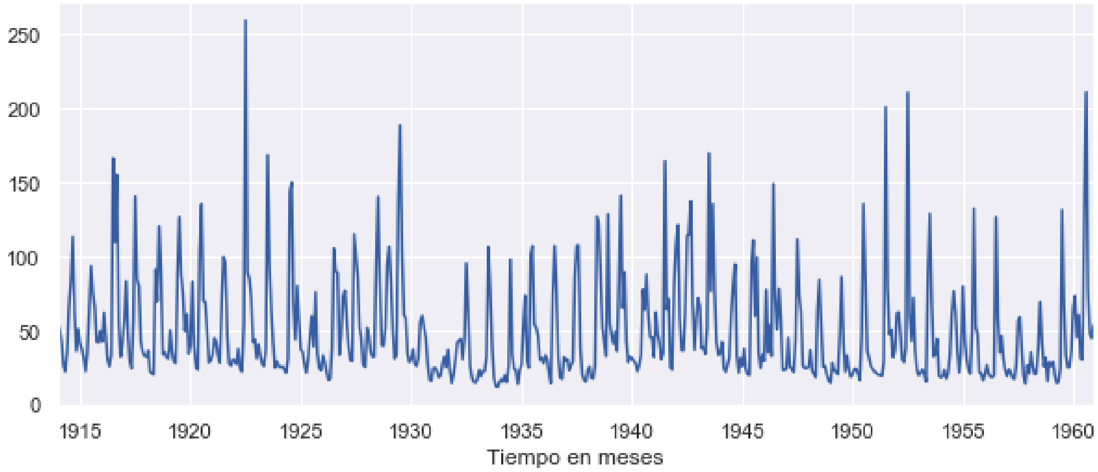
Anexo II. Código y resultados para métodos ingenuos, suavizado exponencial y metodología Box-Jenkins

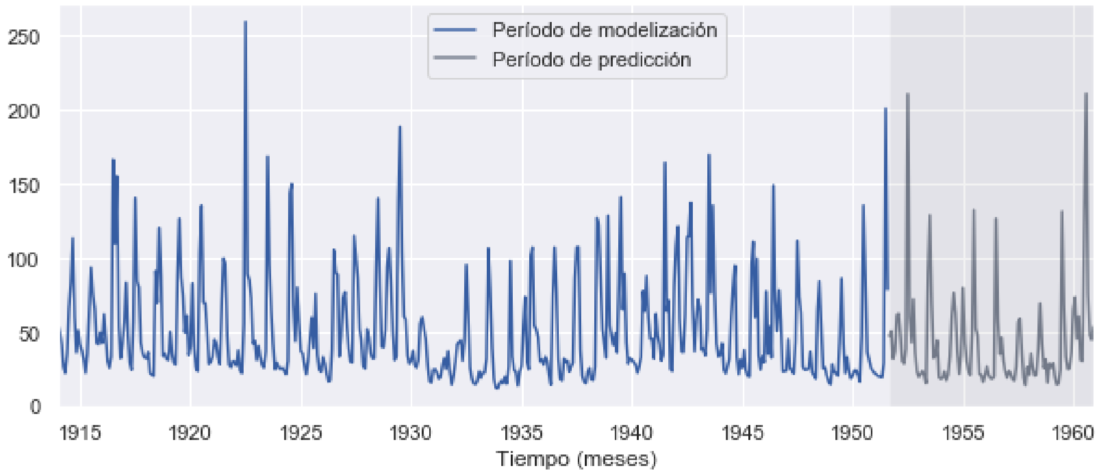
```
In [1]: import pandas as pd
        import numpy as np
        import matplotlib.pyplot as plt
        import seaborn as sns
        %matplotlib inline


        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 statsmodels.tsa.holtwinters import SimpleExpSmoothing
        from statsmodels.tsa.holtwinters import Holt
        from statsmodels.tsa.holtwinters import ExponentialSmoothing

        from statsmodels.tsa.arima_model import ARIMA
        from statsmodels.tsa.statespace.sarimax import SARIMAX

        from pmdarima.arima import ndiffs
        from pmdarima.arima import nsdiffs
        from pmdarima.arima import auto_arima
        from pmdarima.arima import AutoARIMA

        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]
```

