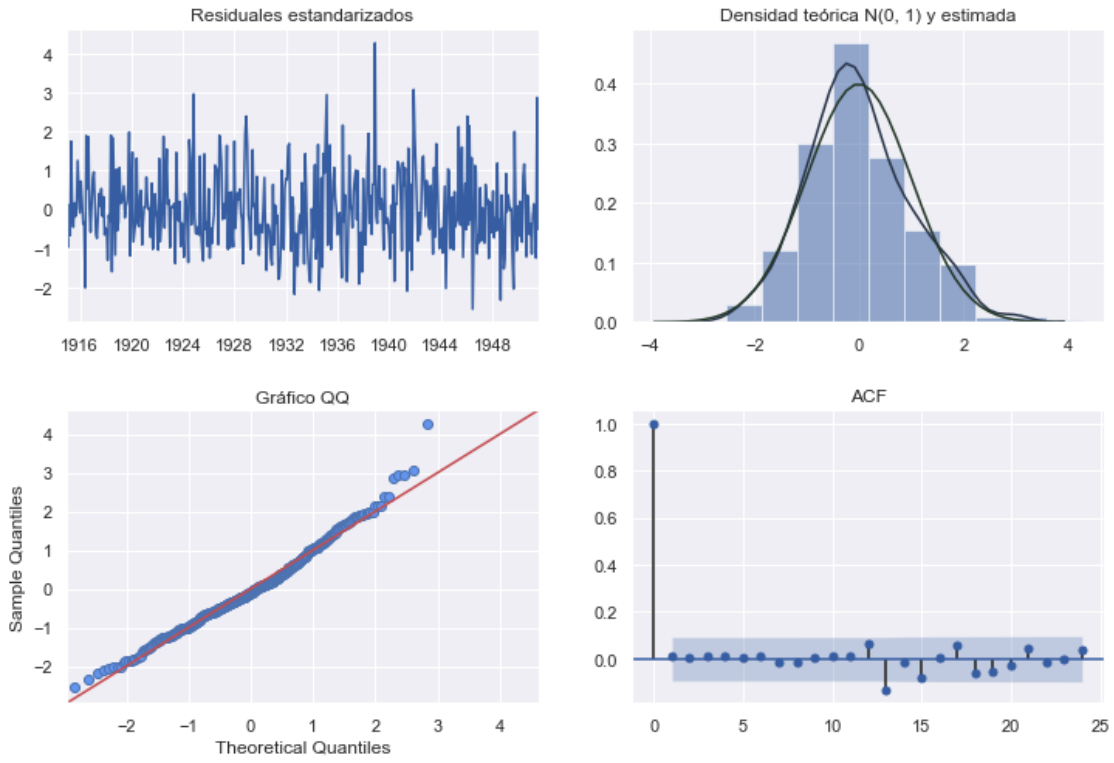
```
Best EN: ratio: 0.1 alpha: 0 | CV RMSE = 0.106
```

```
In [181]: en_hyp = {"l1_ratio": 0.1,
                    "alpha": 0}
```

```
In [182]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                          random_state=seed)
          en_model = en.fit(X_train, y_train)
          en_fitted = pd.Series(en_model.predict(X_train))
          en_fitted
          en_fitted.index = X_train.index
          en_resid = y_train - en_fitted
          en_resid = (en_resid - en_resid.mean()) / en_resid.std()

          en_jb_test = jb(en_resid)
          en_lb_test = lb(en_resid)

          en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [183]: en_seas_forecast = en_forecast + bc_seasonality_forecast
          en_box_forecast = (bc_param * en_seas_forecast + 1) ** (1 / bc_param)
```

```
In [184]: resid_diag(en_resid)
          plt.show()
```

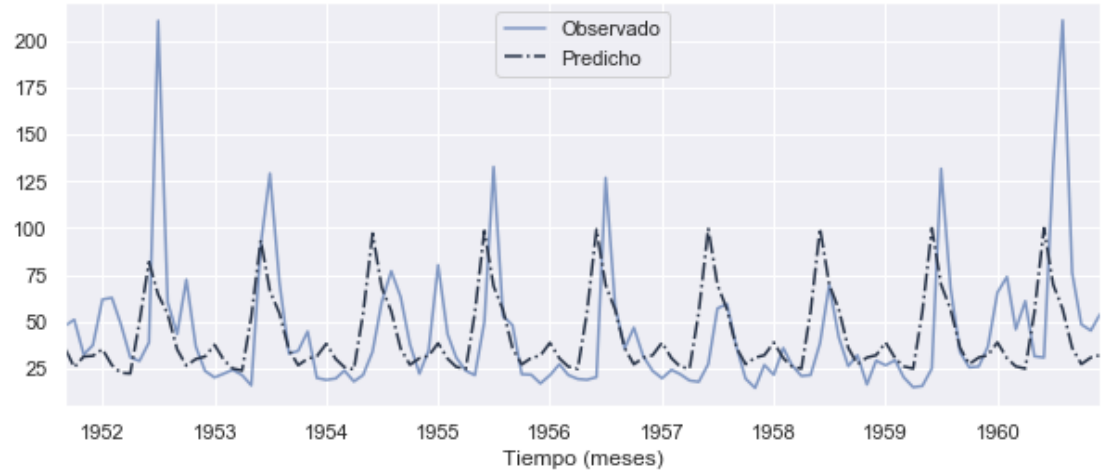



```
In [185]: print("ElasticNet")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(en_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(en_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, en_box_forecast))))
          print("MAE (test):  " + str(mae(test, en_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, en_box_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 7.412106994966741e-06
Test de Ljung-Box para k =  6 (p-valor): 0.9996200800570041
Test de Ljung-Box para k = 12 (p-valor): 0.6760069479969495
```

```
RMSE (test): 34.0536545700252
MAE (test):  21.710813026623878
sMAPE (test):  43.73798854561817
```

```
In [186]: forecast_plot(test, en_box_forecast)
          plt.show()
```



Serie temporal con Box-Cox y diferenciada como estructura de DataFrame

```
In [187]: lag_df = series_to_supervised(diff_bc_train, n_in=12)
          lag_df.head(5)
```

Out[187]:

index	var1(t-12)	var1(t-11)	var1(t-10)	var1(t-9)	var1(t-8)	var1(t-7)	var1(t-6)	var1(t-5)	var1(t-4)	var1(t-3)	var1(t-2)
1915-02-01	-0.022415	-0.036931	-0.120520	-0.050707	0.127983	0.140010	0.046348	0.053055	-0.117011	-0.117013	0.081798
1915-03-01	-0.036931	-0.120520	-0.050707	0.127983	0.140010	0.046348	0.053055	-0.117011	-0.117013	0.081798	-0.048950
1915-04-01	-0.120520	-0.050707	0.127983	0.140010	0.046348	0.053055	-0.117011	-0.117013	0.081798	-0.048950	-0.026461
1915-05-01	-0.050707	0.127983	0.140010	0.046348	0.053055	-0.117011	-0.117013	0.081798	-0.048950	-0.026461	-0.041104
1915-06-01	0.127983	0.140010	0.046348	0.053055	-0.117011	-0.117013	0.081798	-0.048950	-0.026461	-0.041104	-0.096391

```
            var1(t-1)   var1(t)
index
1915-02-01  -0.048950 -0.026461
1915-03-01  -0.026461 -0.041104
1915-04-01  -0.041104 -0.096391
1915-05-01  -0.096391  0.124088
1915-06-01   0.124088  0.142337
```

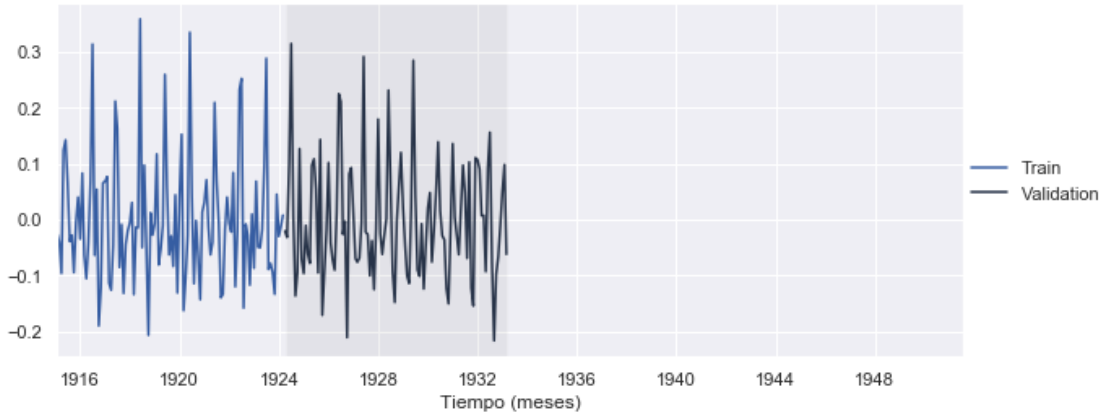
Definición de X (predictoras) e y (a predecir)

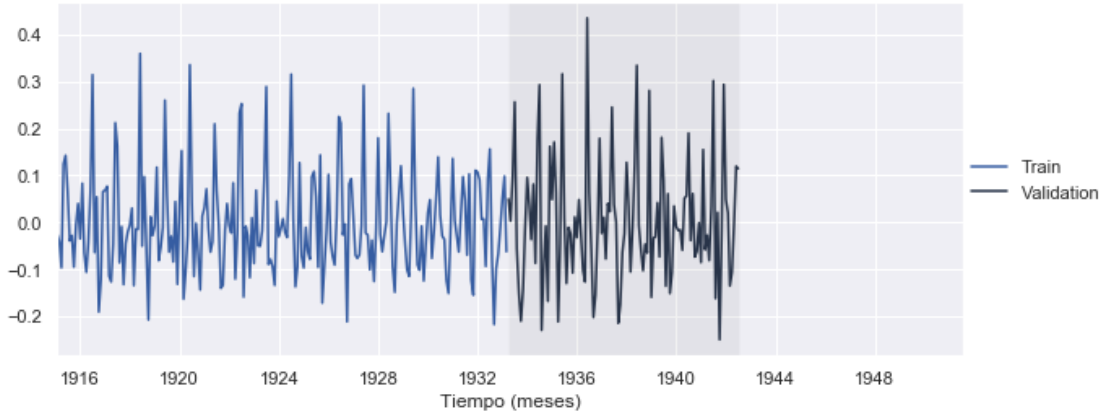
```
In [188]: X_train = lag_df.iloc[:,:-1]
          y_train = lag_df.iloc[:,-1]
```

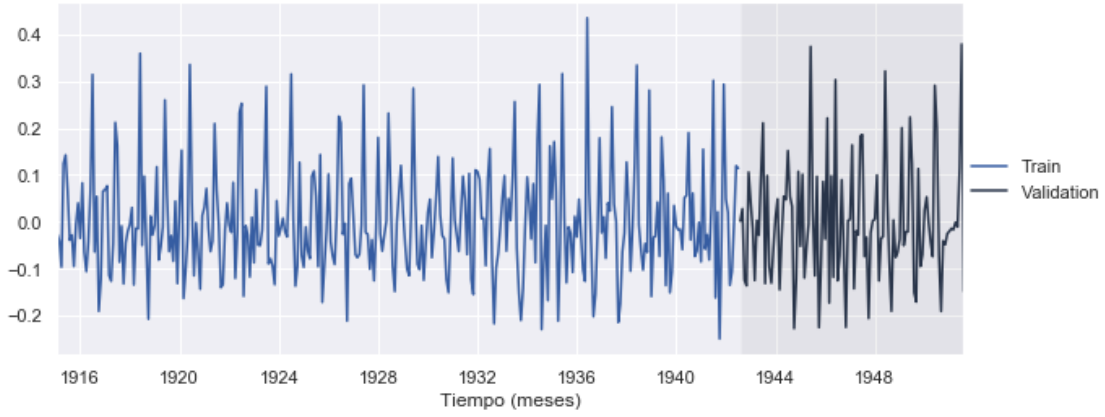
Validación cruzada temporal

```
In [189]: train3, validation3 = ts_split(lag_df, train_size=0.75)
          X_train3 = train3.iloc[:,:-1]
          y_train3 = train3.iloc[:,-1]
          X_val3 = validation3.iloc[:,:-1]
          y_val3 = validation3.iloc[:,-1]

          train2, validation2 = ts_split(train3, train_size=0.66)
          X_train2 = train2.iloc[:,:-1]
          y_train2 = train2.iloc[:,-1]
          X_val2 = validation2.iloc[:,:-1]
          y_val2 = validation2.iloc[:,-1]

          train1, validation1 = ts_split(train2, train_size=0.5)
          X_train1 = train1.iloc[:,:-1]
          y_train1 = train1.iloc[:,-1]
          X_val1 = validation1.iloc[:,:-1]
          y_val1 = validation1.iloc[:,-1]
```

```
In [190]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
          plt.show()
```