0.0.1 Métodos ingenuos

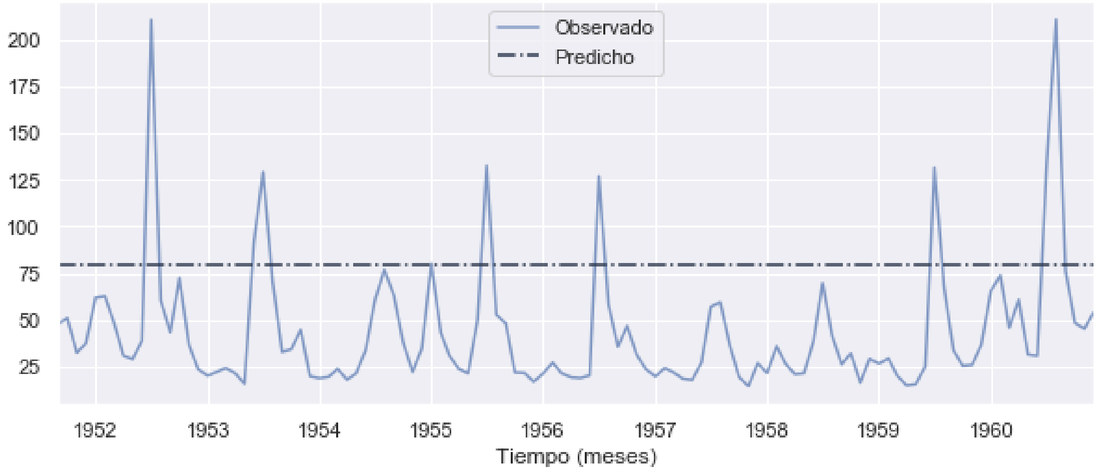
Método ingenuo simple

```
In [10]: naive_forecast = naive(train, test)
```

```
In [11]: print("Método ingenuo simple")
         print("")
         print("RMSE (test):   " + str(round(sqrt(mse(test, naive_forecast)), 2)))
         print("MAE (test):    " + str(round(mae(test, naive_forecast), 2)))
         print("sMAPE (test):  " + str(round(smape(test, naive_forecast), 2)))
```

```
Método ingenuo simple

RMSE (test):   49.56
MAE (test):    45.11
sMAPE (test):  79.4
```

```
In [12]: forecast_plot(test, naive_forecast)
         plt.savefig("river_naive.png", dpi = 400)
         plt.show()
```



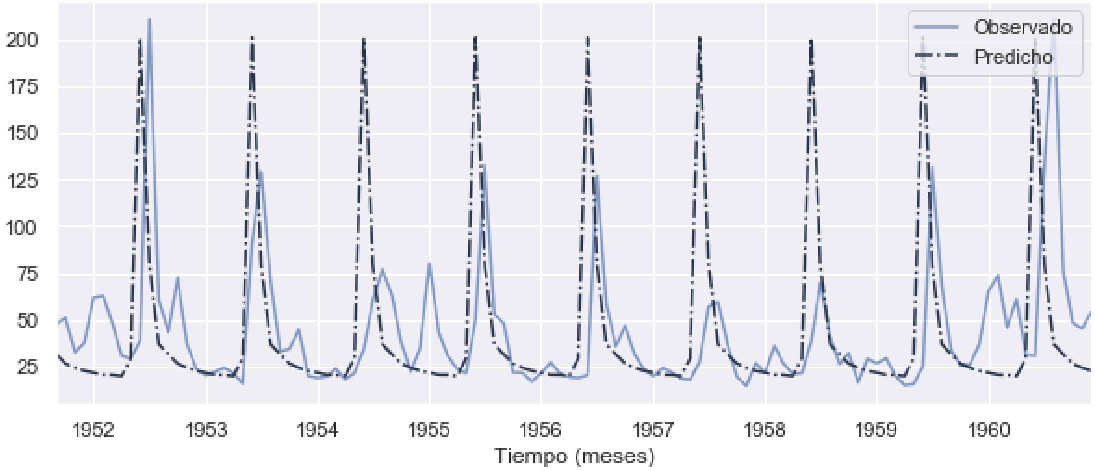
Método ingenuo estacional

```
In [13]: snaive_forecast = snaive(train, test)
```

```
In [14]: print("Método ingenuo estacional")
         print("")
         print("RMSE (test):   " + str(round(sqrt(mse(test, snaive_forecast)), 2)))
         print("MAE (test):    " + str(round(mae(test, snaive_forecast), 2)))
         print("sMAPE (test):  " + str(round(smape(test, snaive_forecast), 2)))
```

```
Método ingenuo estacional

RMSE (test):   54.57
MAE (test):    29.2
sMAPE (test):  45.92
```

```
In [15]: forecast_plot(test, snaive_forecast, leg_position=1)
         plt.savefig("river_snaive.png", dpi = 400)
         plt.show()
```