0.3
0.2
0.1
0.0
−0.1
−0.2
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

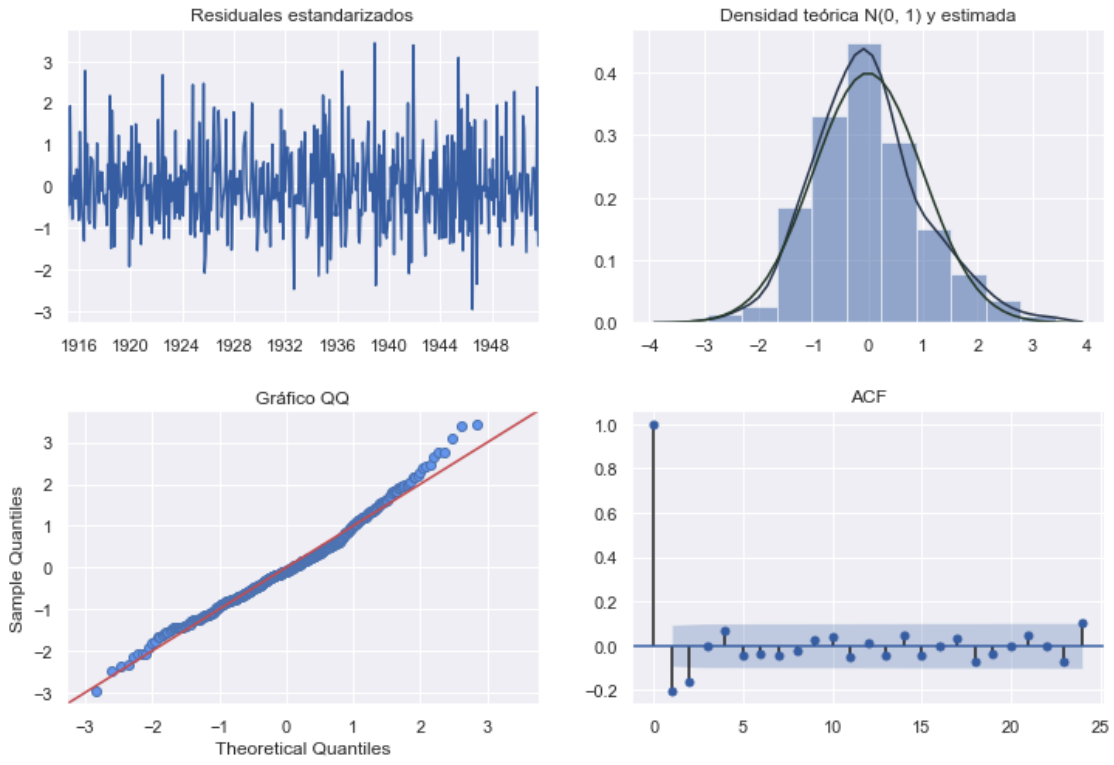
K-Nearest Neighbors

```
In [191]: neigb = list(np.arange(2, 41, 1))

In [192]: best_score, best_knn = float("inf"), None

          for k in neigb:
                  knn = KNeighborsRegressor(n_neighbors=k)

                  knn_model1 = knn.fit(X_train1, y_train1)
                  knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                  knn_model2 = knn.fit(X_val1, y_val1)
                  knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                  knn_model3 = knn.fit(X_val2, y_val2)
                  knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                  rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                  cvrmse = mean([rmse1, rmse2, rmse3])
                  if cvrmse < best_score:
                      best_score, best_knn = cvrmse, knn.get_params()

          print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))

Best KNN 21 CVRMSE = 0.102


In [193]: knn_hyp = {"k": 21}

In [194]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
          knn_model = knn.fit(X_train, y_train)
          knn_fitted = pd.Series(knn_model.predict(X_train))
          knn_fitted
          knn_fitted.index = X_train.index
          knn_resid = y_train - knn_fitted
          knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

          knn_jb_test = jb(knn_resid)
          knn_lb_test = lb(knn_resid)

          knn_forecast = iter_forecast(knn, y_train, 12, test)

In [195]: knn_undiff_forecast = []
          last_obser = bc_train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + knn_forecast[i]
```

```
        knn_undiff_forecast.append(yhat)
        last_obser = yhat

    knn_undiff_forecast = pd.Series(knn_undiff_forecast)
    knn_undiff_forecast.index = test.index
```

In [196]:
```
knn_box_forecast = (bc_param * knn_undiff_forecast + 1) ** (1 / bc_param)
```

In [197]:
```
resid_diag(knn_resid)
plt.show()
```

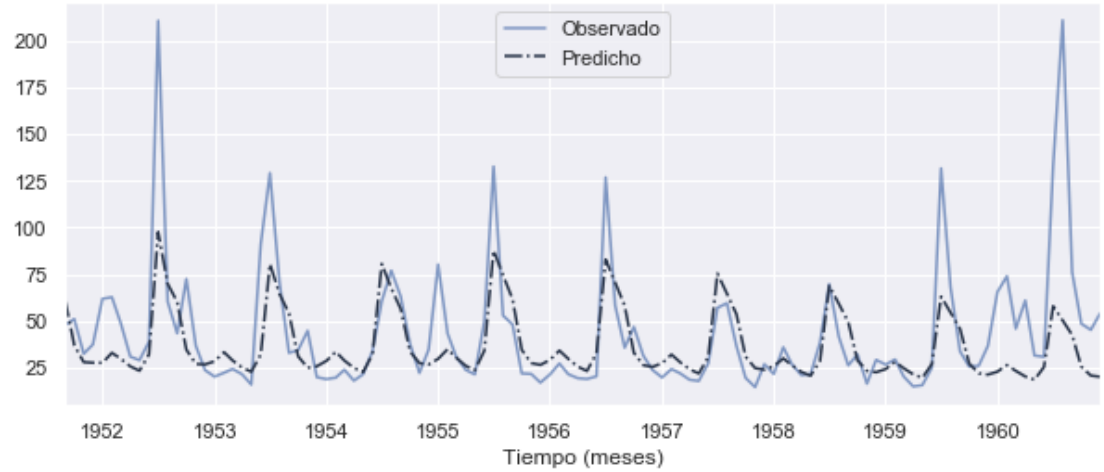


In [198]:
```
print("K-Nearest Neighbors")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " +
      str(knn_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(knn_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(knn_lb_test[1][12]))
print("")
```

```
        print("RMSE (test): " + str(sqrt(mse(test, knn_box_forecast))))
        print("MAE (test):  " + str(mae(test, knn_box_forecast)))
        print("sMAPE (test):  " + str(smape(test, knn_box_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 4.5246797922048964e-05
Test de Ljung-Box para k =  6 (p-valor): 1.426702194406454e-05
Test de Ljung-Box para k = 12 (p-valor): 0.0002938382649062492

RMSE (test): 27.372119226343877
MAE (test):  16.042767653266925
sMAPE (test):  34.04440035728844
```

```
In [199]: forecast_plot(test, knn_box_forecast)
          plt.show()
```



Regresion tree

```
In [200]: depths = list(np.arange(1, 21, 1))
```

```
In [201]: best_score, best_tree = float("inf"), None

          for depth in depths:
                  tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                  tree_model1 = tree.fit(X_train1, y_train1)
```

```
                tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                tree_model2 = tree.fit(X_val1, y_val1)
                tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                tree_model3 = tree.fit(X_val2, y_val2)
                tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])

                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

```
Best Tree 1 CV RMSE = 0.120
```

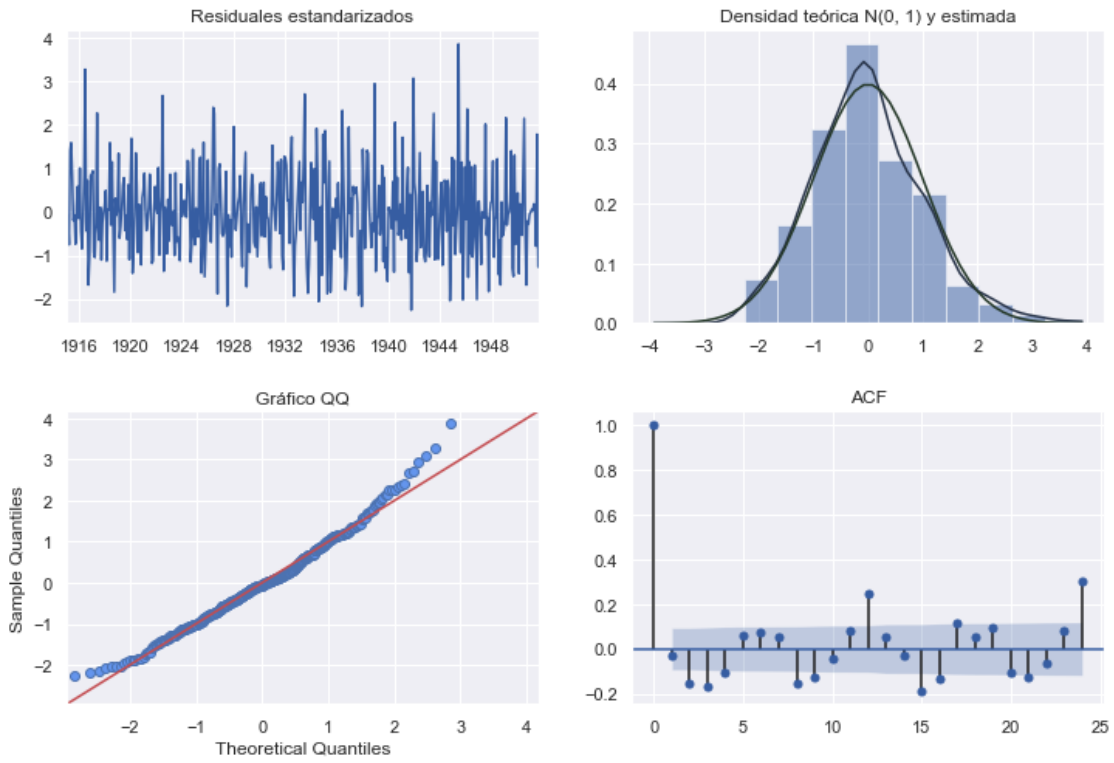
```
In [202]: tree_hyp = {"depth": 1}
```

```
In [203]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                       random_state=seed)
          tree_model = tree.fit(X_train, y_train)
          tree_fitted = pd.Series(tree_model.predict(X_train))
          tree_fitted
          tree_fitted.index = X_train.index
          tree_resid = y_train - tree_fitted
          tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

          tree_jb_test = jb(tree_resid)
          tree_lb_test = lb(tree_resid)

          tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [204]: tree_undiff_forecast = []
          last_obser = bc_train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + tree_forecast[i]
              tree_undiff_forecast.append(yhat)
              last_obser = yhat

          tree_undiff_forecast = pd.Series(tree_undiff_forecast)
          tree_undiff_forecast.index = test.index
```

```
In [205]: tree_box_forecast = (bc_param * tree_undiff_forecast + 1) ** (1 / bc_param)
```

In [206]:
```
resid_diag(tree_resid)
plt.show()
```

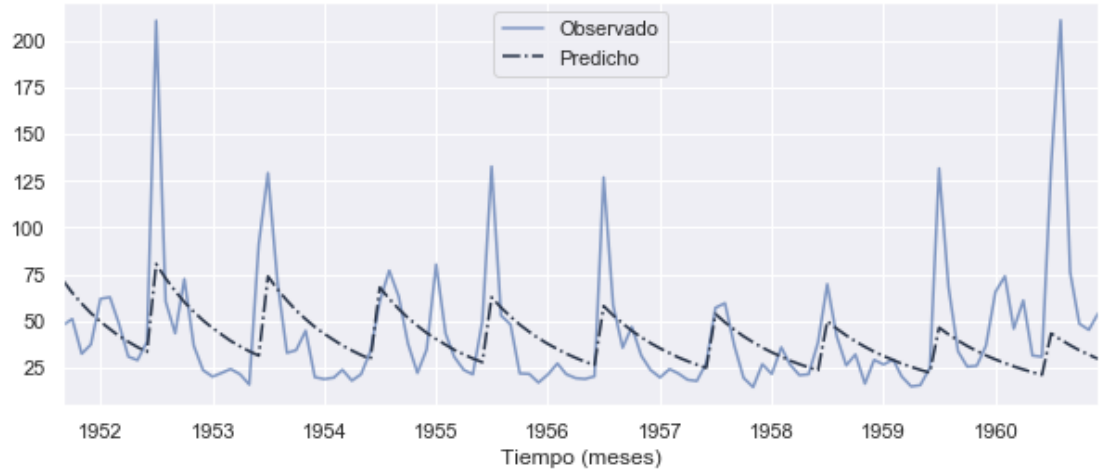


In [207]:
```
print("Decision Tree")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " +
      str(tree_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(tree_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(tree_lb_test[1][12]))
print("")
print("RMSE (test): " + str(sqrt(mse(test, tree_box_forecast))))
print("MAE (test):  " + str(mae(test, tree_box_forecast)))
print("sMAPE (test):  " + str(smape(test, tree_box_forecast)))
```

```
Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112
```

```
Test de Jarque-Bera (p-valor): 6.676127468555702e-05
Test de Ljung-Box para k =  6 (p-valor): 2.6885859567584192e-05
Test de Ljung-Box para k = 12 (p-valor): 1.6607113930256373e-12

RMSE (test): 30.862439905297794
MAE (test):  19.343326550124953
sMAPE (test):  41.765027713266996
```

```
In [208]: forecast_plot(test, tree_box_forecast)
          plt.show()
```



Random Forest

```
In [209]: best_score, best_tree = float("inf"), None

          n_estimators = [50, 100, 200, 500]
          depths = np.linspace(1, 61, 20)
          max_features = [0.8, 1]


          for n in n_estimators:
              for depth in depths:
                  for features in max_features:
                      rf = RandomForestRegressor(n_estimators=n,
                                                 max_depth=depth,
                                                 max_features=features,
                                                 random_state=seed)
```

```
                        rf_model1 = rf.fit(X_train1, y_train1)
                        rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                        rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))

                        rf_model2 = rf.fit(X_val1, y_val1)
                        rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                        rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                        rf_model3 = rf.fit(X_val2, y_val2)
                        rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                        rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                        cvrmse = mean([rmse1, rmse2, rmse3])
                        if cvrmse < best_score:
                            best_score, best_rf = cvrmse, rf.get_params()

            print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f'
                  % (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_
```

```
Best RF: n_estimators: 500 max_depth: 4.157894736842105 max_features :0.8 | CV RMSE = 0.113
```

```
In [210]: rf_hyp = {"max_depth": 4.15,
                    "n_estimators": 500,
                    "max_features": 0.8}
```

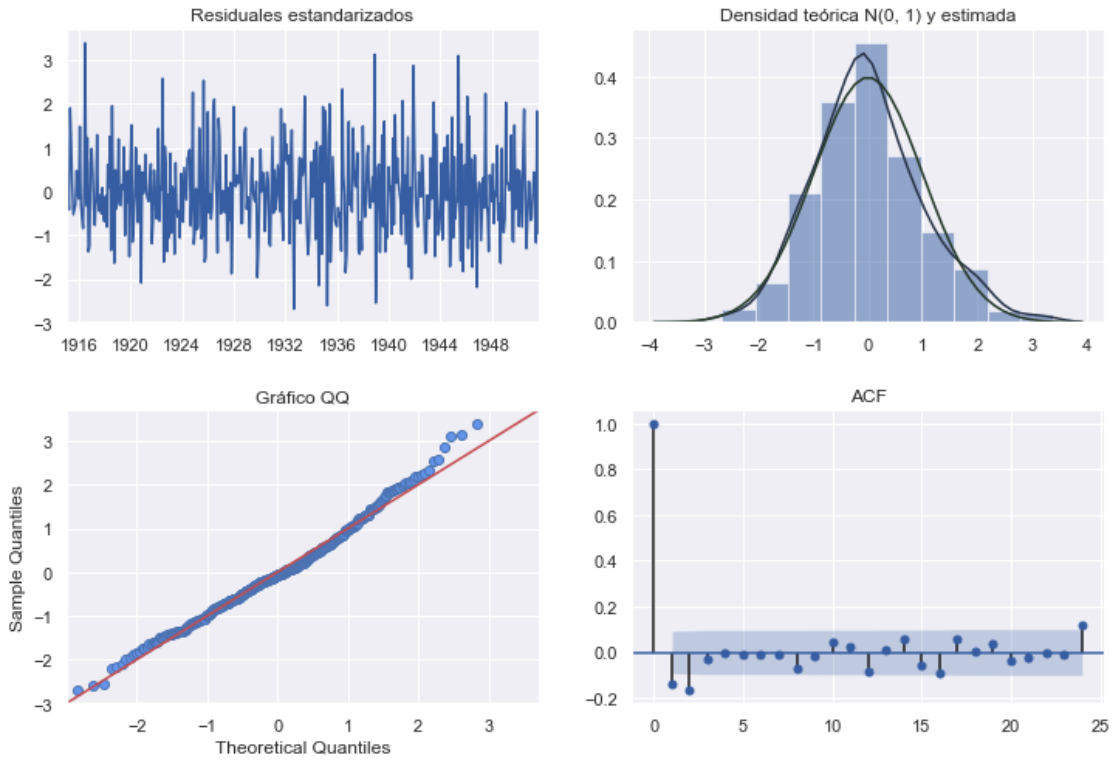
```
In [211]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                     n_estimators=rf_hyp["n_estimators"],
                                     max_features=rf_hyp["max_features"],
                                     random_state=seed)

          rf_model = rf.fit(X_train, y_train)
          rf_fitted = pd.Series(rf_model.predict(X_train))
          rf_fitted
          rf_fitted.index = X_train.index
          rf_resid = y_train - rf_fitted
          rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

          rf_jb_test = jb(rf_resid)
          rf_lb_test = lb(rf_resid)

          rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [212]: rf_undiff_forecast = []
          last_obser = bc_deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + rf_forecast[i]
              rf_undiff_forecast.append(yhat)
              last_obser = yhat
```

```
rf_undiff_forecast = pd.Series(rf_undiff_forecast)
rf_undiff_forecast.index = test.index
```

In [213]:
```
rf_box_forecast = (bc_param * rf_undiff_forecast + 1) ** (1 / bc_param)
```

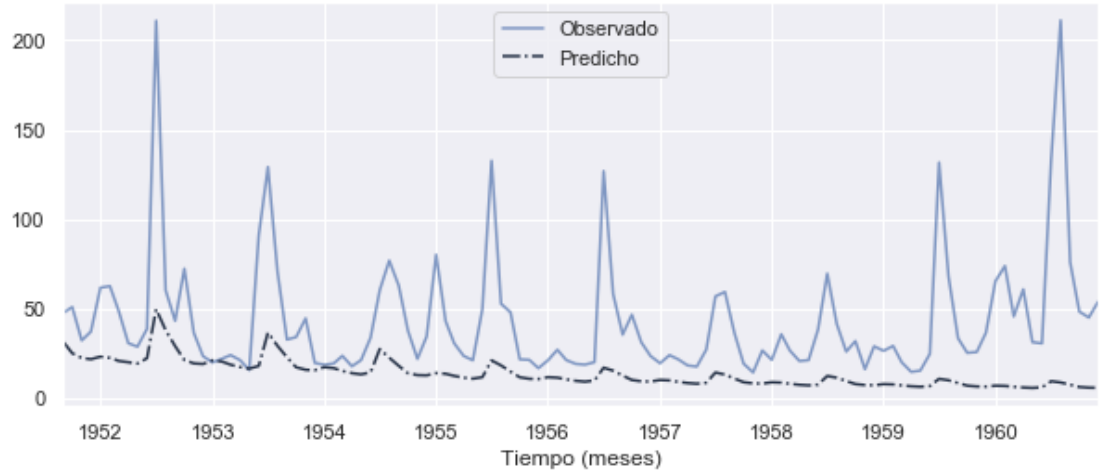
In [214]:
```
resid_diag(rf_resid)
plt.show()
```



In [215]:
```
print("Random Forest")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(rf_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(rf_lb_test[1][12]))
print("")
print("RMSE (test): " + str(sqrt(mse(test, rf_box_forecast))))
print("MAE (test):  " + str(mae(test, rf_box_forecast)))
print("sMAPE (test):  " + str(smape(test, rf_box_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.0017866076588243709
Test de Ljung-Box para k =  6 (p-valor): 0.0036130029610332488
Test de Ljung-Box para k = 12 (p-valor): 0.008784333768246519

RMSE (test): 43.79388980909914
MAE (test):  29.732433883121928
sMAPE (test):  90.94202211425733
```

```
In [216]: forecast_plot(test, rf_box_forecast)
          plt.show()
```



ElasticNet

```
In [217]: best_score, best_tree = float("inf"), None

          ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
          alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


          for rat in ratio:
              for alp in alpha:
                  en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                  en_model1 = en.fit(X_train1, y_train1)
```

```
                    en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                    rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                    en_model2 = en.fit(X_val1, y_val1)
                    en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                    en_model3 = en.fit(X_val2, y_val2)
                    en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_en = cvrmse, en.get_params()

            print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
                  (best_en['l1_ratio'], best_en['alpha'], best_score))
```

```
Best EN: ratio: 0.1 alpha: 0 | CV RMSE = 0.111
```

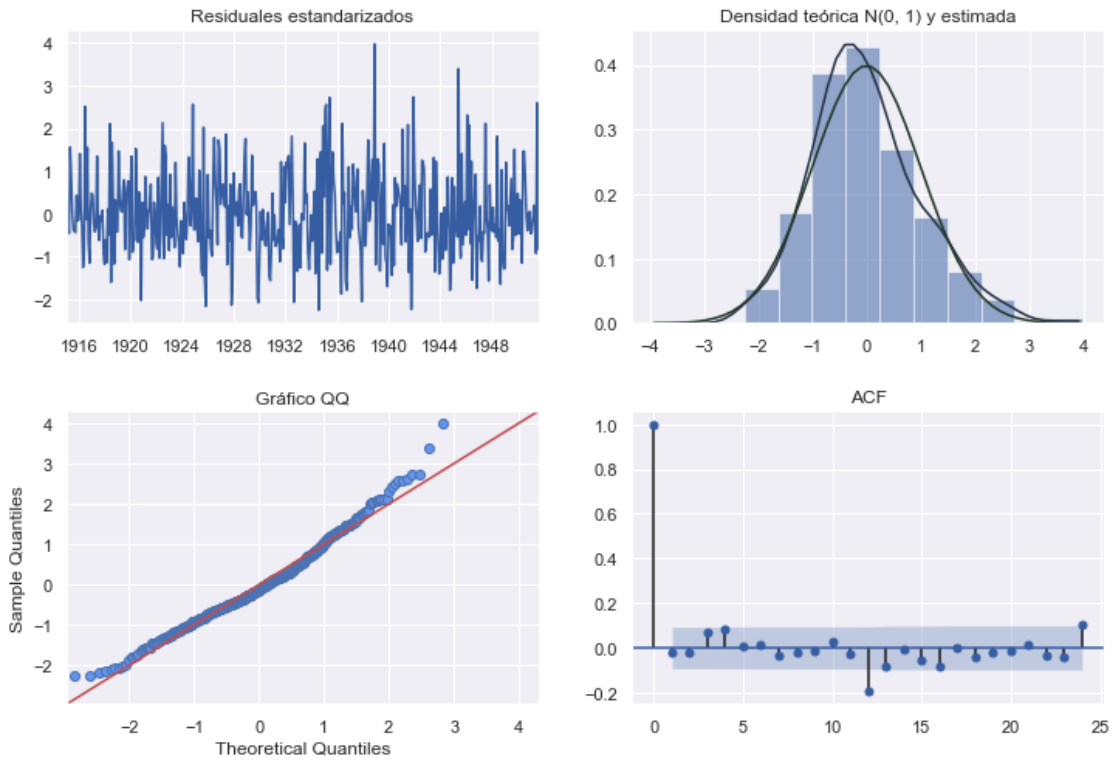
```
In [218]: en_hyp = {"l1_ratio": 0.1,
                    "alpha": 0}
```

```
In [219]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                          random_state=seed)
          en_model = en.fit(X_train, y_train)
          en_fitted = pd.Series(en_model.predict(X_train))
          en_fitted
          en_fitted.index = X_train.index
          en_resid = y_train - en_fitted
          en_resid = (en_resid - en_resid.mean()) / en_resid.std()

          en_jb_test = jb(en_resid)
          en_lb_test = lb(en_resid)

          en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [220]: en_undiff_forecast = []
          last_obser = bc_train.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + en_forecast[i]
              en_undiff_forecast.append(yhat)
              last_obser = yhat

          en_undiff_forecast = pd.Series(en_undiff_forecast)
          en_undiff_forecast.index = test.index
```

```
In [221]: en_box_forecast = (bc_param * en_undiff_forecast + 1) ** (1 / bc_param)
```

```
In [222]: resid_diag(en_resid)
          plt.show()
```

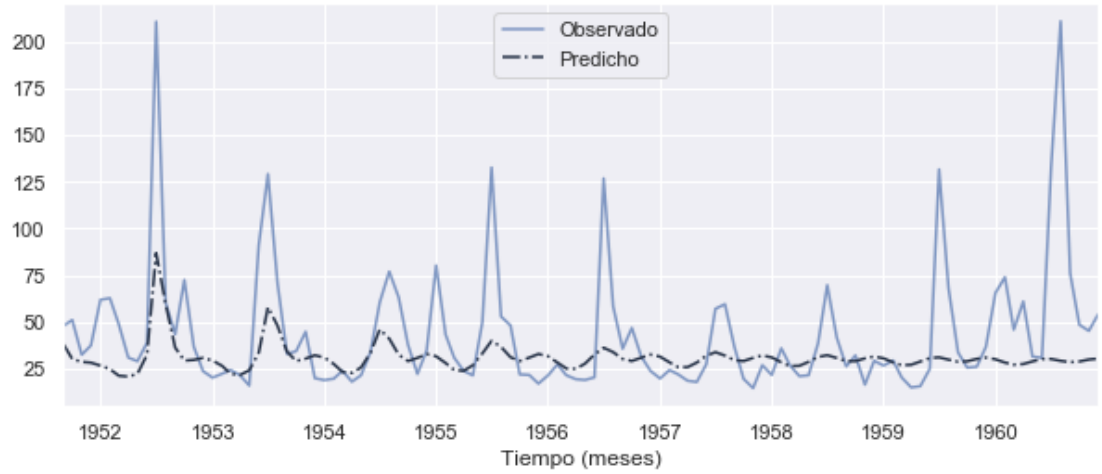



```
In [223]: print("ElasticNet")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(en_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(en_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, en_box_forecast))))
          print("MAE (test):  " + str(mae(test, en_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, en_box_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112
```

```
Test de Jarque-Bera (p-valor): 1.621113733273755e-06
Test de Ljung-Box para k =  6 (p-valor): 0.5239960585921445
Test de Ljung-Box para k = 12 (p-valor): 0.012392484507714213

RMSE (test): 33.327165564718044
MAE (test):  18.778881608977922
sMAPE (test):  39.585127561297675
```

```
In [224]: forecast_plot(test, en_box_forecast)
          plt.show()
```



Serie temporal desestacionalizada y diferenciada como estructura de DataFrame

```
In [225]: diff_deseas = deseas.diff(1).iloc[1:]
```

```
In [226]: lag_df = series_to_supervised(diff_deseas, n_in=12)
          lag_df.head(5)
```

```
Out[226]:             var1(t-12)  var1(t-11)  var1(t-10)  var1(t-9)  var1(t-8)  \
          index
          1915-02-01  -12.568751    4.257272  -10.102387  -2.545743 -27.175797
          1915-03-01    4.257272  -10.102387   -2.545743 -27.175797 -17.669263
          1915-04-01  -10.102387   -2.545743  -27.175797 -17.669263  54.286194
          1915-05-01   -2.545743  -27.175797  -17.669263  54.286194  39.474457
          1915-06-01  -27.175797  -17.669263   54.286194  39.474457 -25.286546

                      var1(t-7)  var1(t-6)  var1(t-5)  var1(t-4)  var1(t-3)  var1(t-2)  \
          index
          1915-02-01 -17.669263  54.286194  39.474457 -25.286546 -14.752516   8.114108
          1915-03-01  54.286194  39.474457 -25.286546 -14.752516   8.114108  -9.567028
```