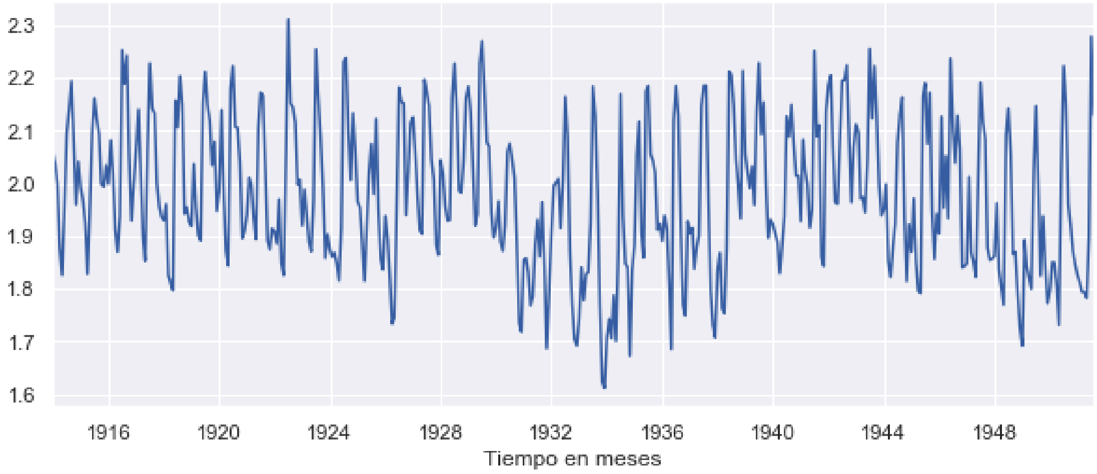
0.0.2 No estacionariedad en varianza: Transformación de Box-Cox

```
In [16]: boxcox_trans = boxcox(train)
         bc_param = boxcox_trans[1][0]
         bc_train = ((train**bc_param)-1)/bc_param
```

```
In [17]: print("Transformación de Box-Cox")
         print("")
         print("Parámetro lambda de transformación: " + str(round(bc_param, 4)))
```

```
Transformación de Box-Cox

Parámetro lambda de transformación: -0.3807
```

```
In [18]: tsplot(bc_train)
         plt.savefig("river_box.png", dpi = 400)
         plt.show()
```