```
1915-04-01  39.474457 -25.286546 -14.752516   8.114108  -9.567028 -11.491751
1915-05-01 -25.286546 -14.752516   8.114108  -9.567028 -11.491751   6.097272
1915-06-01 -14.752516   8.114108  -9.567028 -11.491751   6.097272  -3.561387

            var1(t-1)    var1(t)
index
1915-02-01  -9.567028 -11.491751
1915-03-01 -11.491751   6.097272
1915-04-01   6.097272  -3.561387
1915-05-01  -3.561387  14.444257
1915-06-01  14.444257  -9.590797
```

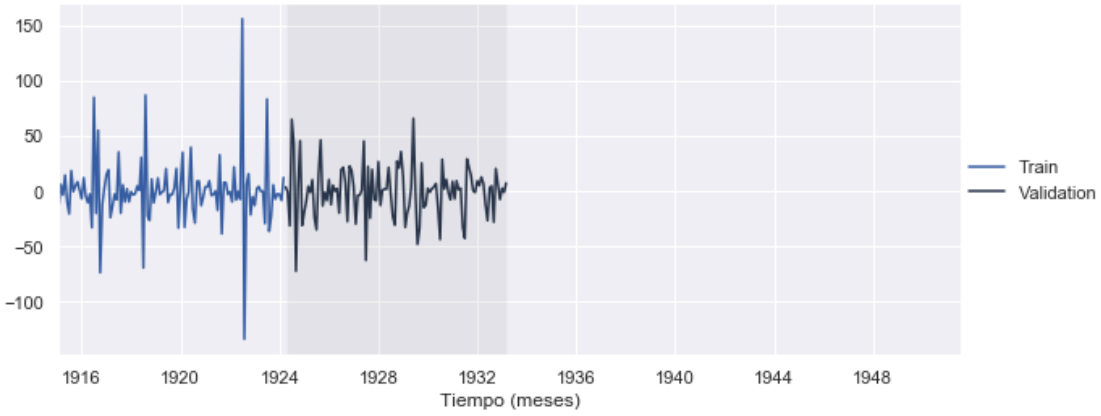
Definición de X (predictoras) e y (a predecir)

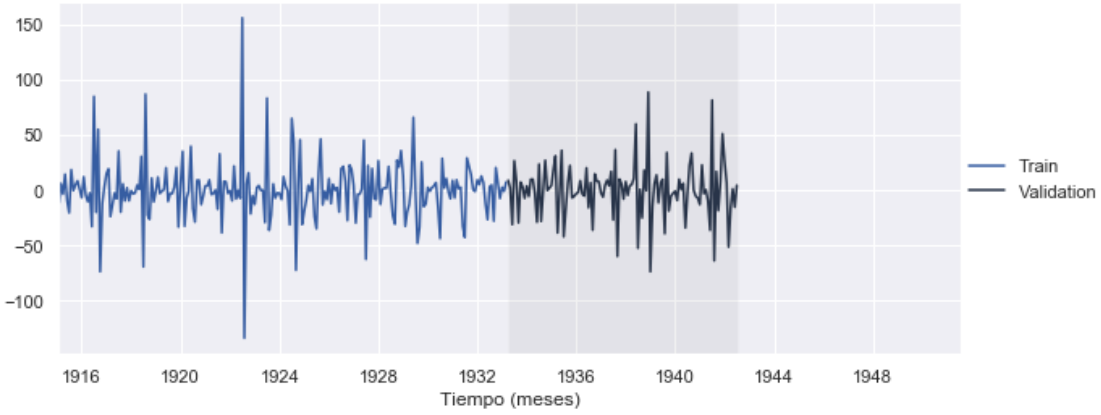
```
In [227]: X_train = lag_df.iloc[:,:-1]
          y_train = lag_df.iloc[:,-1]
```

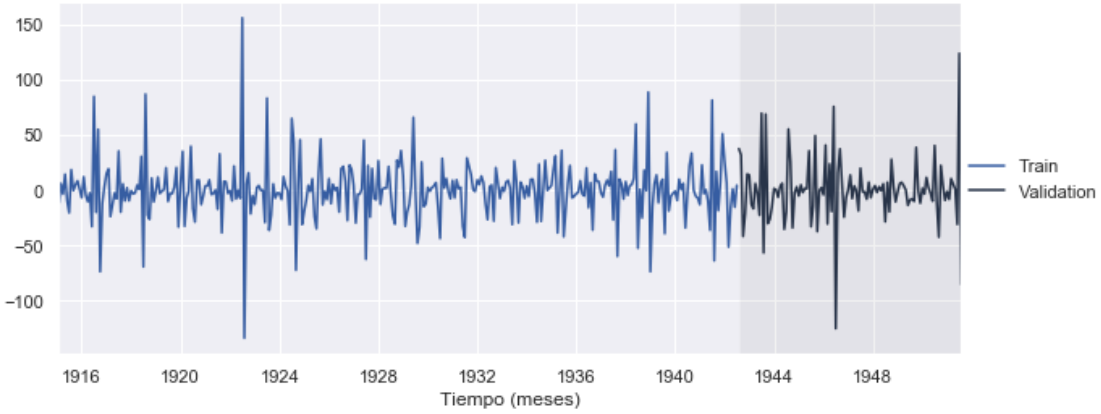
Validación cruzada temporal

```
In [228]: train3, validation3 = ts_split(lag_df, train_size=0.75)
          X_train3 = train3.iloc[:,:-1]
          y_train3 = train3.iloc[:,-1]
          X_val3 = validation3.iloc[:,:-1]
          y_val3 = validation3.iloc[:,-1]

          train2, validation2 = ts_split(train3, train_size=0.66)
          X_train2 = train2.iloc[:,:-1]
          y_train2 = train2.iloc[:,-1]
          X_val2 = validation2.iloc[:,:-1]
          y_val2 = validation2.iloc[:,-1]

          train1, validation1 = ts_split(train2, train_size=0.5)
          X_train1 = train1.iloc[:,:-1]
          y_train1 = train1.iloc[:,-1]
          X_val1 = validation1.iloc[:,:-1]
          y_val1 = validation1.iloc[:,-1]
```

```
In [229]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
          plt.show()
```


150
100
50
0
−50
−100
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


150
100
50
0
−50
−100
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


150
100
50
0
−50
−100
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

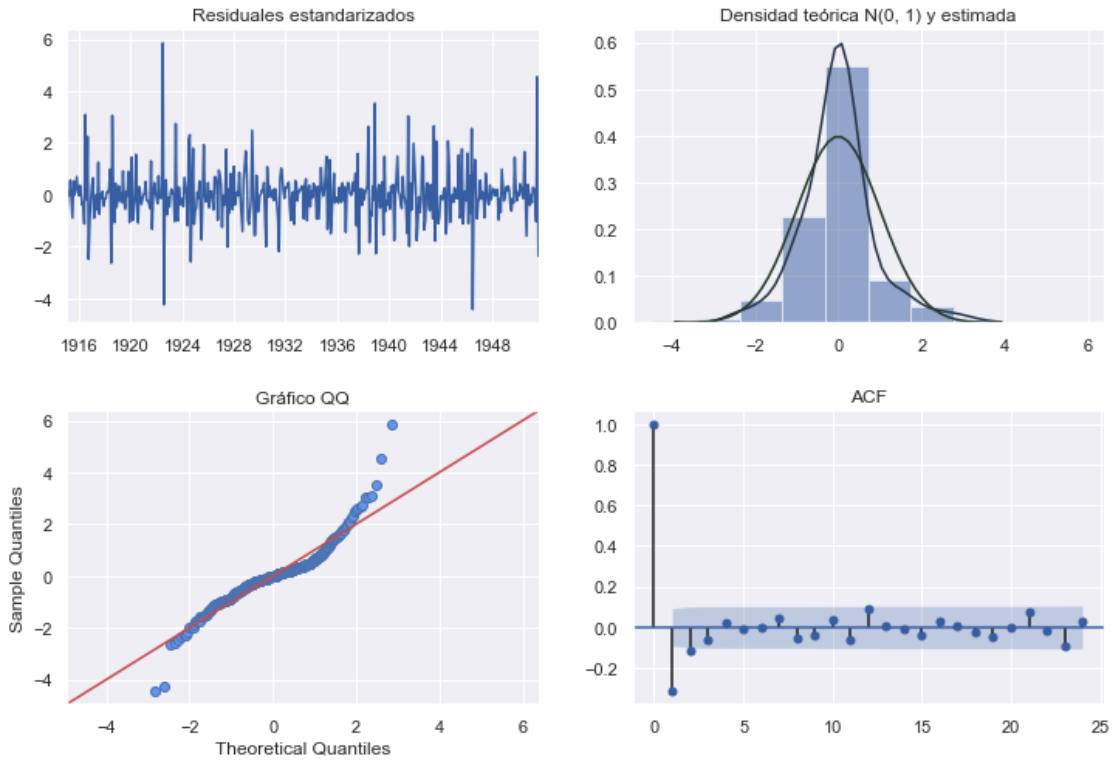
K-Nearest Neighbors

```
In [230]: neigb = list(np.arange(2, 41, 1))

In [231]: best_score, best_knn = float("inf"), None

          for k in neigb:
                  knn = KNeighborsRegressor(n_neighbors=k)

                  knn_model1 = knn.fit(X_train1, y_train1)
                  knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                  knn_model2 = knn.fit(X_val1, y_val1)
                  knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                  knn_model3 = knn.fit(X_val2, y_val2)
                  knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                  rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                  cvrmse = mean([rmse1, rmse2, rmse3])
                  if cvrmse < best_score:
                      best_score, best_knn = cvrmse, knn.get_params()

          print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))

Best KNN 33 CVRMSE = 25.992


In [232]: knn_hyp = {"k": 33}

In [233]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
          knn_model = knn.fit(X_train, y_train)
          knn_fitted = pd.Series(knn_model.predict(X_train))
          knn_fitted
          knn_fitted.index = X_train.index
          knn_resid = y_train - knn_fitted
          knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

          knn_jb_test = jb(knn_resid)
          knn_lb_test = lb(knn_resid)

          knn_forecast = iter_forecast(knn, y_train, 12, test)

In [234]: knn_undiff_forecast = []
          last_obser = deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + knn_forecast[i]
```

```
        knn_undiff_forecast.append(yhat)
        last_obser = yhat

    knn_undiff_forecast = pd.Series(knn_undiff_forecast)
    knn_undiff_forecast.index = test.index
```

In [235]:
```
knn_seas_forecast = knn_undiff_forecast + seasonality_forecast
```

In [236]:
```
resid_diag(knn_resid)
plt.show()
```

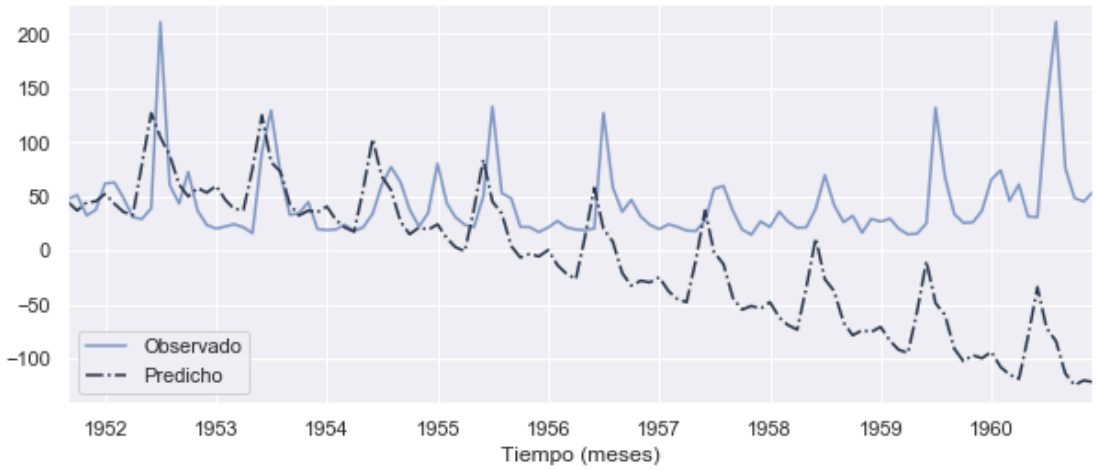


In [237]:
```
print("K-Nearest Neighbors")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(knn_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(knn_lb_test[1][12]))
print("")
print("RMSE (test): " + str(sqrt(mse(test, knn_seas_forecast))))
```

```
        print("MAE (test):  " + str(mae(test, knn_seas_forecast)))
        print("sMAPE (test):  " + str(smape(test, knn_seas_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 5.717097260166605e-124
Test de Ljung-Box para k =  6 (p-valor): 7.070382754371443e-09
Test de Ljung-Box para k = 12 (p-valor): 5.902152283903449e-08

RMSE (test): 84.05832496249754
MAE (test):  63.474552623087746
sMAPE (test):  132.40169832978398
```

```
In [238]: forecast_plot(test, knn_seas_forecast)
          plt.show()
```



Regresion tree

```
In [239]: depths = list(np.arange(1, 21, 1))

In [240]: best_score, best_tree = float("inf"), None

          for depth in depths:
                  tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                  tree_model1 = tree.fit(X_train1, y_train1)
                  tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
```

```
                rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                tree_model2 = tree.fit(X_val1, y_val1)
                tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                tree_model3 = tree.fit(X_val2, y_val2)
                tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

```
Best Tree 1 CV RMSE = 26.466
```

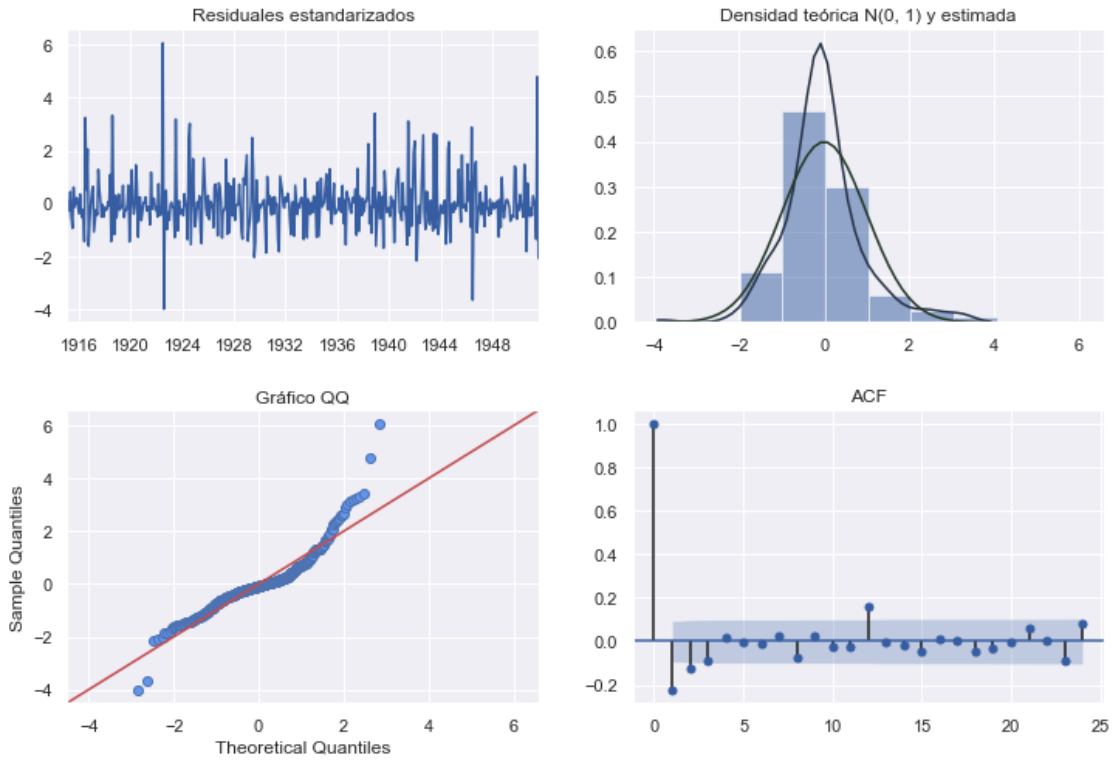
```
In [241]: tree_hyp = {"depth": 1}
```

```
In [242]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                       random_state=seed)
          tree_model = tree.fit(X_train, y_train)
          tree_fitted = pd.Series(tree_model.predict(X_train))
          tree_fitted
          tree_fitted.index = X_train.index
          tree_resid = y_train - tree_fitted
          tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

          tree_jb_test = jb(tree_resid)
          tree_lb_test = lb(tree_resid)

          tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [243]: tree_undiff_forecast = []
          last_obser = deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + tree_forecast[i]
              tree_undiff_forecast.append(yhat)
              last_obser = yhat

          tree_undiff_forecast = pd.Series(tree_undiff_forecast)
          tree_undiff_forecast.index = test.index
```

```
In [244]: tree_seas_forecast = tree_undiff_forecast + seasonality_forecast
```

```
In [245]: resid_diag(tree_resid)
          plt.show()
```

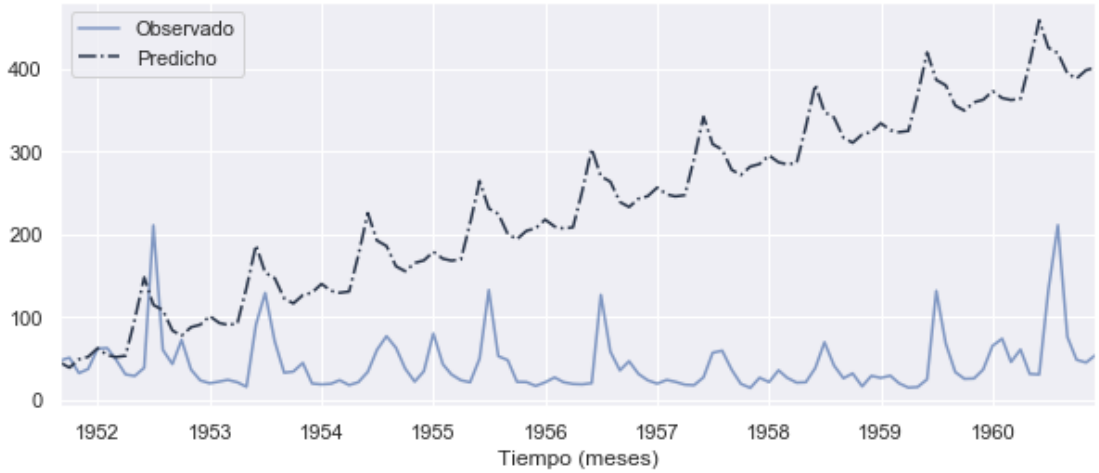



```
In [246]: print("Decision Tree")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(tree_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(tree_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, tree_seas_forecast))))
          print("MAE (test):  " + str(mae(test, tree_seas_forecast)))
          print("sMAPE (test):  " + str(smape(test, tree_seas_forecast)))
```

```
Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 5.984587735691505e-150
Test de Ljung-Box para k =  6 (p-valor): 3.310821158172319e-05
Test de Ljung-Box para k = 12 (p-valor): 7.717590622639042e-06
```

```
RMSE (test): 220.1524782212875
MAE (test):  192.52545166614178
sMAPE (test):  130.60223449593917
```

```
In [247]: forecast_plot(test, tree_seas_forecast)
          plt.show()
```



Random Forest

```
In [248]: best_score, best_tree = float("inf"), None

          n_estimators = [50, 100, 200, 500]
          depths = np.linspace(1, 61, 20)
          max_features = [0.8, 1]


          for n in n_estimators:
              for depth in depths:
                  for features in max_features:
                      rf = RandomForestRegressor(n_estimators=n,
                                                 max_depth=depth,
                                                 max_features=features,
                                                 random_state=seed)

                      rf_model1 = rf.fit(X_train1, y_train1)
                      rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                      rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))
```

```
                    rf_model2 = rf.fit(X_val1, y_val1)
                    rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                    rf_model3 = rf.fit(X_val2, y_val2)
                    rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_rf = cvrmse, rf.get_params()

        print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f' %
              (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_sc
```

```
Best RF: n_estimators: 500 max_depth: 1.0 max_features :1 | CV RMSE = 25.879
```

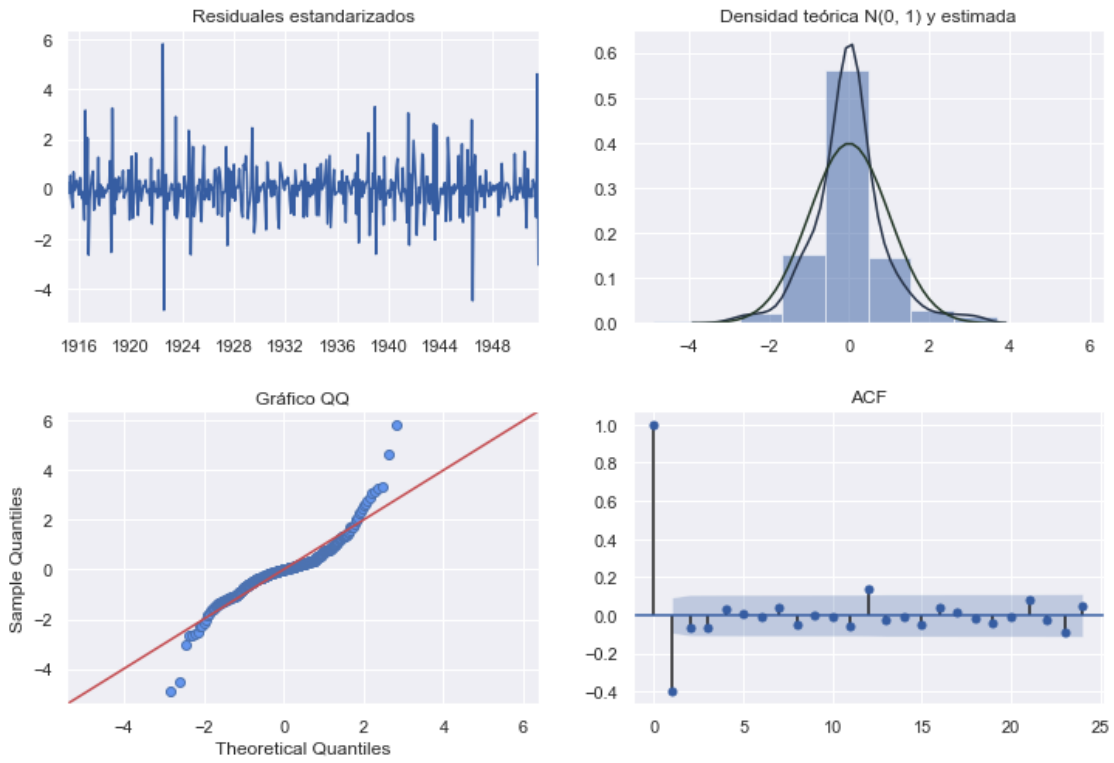
```
In [249]: rf_hyp = {"max_depth": 1,
                    "n_estimators": 500,
                    "max_features": 1}
```

```
In [250]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                     n_estimators=rf_hyp["n_estimators"],
                                     max_features=rf_hyp["max_features"],
                                     random_state=seed)
          rf_model = rf.fit(X_train, y_train)
          rf_fitted = pd.Series(rf_model.predict(X_train))
          rf_fitted
          rf_fitted.index = X_train.index
          rf_resid = y_train - rf_fitted
          rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

          rf_jb_test = jb(rf_resid)
          rf_lb_test = lb(rf_resid)

          rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [251]: rf_undiff_forecast = []
          last_obser = deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + rf_forecast[i]
              rf_undiff_forecast.append(yhat)
              last_obser = yhat

          rf_undiff_forecast = pd.Series(rf_undiff_forecast)
          rf_undiff_forecast.index = test.index
```

```
In [252]: rf_seas_forecast = rf_undiff_forecast + seasonality_forecast
```

In [253]:
```
resid_diag(rf_resid)
plt.show()
```

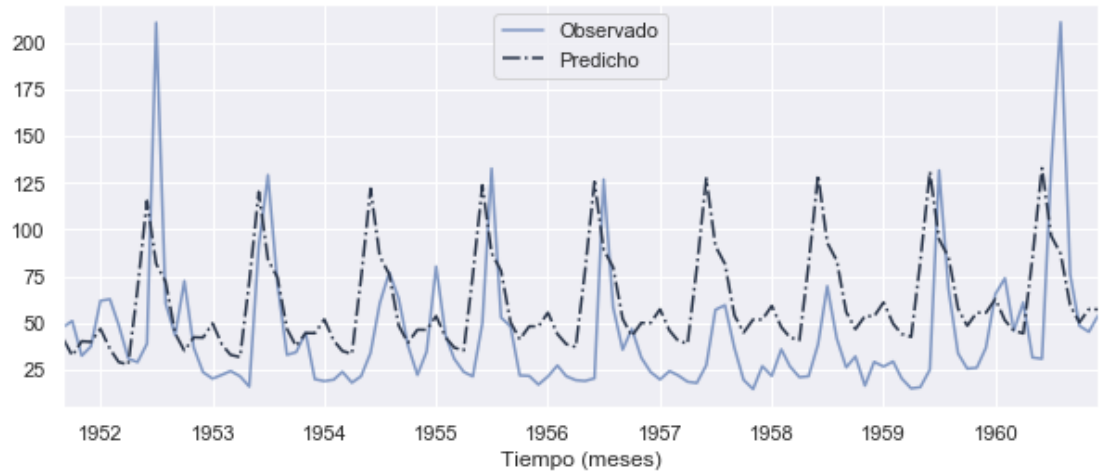


In [254]:
```
print("Random Forest")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(rf_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(rf_lb_test[1][12]))
print("")
print("RMSE (test): " + str(sqrt(mse(test, rf_seas_forecast))))
print("MAE (test):  " + str(mae(test, rf_seas_forecast)))
print("sMAPE (test):  " + str(smape(test, rf_seas_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112
```

```
Test de Jarque-Bera (p-valor): 1.236348856640542e-154
Test de Ljung-Box para k =  6 (p-valor): 2.0612833395810488e-13
Test de Ljung-Box para k = 12 (p-valor): 9.123411363294815e-13

RMSE (test): 39.87890461677487
MAE (test):  29.491078404147572
sMAPE (test):  56.01068915026782
```

```
In [255]: forecast_plot(test, rf_seas_forecast)
          plt.show()
```



ElasticNet

```
In [256]: best_score, best_tree = float("inf"), None

          ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
          alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


          for rat in ratio:
              for alp in alpha:
                  en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                  en_model1 = en.fit(X_train1, y_train1)
                  en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                  en_model2 = en.fit(X_val1, y_val1)
                  en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
```

```
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                    en_model3 = en.fit(X_val2, y_val2)
                    en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_en = cvrmse, en.get_params()

            print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
                  (best_en['l1_ratio'], best_en['alpha'], best_score))
```

```
Best EN: ratio: 0.1 alpha: 0 | CV RMSE = 25.778
```