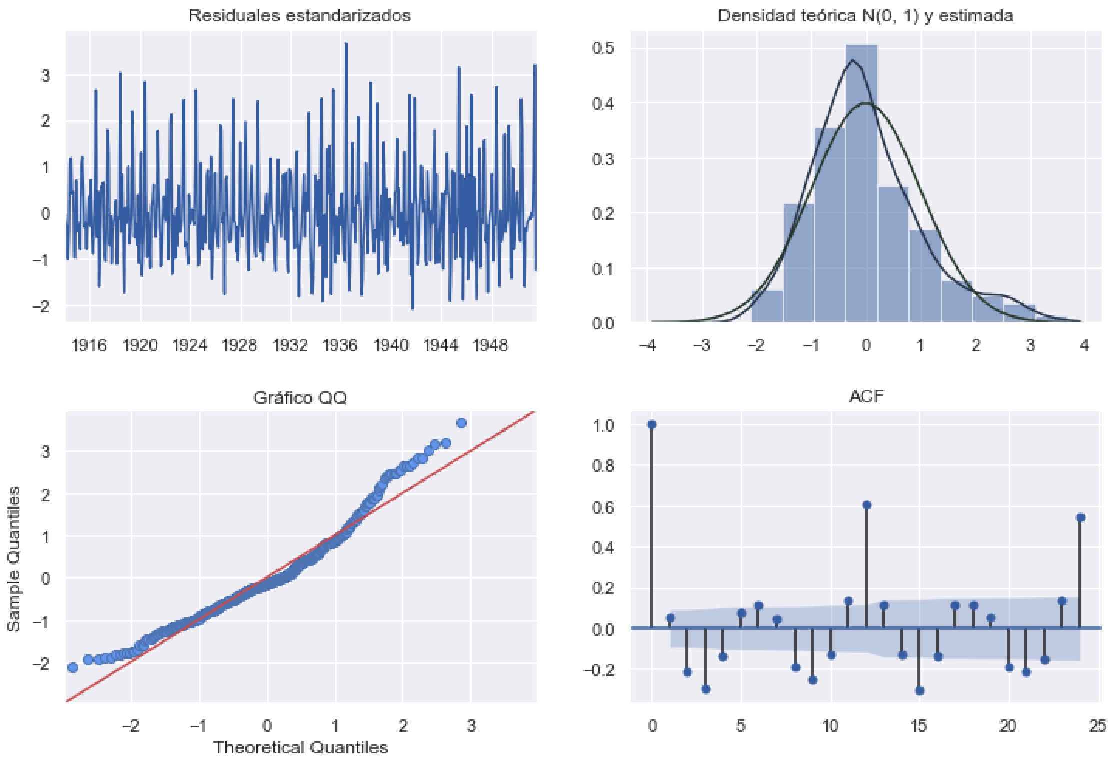


0.0.3 Métodos de Suavizado Exponencial

Suavizado Exponencial Simple

```
In [19]: ses = ExponentialSmoothing(bc_train)
         ses_model = ses.fit()

         ses_alpha = ses_model.params["smoothing_level"]
         ses_aic = ses_model.aic

         ses_fitted = ses_model.fittedvalues
         ses_resid = (ses_model.resid -
                      ses_model.resid.mean()) / ses_model.resid.std()
         ses_jb_test = jb(ses_resid)
         ses_lb_test = lb(ses_resid)

         ses_forecast = ses_model.predict(split_date, end_date)
         ses_box_forecast = (bc_param * ses_forecast + 1) ** (1 / bc_param)
```

```
In [20]: resid_diag(ses_resid)
         plt.show()
```

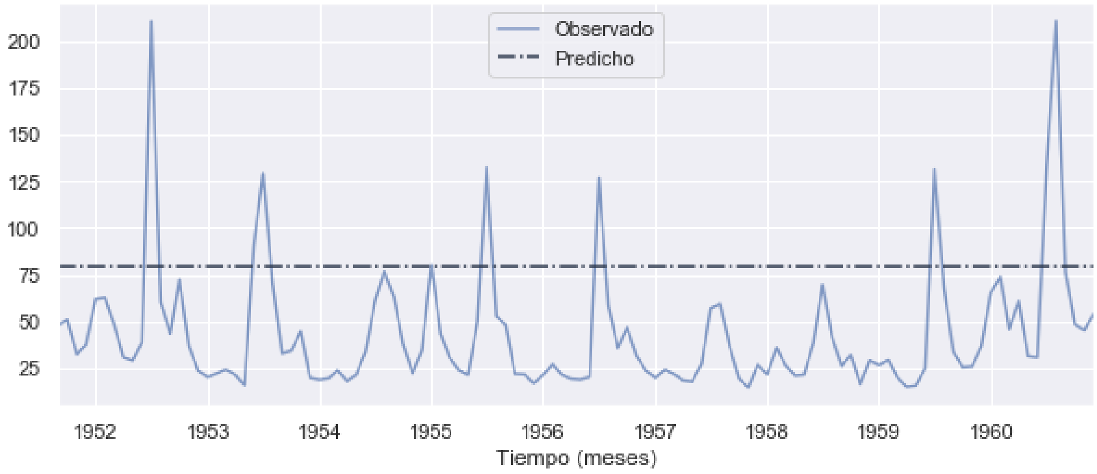


```
In [21]: print("Suavizado Exponencial Simple")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Parámetro alfa de suavizado: " + str(ses_alpha))
         print("")
         print("AIC: " + str(ses_aic))
         print("Test de Jarque-Bera (p-valor): "
               + str(round(ses_jb_test[1], 6)))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(round(ses_lb_test[1][6], 6)))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(round(ses_lb_test[1][12], 6)))
         print("")
         print("RMSE (test):   " + str(round(sqrt(mse(test, ses_box_forecast)), 2)))
         print("MAE (test):    " + str(round(mae(test, ses_box_forecast), 2)))
         print("sMAPE (test):  " + str(round(smape(test, ses_box_forecast), 2)))
```

```
Suavizado Exponencial Simple

Observaciones ajustadas: 452
Observaciones predichas: 112
```

```
Parámetro alfa de suavizado: 1.0

AIC: -1924.5128147975815
Test de Jarque-Bera (p-valor): 0.0
Test de Ljung-Box para k =  6 (p-valor): 0.0
Test de Ljung-Box para k = 12 (p-valor): 0.0

RMSE (test):   49.56
MAE (test):    45.11
sMAPE (test):  79.4
```