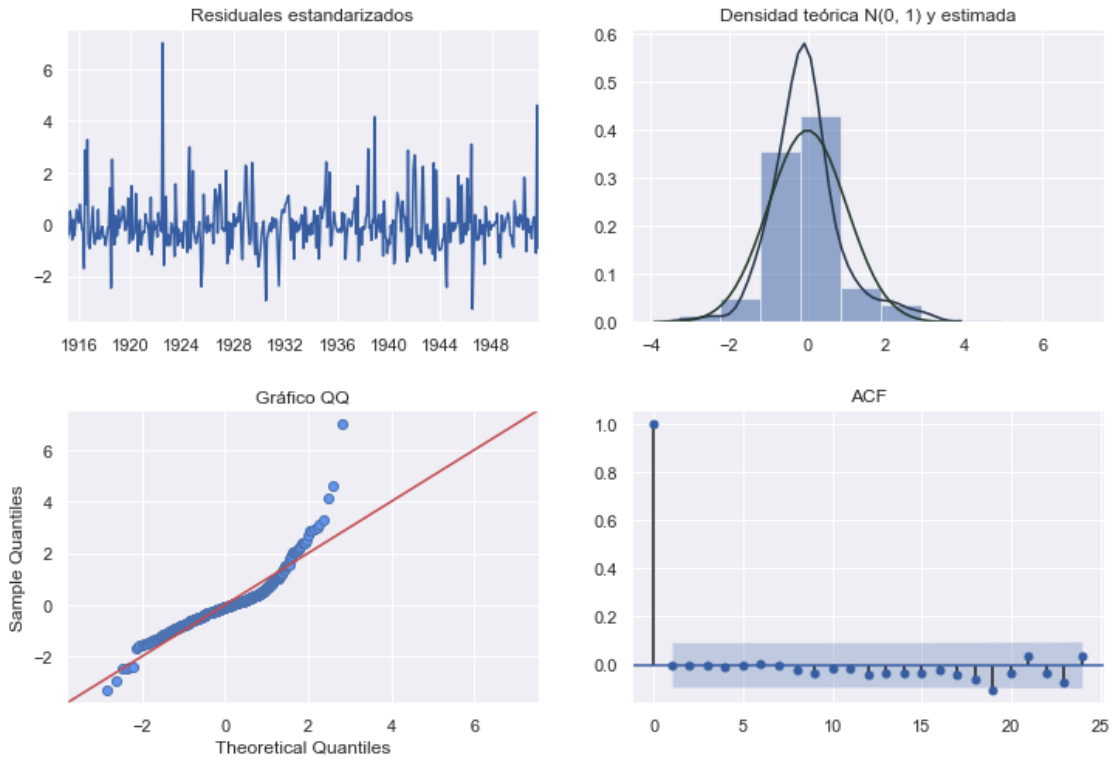
```
In [257]: en_hyp = {"l1_ratio": 0.1,
                    "alpha": 0}
```

```
In [258]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                          random_state=seed)
          en_model = en.fit(X_train, y_train)
          en_fitted = pd.Series(en_model.predict(X_train))
          en_fitted
          en_fitted.index = X_train.index
          en_resid = y_train - en_fitted
          en_resid = (en_resid - en_resid.mean()) / en_resid.std()

          en_jb_test = jb(en_resid)
          en_lb_test = lb(en_resid)

          en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [259]: en_undiff_forecast = []
          last_obser = deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + en_forecast[i]
              en_undiff_forecast.append(yhat)
              last_obser = yhat

          en_undiff_forecast = pd.Series(en_undiff_forecast)
          en_undiff_forecast.index = test.index
```

```
In [260]: en_seas_forecast = en_undiff_forecast + seasonality_forecast
```

```
In [261]: resid_diag(en_resid)
          plt.show()
```

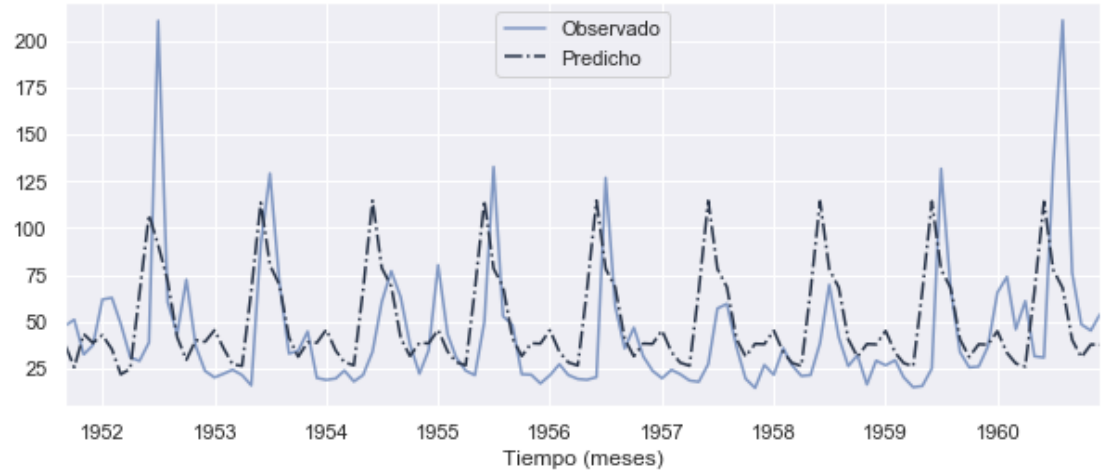



```
In [262]: print("ElasticNet")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(en_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(en_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, en_seas_forecast))))
          print("MAE (test):  " + str(mae(test, en_seas_forecast)))
          print("sMAPE (test):  " + str(smape(test, en_seas_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 2.0755161120405965e-264
Test de Ljung-Box para k =  6 (p-valor): 0.9999999468181409
Test de Ljung-Box para k = 12 (p-valor): 0.9994838286140066
```

```
RMSE (test): 35.74647450822158
MAE (test):  24.364237928781076
sMAPE (test):  47.541746791674875
```

```
In [263]: forecast_plot(test, en_seas_forecast)
          plt.show()
```



Serie temporal con Box-Cox, desestacionalizada y diferenciada como estructura de DataFrame

```
In [264]: lag_df = series_to_supervised(bc_diff_deseas, n_in=12)
          lag_df.head(5)
```

Out[264]:

index	var1(t-12)	var1(t-11)	var1(t-10)	var1(t-9)	var1(t-8)
1915-02-01	-0.072518	0.026679	-0.076088	-0.037124	-0.075538
1915-03-01	0.026679	-0.076088	-0.037124	-0.075538	0.024702
1915-04-01	-0.076088	-0.037124	-0.075538	0.024702	0.113124
1915-05-01	-0.037124	-0.075538	0.024702	0.113124	0.096046
1915-06-01	-0.075538	0.024702	0.113124	0.096046	-0.009864

index	var1(t-7)	var1(t-6)	var1(t-5)	var1(t-4)	var1(t-3)	var1(t-2)
1915-02-01	0.024702	0.113124	0.096046	-0.009864	-0.041726	0.047586
1915-03-01	0.113124	0.096046	-0.009864	-0.041726	0.047586	-0.059635
1915-04-01	0.096046	-0.009864	-0.041726	0.047586	-0.059635	-0.076563
1915-05-01	-0.009864	-0.041726	0.047586	-0.059635	-0.076563	0.022506
1915-06-01	-0.041726	0.047586	-0.059635	-0.076563	0.022506	-0.051959

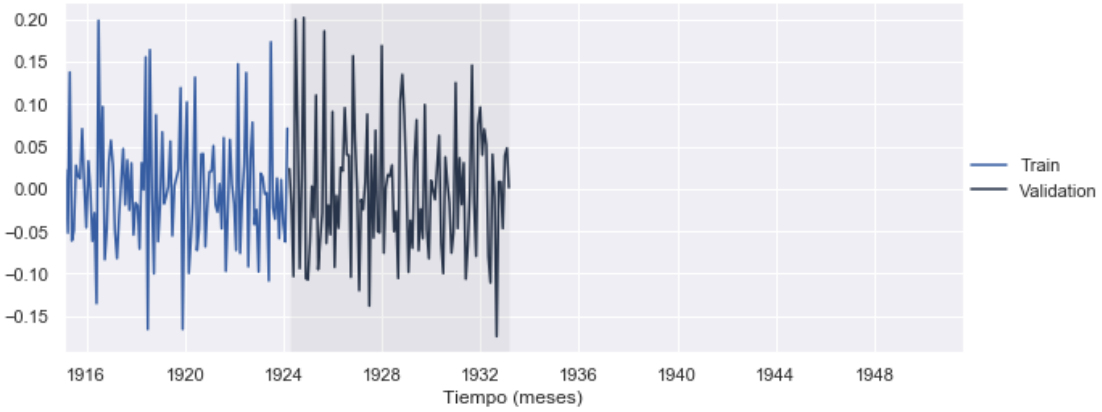
```
             var1(t-1)   var1(t)
index
1915-02-01  -0.059635 -0.076563
1915-03-01  -0.076563  0.022506
1915-04-01   0.022506 -0.051959
1915-05-01  -0.051959  0.137671
1915-06-01   0.137671 -0.061183
```

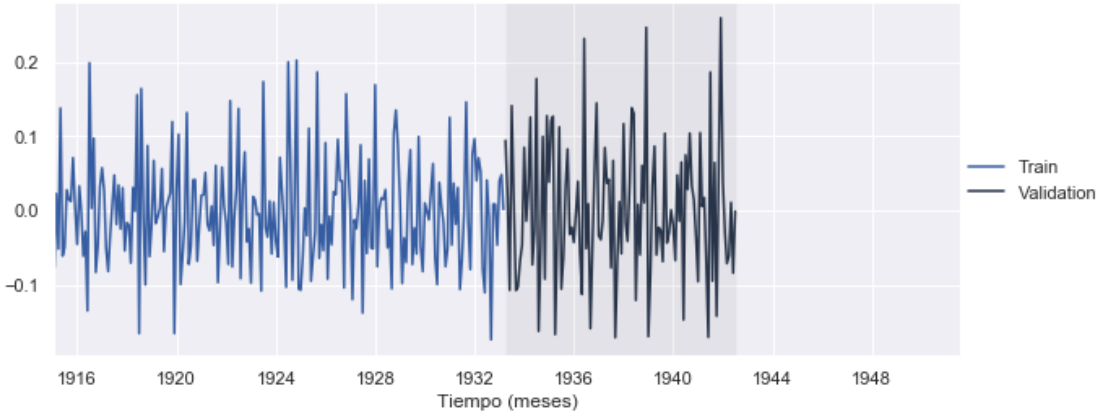
Definición de X (predictoras) e y (a predecir)

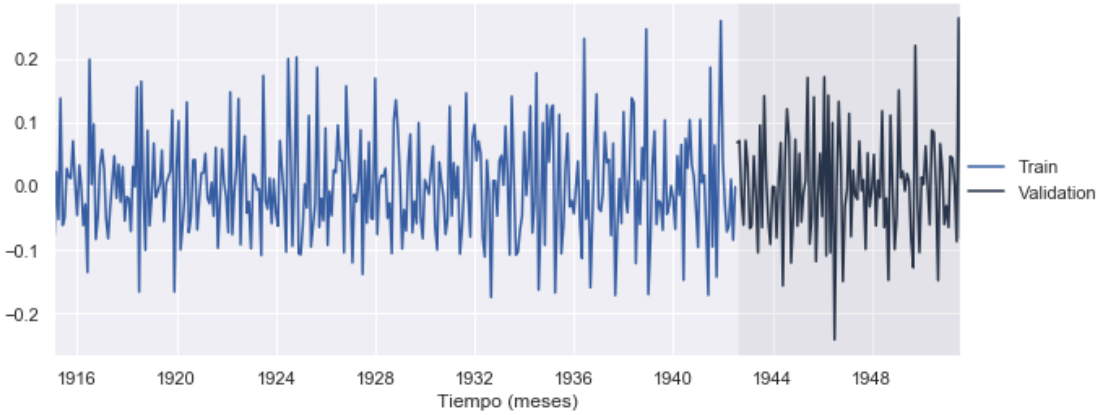
```
In [265]: X_train = lag_df.iloc[:,:-1]
          y_train = lag_df.iloc[:,-1]
```

Validación cruzada temporal

```
In [266]: train3, validation3 = ts_split(lag_df, train_size=0.75)
          X_train3 = train3.iloc[:,:-1]
          y_train3 = train3.iloc[:,-1]
          X_val3 = validation3.iloc[:,:-1]
          y_val3 = validation3.iloc[:,-1]

          train2, validation2 = ts_split(train3, train_size=0.66)
          X_train2 = train2.iloc[:,:-1]
          y_train2 = train2.iloc[:,-1]
          X_val2 = validation2.iloc[:,:-1]
          y_val2 = validation2.iloc[:,-1]

          train1, validation1 = ts_split(train2, train_size=0.5)
          X_train1 = train1.iloc[:,:-1]
          y_train1 = train1.iloc[:,-1]
          X_val1 = validation1.iloc[:,:-1]
          y_val1 = validation1.iloc[:,-1]

In [267]: tscv_plot(train1["var1(t)"], validation1["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train2["var1(t)"], validation2["var1(t)"], train.index[-1])
          plt.show()
          tscv_plot(train3["var1(t)"], validation3["var1(t)"], train.index[-1])
          plt.show()
```


0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


0.2
0.1
0.0
−0.1
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation


0.2
0.1
0.0
−0.1
−0.2
1916
1920
1924
1928
1932
1936
1940
1944
1948
Tiempo (meses)
Train
Validation

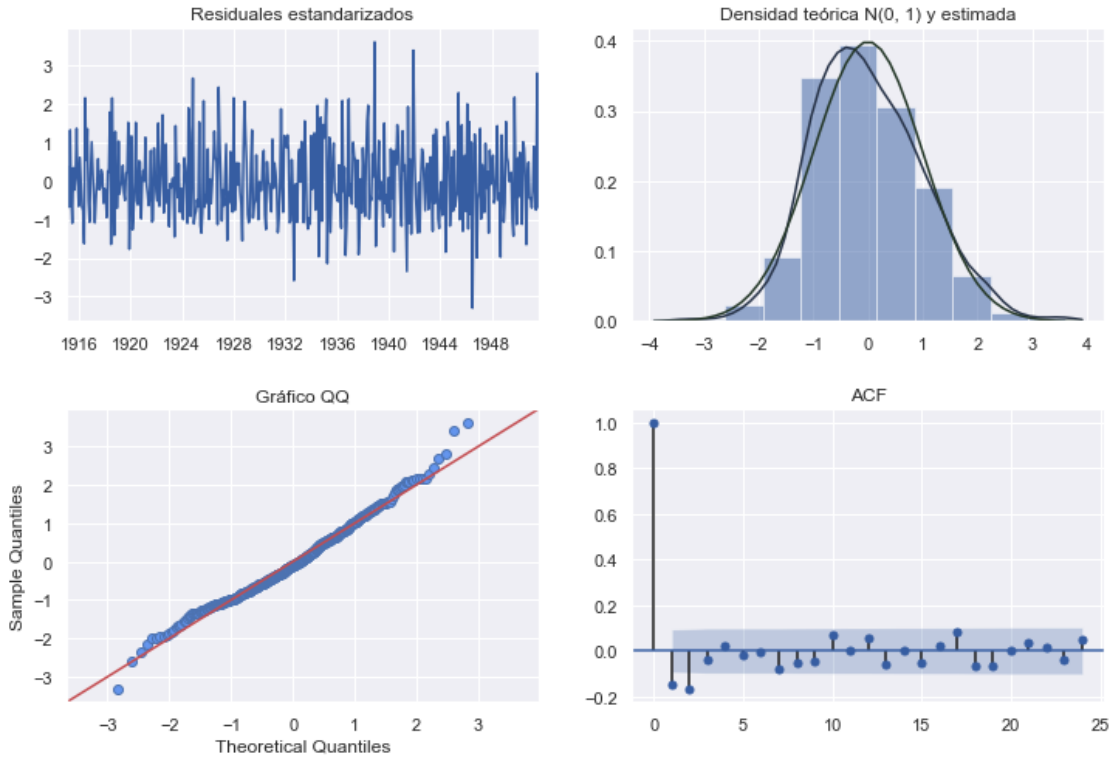
K-Nearest Neighbors

```
In [268]: neigb = list(np.arange(2, 41, 1))

In [269]: best_score, best_knn = float("inf"), None

          for k in neigb:
                  knn = KNeighborsRegressor(n_neighbors=k)

                  knn_model1 = knn.fit(X_train1, y_train1)
                  knn_forecast = iter_forecast(knn_model1, y_train1, 12, validation1)
                  rmse1 = sqrt(mse(validation1.iloc[:,-1], knn_forecast))

                  knn_model2 = knn.fit(X_val1, y_val1)
                  knn_forecast = iter_forecast(knn_model2, y_val1, 12, validation2)
                  rmse2 = sqrt(mse(validation2.iloc[:,-1], knn_forecast))

                  knn_model3 = knn.fit(X_val2, y_val2)
                  knn_forecast = iter_forecast(knn_model3, y_val2, 12, validation3)
                  rmse3 = sqrt(mse(validation3.iloc[:,-1], knn_forecast))

                  cvrmse = mean([rmse1, rmse2, rmse3])
                  if cvrmse < best_score:
                      best_score, best_knn = cvrmse, knn.get_params()

          print('Best KNN %s CVRMSE = %.3f' % (best_knn['n_neighbors'], best_score))

Best KNN 27 CVRMSE = 0.084


In [270]: knn_hyp = {"k": 27}

In [271]: knn = KNeighborsRegressor(n_neighbors=knn_hyp["k"])
          knn_model = knn.fit(X_train, y_train)
          knn_fitted = pd.Series(knn_model.predict(X_train))
          knn_fitted
          knn_fitted.index = X_train.index
          knn_resid = y_train - knn_fitted
          knn_resid = (knn_resid - knn_resid.mean()) / knn_resid.std()

          knn_jb_test = jb(knn_resid)
          knn_lb_test = lb(knn_resid)

          knn_forecast = iter_forecast(knn, y_train, 12, test)

In [272]: knn_undiff_forecast = []
          last_obser = bc_deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + knn_forecast[i]
```

```
        knn_undiff_forecast.append(yhat)
        last_obser = yhat

    knn_undiff_forecast = pd.Series(knn_undiff_forecast)
    knn_undiff_forecast.index = test.index
```

In [273]:
```
knn_seas_forecast = knn_undiff_forecast + bc_seasonality_forecast
knn_box_forecast = (bc_param * knn_seas_forecast + 1) ** (1 / bc_param)
```

In [274]:
```
resid_diag(knn_resid)
plt.show()
```

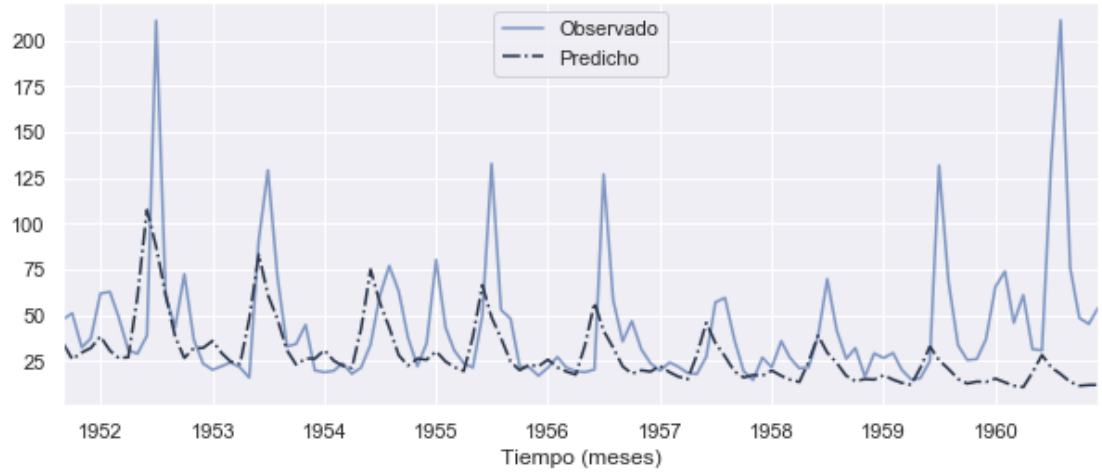


In [275]:
```
print("K-Nearest Neighbors")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(knn_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(knn_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(knn_lb_test[1][12]))
print("")
```

```
        print("RMSE (test): " + str(sqrt(mse(test, knn_box_forecast))))
        print("MAE (test):  " + str(mae(test, knn_box_forecast)))
        print("sMAPE (test):  " + str(smape(test, knn_box_forecast)))
```

```
K-Nearest Neighbors

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.003383083593474169
Test de Ljung-Box para k =  6 (p-valor): 0.0005375519245986289
Test de Ljung-Box para k = 12 (p-valor): 0.0015617704092770694

RMSE (test): 36.49420211710823
MAE (test):  22.4493403519271
sMAPE (test):  52.483487500997285
```

```
In [276]: forecast_plot(test, knn_box_forecast)
          plt.show()
```



Regresion tree

```
In [277]: depths = list(np.arange(1, 21, 1))
```

```
In [278]: best_score, best_tree = float("inf"), None

          for depth in depths:
                  tree = DecisionTreeRegressor(max_depth=depth, random_state=seed)

                  tree_model1 = tree.fit(X_train1, y_train1)
```

```
                tree_forecast = iter_forecast(tree_model1, y_train1, 12, validation1)
                rmse1 = sqrt(mse(validation1.iloc[:,-1], tree_forecast))

                tree_model2 = tree.fit(X_val1, y_val1)
                tree_forecast = iter_forecast(tree_model2, y_val1, 12, validation2)
                rmse2 = sqrt(mse(validation2.iloc[:,-1], tree_forecast))

                tree_model3 = tree.fit(X_val2, y_val2)
                tree_forecast = iter_forecast(tree_model3, y_val2, 12, validation3)
                rmse3 = sqrt(mse(validation3.iloc[:,-1], tree_forecast))

                cvrmse = mean([rmse1, rmse2, rmse3])
                if cvrmse < best_score:
                    best_score, best_tree = cvrmse, tree.get_params()

        print('Best Tree %s CV RMSE = %.3f' % (best_tree['max_depth'], best_score))
```

```
Best Tree 1 CV RMSE = 0.088
```

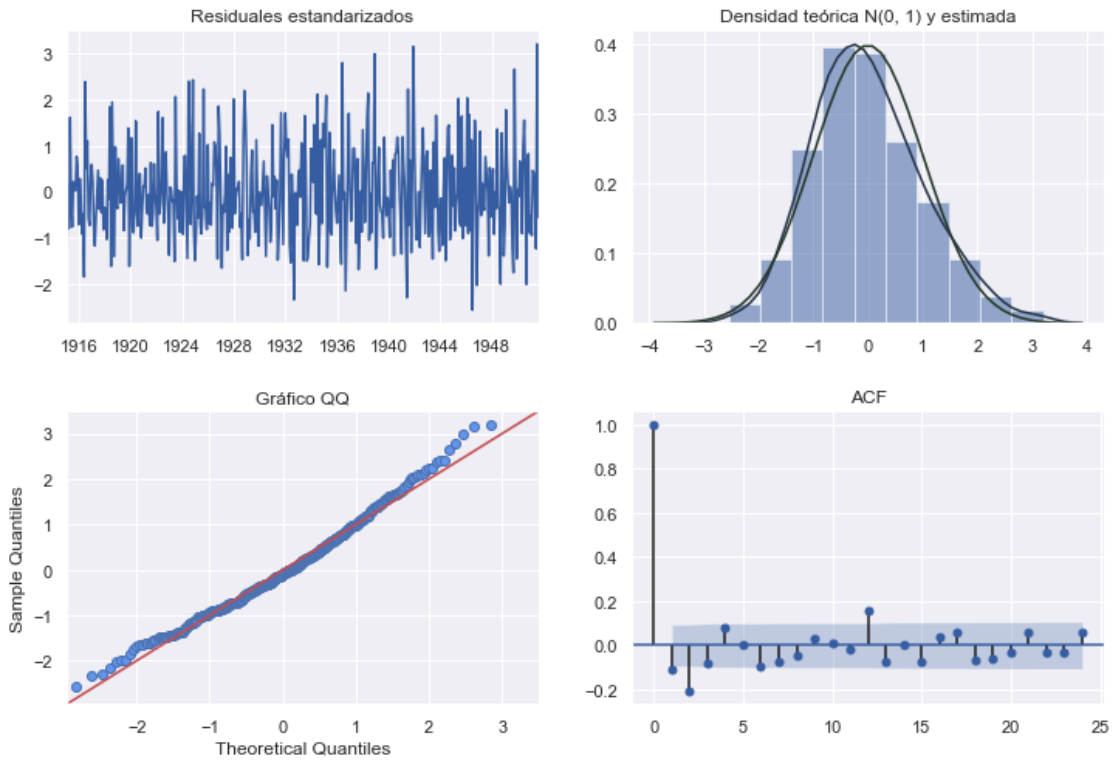
```
In [279]: tree_hyp = {"depth": 1}
```

```
In [280]: tree = DecisionTreeRegressor(max_depth=tree_hyp["depth"],
                                       random_state=seed)
          tree_model = tree.fit(X_train, y_train)
          tree_fitted = pd.Series(tree_model.predict(X_train))
          tree_fitted
          tree_fitted.index = X_train.index
          tree_resid = y_train - tree_fitted
          tree_resid = (tree_resid - tree_resid.mean()) / tree_resid.std()

          tree_jb_test = jb(tree_resid)
          tree_lb_test = lb(tree_resid)

          tree_forecast = iter_forecast(tree, y_train, 12, test)
```

```
In [281]: tree_undiff_forecast = []
          last_obser = bc_deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + tree_forecast[i]
              tree_undiff_forecast.append(yhat)
              last_obser = yhat

          tree_undiff_forecast = pd.Series(tree_undiff_forecast)
          tree_undiff_forecast.index = test.index
```

```
In [282]: tree_seas_forecast = knn_undiff_forecast + bc_seasonality_forecast
          tree_box_forecast = (bc_param * tree_seas_forecast + 1) ** (1 / bc_param)
```

```
In [283]: resid_diag(tree_resid)
          plt.show()
```

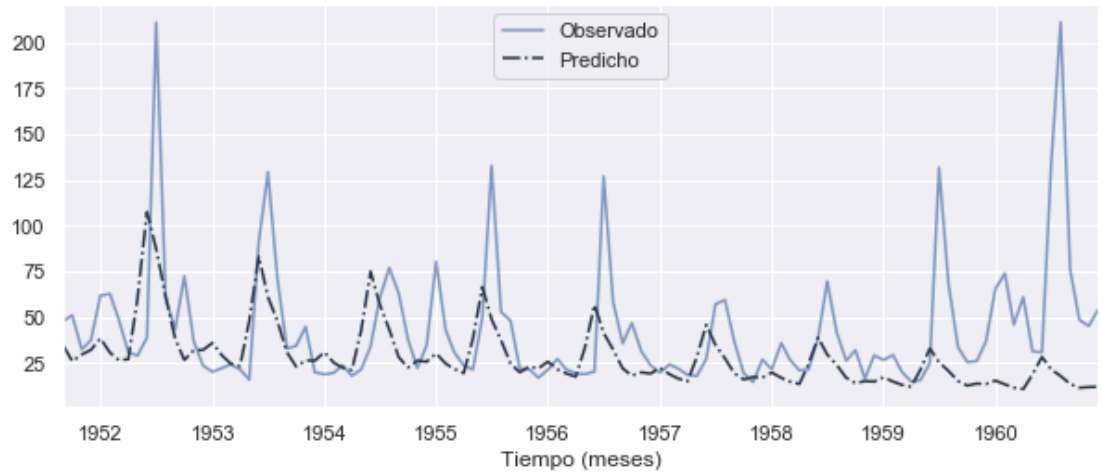



```
In [284]: print("Decision Tree")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(tree_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(tree_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(tree_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, tree_box_forecast))))
          print("MAE (test):  " + str(mae(test, tree_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, tree_box_forecast)))
```

```
Decision Tree

Observaciones ajustadas: 452
Observaciones predichas: 112
```

```
Test de Jarque-Bera (p-valor): 0.0010506447401931551
Test de Ljung-Box para k =  6 (p-valor): 7.73151312209853e-06
Test de Ljung-Box para k = 12 (p-valor): 1.3985418477241946e-06

RMSE (test): 36.49420211710823
MAE (test):  22.4493403519271
sMAPE (test):  52.483487500997285
```

```
In [285]: forecast_plot(test, tree_box_forecast)
          plt.show()
```



Random Forest

```
In [286]: best_score, best_tree = float("inf"), None

          n_estimators = [50, 100, 200, 500]
          depths = np.linspace(1, 61, 20)
          max_features = [0.8, 1]


          for n in n_estimators:
              for depth in depths:
                  for features in max_features:
                      rf = RandomForestRegressor(n_estimators=n,
                                                 max_depth=depth,
                                                 max_features=features,
                                                 random_state=seed)

                      rf_model1 = rf.fit(X_train1, y_train1)
```

```
                        rf_forecast = iter_forecast(rf_model1, y_train1, 12, validation1)
                        rmse1 = sqrt(mse(validation1.iloc[:,-1], rf_forecast))

                        rf_model2 = rf.fit(X_val1, y_val1)
                        rf_forecast = iter_forecast(rf_model2, y_val1, 12, validation2)
                        rmse2 = sqrt(mse(validation2.iloc[:,-1], rf_forecast))

                        rf_model3 = rf.fit(X_val2, y_val2)
                        rf_forecast = iter_forecast(rf_model3, y_val2, 12, validation3)
                        rmse3 = sqrt(mse(validation3.iloc[:,-1], rf_forecast))

                        cvrmse = mean([rmse1, rmse2, rmse3])
                        if cvrmse < best_score:
                            best_score, best_rf = cvrmse, rf.get_params()

            print('Best RF: n_estimators: %s max_depth: %s max_features :%s | CV RMSE = %.3f' %
                  (best_rf['n_estimators'], best_rf['max_depth'], best_rf['max_features'], best_sc
```

```
Best RF: n_estimators: 200 max_depth: 10.473684210526315 max_features :1 | CV RMSE = 0.085
```

```
In [287]: rf_hyp = {"max_depth": 10.47,
                    "n_estimators": 200,
                    "max_features": 1}
```