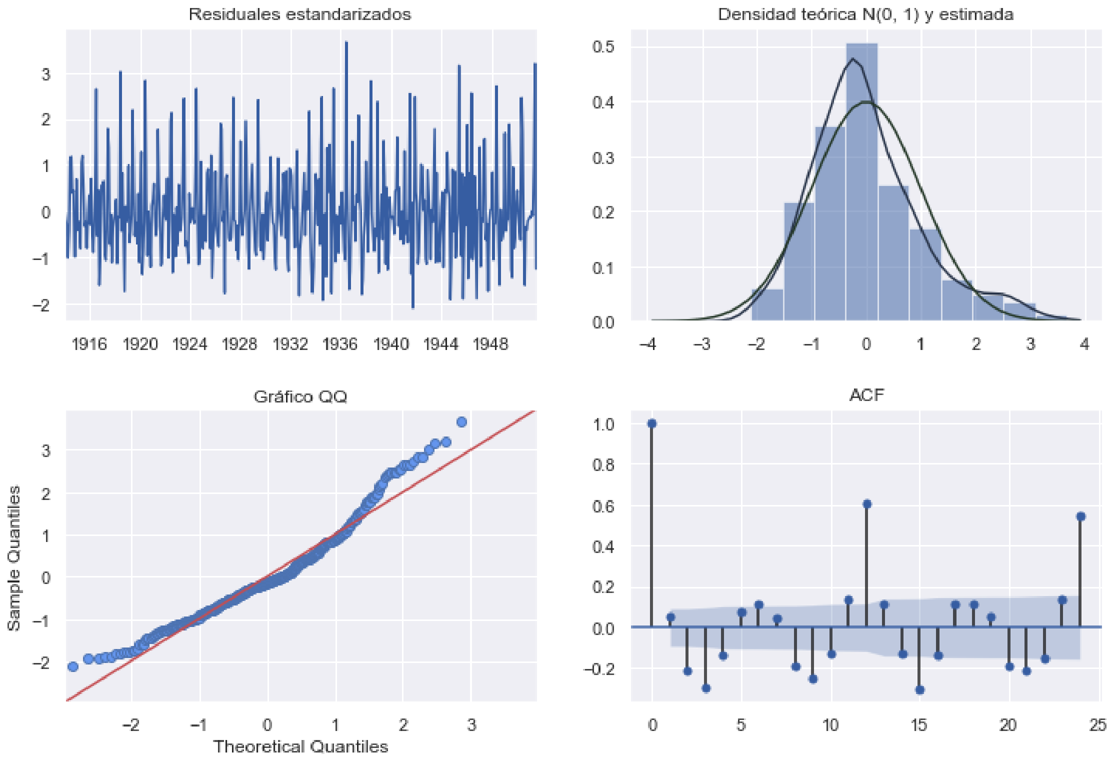
```
In [22]: forecast_plot(test, ses_box_forecast)
         plt.show()
```