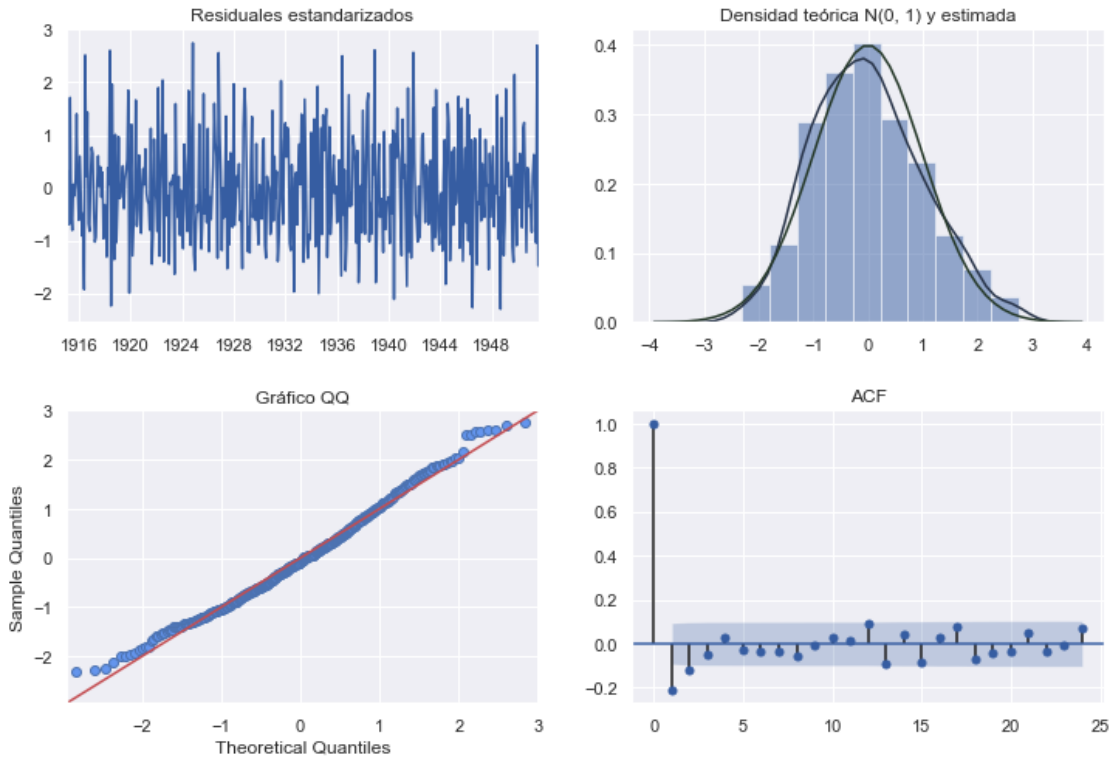
```
In [288]: rf = RandomForestRegressor(max_depth=rf_hyp["max_depth"],
                                     n_estimators=rf_hyp["n_estimators"],
                                     max_features=rf_hyp["max_features"],
                                     random_state=seed)

          rf_model = rf.fit(X_train, y_train)
          rf_fitted = pd.Series(rf_model.predict(X_train))
          rf_fitted
          rf_fitted.index = X_train.index
          rf_resid = y_train - rf_fitted
          rf_resid = (rf_resid - rf_resid.mean()) / rf_resid.std()

          rf_jb_test = jb(rf_resid)
          rf_lb_test = lb(rf_resid)

          rf_forecast = iter_forecast(rf, y_train, 12, test)
```

```
In [289]: rf_undiff_forecast = []
          last_obser = bc_deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + rf_forecast[i]
              rf_undiff_forecast.append(yhat)
              last_obser = yhat
```

```
rf_undiff_forecast = pd.Series(rf_undiff_forecast)
rf_undiff_forecast.index = test.index
```

In [290]:
```
rf_seas_forecast = rf_undiff_forecast + bc_seasonality_forecast
rf_box_forecast = (bc_param * rf_seas_forecast + 1) ** (1 / bc_param)
```

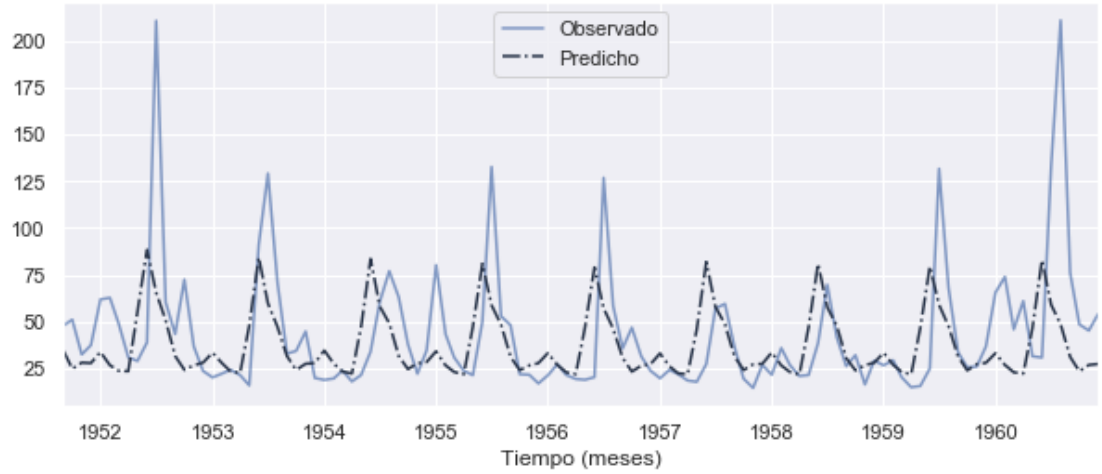
In [291]:
```
resid_diag(rf_resid)
plt.show()
```



In [292]:
```
print("Random Forest")
print("")
print("Observaciones ajustadas: " + str(len(train)))
print("Observaciones predichas: " + str(len(test)))
print("")
print("Test de Jarque-Bera (p-valor): " + str(rf_jb_test[1]))
print("Test de Ljung-Box para k =  6 (p-valor): " +
      str(rf_lb_test[1][6]))
print("Test de Ljung-Box para k = 12 (p-valor): " +
      str(rf_lb_test[1][12]))
print("")
print("RMSE (test): " + str(sqrt(mse(test, rf_box_forecast))))
print("MAE (test):  " + str(mae(test, rf_box_forecast)))
print("sMAPE (test):  " + str(smape(test, rf_box_forecast)))
```

```
Random Forest

Observaciones ajustadas: 452
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.011941226814951477
Test de Ljung-Box para k =  6 (p-valor): 0.00015047040565678517
Test de Ljung-Box para k = 12 (p-valor): 0.0002746332719588352

RMSE (test): 33.32998445529877
MAE (test):  20.927560058562502
sMAPE (test):  43.07766738416892
```

```
In [293]: forecast_plot(test, rf_box_forecast)
          plt.show()
```



ElasticNet

```
In [294]: best_score, best_tree = float("inf"), None

          ratio = [0.1, 0.5, 0.7, 0.9, 0.95, 0.99, 1]
          alpha = [0, 0.01, 0.1, 0.5, 1, 5, 10, 50, 100]


          for rat in ratio:
              for alp in alpha:
                  en = ElasticNet(l1_ratio=rat, alpha=alp, random_state=seed)

                  en_model1 = en.fit(X_train1, y_train1)
```

```
                    en_forecast = iter_forecast(en_model1, y_train1, 12, validation1)
                    rmse1 = sqrt(mse(validation1.iloc[:,-1], en_forecast))

                    en_model2 = en.fit(X_val1, y_val1)
                    en_forecast = iter_forecast(en_model2, y_val1, 12, validation2)
                    rmse2 = sqrt(mse(validation2.iloc[:,-1], en_forecast))

                    en_model3 = en.fit(X_val2, y_val2)
                    en_forecast = iter_forecast(en_model3, y_val2, 12, validation3)
                    rmse3 = sqrt(mse(validation3.iloc[:,-1], en_forecast))

                    cvrmse = mean([rmse1, rmse2, rmse3])
                    if cvrmse < best_score:
                        best_score, best_en = cvrmse, en.get_params()

            print('Best EN: ratio: %s alpha: %s | CV RMSE = %.3f' %
                  (best_en['l1_ratio'], best_en['alpha'], best_score))
```

```
Best EN: ratio: 0.1 alpha: 0.1 | CV RMSE = 0.085
```

```
In [295]: en_hyp = {"l1_ratio": 0.1,
                    "alpha": 0.1}
```

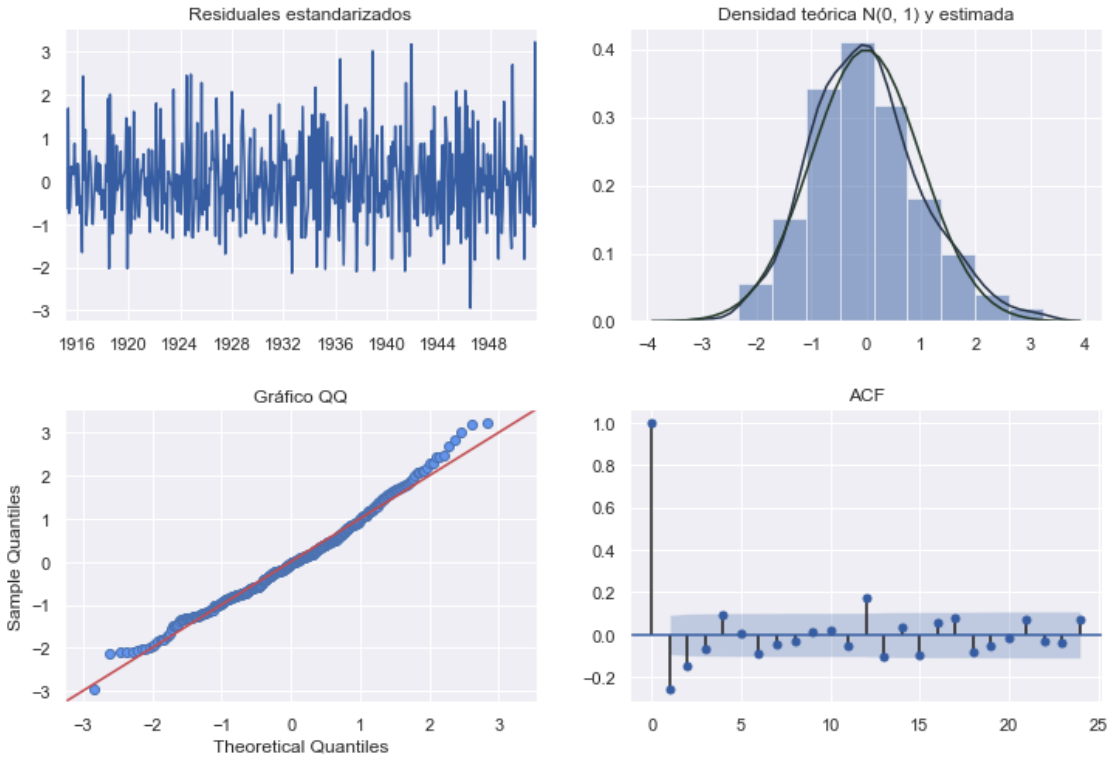
```
In [296]: en = ElasticNet(l1_ratio=en_hyp["l1_ratio"], alpha=en_hyp["alpha"],
                          random_state=seed)
          en_model = en.fit(X_train, y_train)
          en_fitted = pd.Series(en_model.predict(X_train))
          en_fitted
          en_fitted.index = X_train.index
          en_resid = y_train - en_fitted
          en_resid = (en_resid - en_resid.mean()) / en_resid.std()

          en_jb_test = jb(en_resid)
          en_lb_test = lb(en_resid)

          en_forecast = iter_forecast(en, y_train, 12, test)
```

```
In [297]: en_undiff_forecast = []
          last_obser = bc_deseas.iloc[-1].value
          for i in range(len(test)):
              yhat = last_obser + en_forecast[i]
              en_undiff_forecast.append(yhat)
              last_obser = yhat

          en_undiff_forecast = pd.Series(en_undiff_forecast)
          en_undiff_forecast.index = test.index
```

```
In [298]: en_seas_forecast = en_undiff_forecast + bc_seasonality_forecast
          en_box_forecast = (bc_param * en_seas_forecast + 1) ** (1 / bc_param)
```

```
In [299]: en_box_forecast = (bc_param * en_seas_forecast + 1) ** (1 / bc_param)
```

```
In [300]: resid_diag(en_resid)
          plt.show()
```




```
In [301]: print("ElasticNet")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("Test de Jarque-Bera (p-valor): " + str(en_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(en_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(en_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, en_box_forecast))))
          print("MAE (test):  " + str(mae(test, en_box_forecast)))
          print("sMAPE (test):  " + str(smape(test, en_box_forecast)))
```

```
ElasticNet

Observaciones ajustadas: 452
```

```
Observaciones predichas: 112

Test de Jarque-Bera (p-valor): 0.001788964092508347
Test de Ljung-Box para k =  6 (p-valor): 2.3939918413298452e-08
Test de Ljung-Box para k = 12 (p-valor): 1.0498455598897642e-09

RMSE (test): 35.28368401389798
MAE (test):  23.133149094283
sMAPE (test):  45.15517516895144
```

```
In [302]: forecast_plot(test, en_box_forecast)
          plt.show()
```