Suavizado Exponencial Doble

```
In [23]: hl = ExponentialSmoothing(bc_train, trend = "add")
         hl_model = hl.fit()

         hl_alpha = hl_model.params["smoothing_level"]
         hl_beta = hl_model.params["smoothing_slope"]
         hl_aic = hl_model.aic

         hl_fitted = hl_model.fittedvalues
         hl_resid = (hl_model.resid - hl_model.resid.mean()) / hl_model.resid.std()
         hl_jb_test = jb(hl_resid)
         hl_lb_test = lb(hl_resid)
```

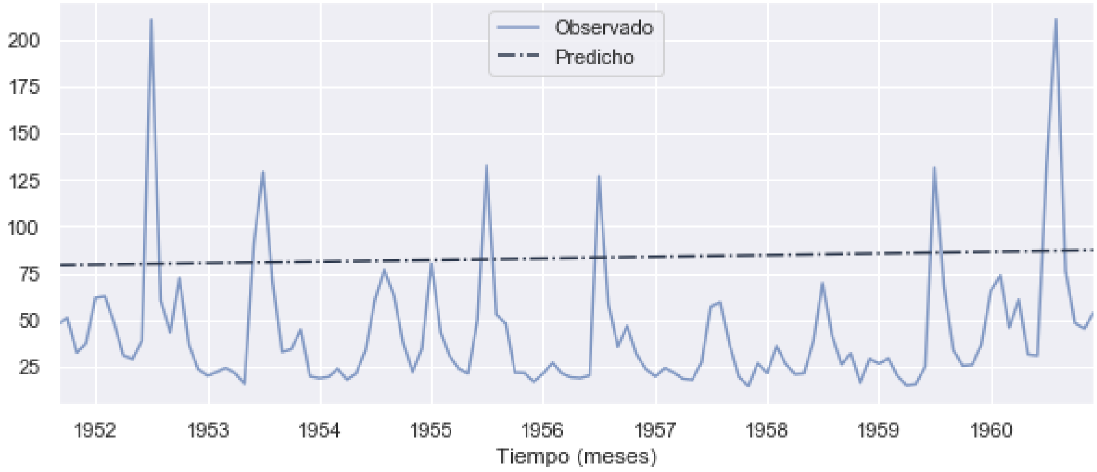
```
          hl_forecast = hl_model.predict(split_date, end_date)
          hl_box_forecast = (bc_param * hl_forecast + 1) ** (1 / bc_param)

In [24]: resid_diag(hl_resid)
         plt.show()
```



```
In [25]: print("Suavizado Exponencial Doble")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Parámetro alfa de suavizado: " + str(hl_alpha))
         print("Parámetro beta de suavizado: " + str(hl_beta))
         print("")
         print("AIC: " + str(hl_aic))
         print("Test de Jarque-Bera (p-valor): " + str(round(hl_jb_test[1], 6)))
         print("Test de Ljung-Box para k =  6 (p-valor): "
               + str(round(hl_lb_test[1][6], 6)))
         print("Test de Ljung-Box para k = 12 (p-valor): "
               + str(round(hl_lb_test[1][12], 6)))
         print("")
         print("RMSE (test):   " + str(round(sqrt(mse(test, hl_box_forecast)), 2)))
         print("MAE (test):    " + str(round(mae(test, hl_box_forecast), 2)))
         print("sMAPE (test):  " + str(round(smape(test, hl_box_forecast), 2)))
```

```
Suavizado Exponencial Doble

Observaciones ajustadas: 452
Observaciones predichas: 112

Parámetro alfa de suavizado: 1.0
Parámetro beta de suavizado: 0.0

AIC: -1920.5136536138625
Test de Jarque-Bera (p-valor): 0.0
Test de Ljung-Box para k =  6 (p-valor): 0.0
Test de Ljung-Box para k = 12 (p-valor): 0.0

RMSE (test):   52.5
MAE (test):    48.48
sMAPE (test):  82.59
```

```
In [26]: forecast_plot(test, hl_box_forecast)
         plt.show()
```

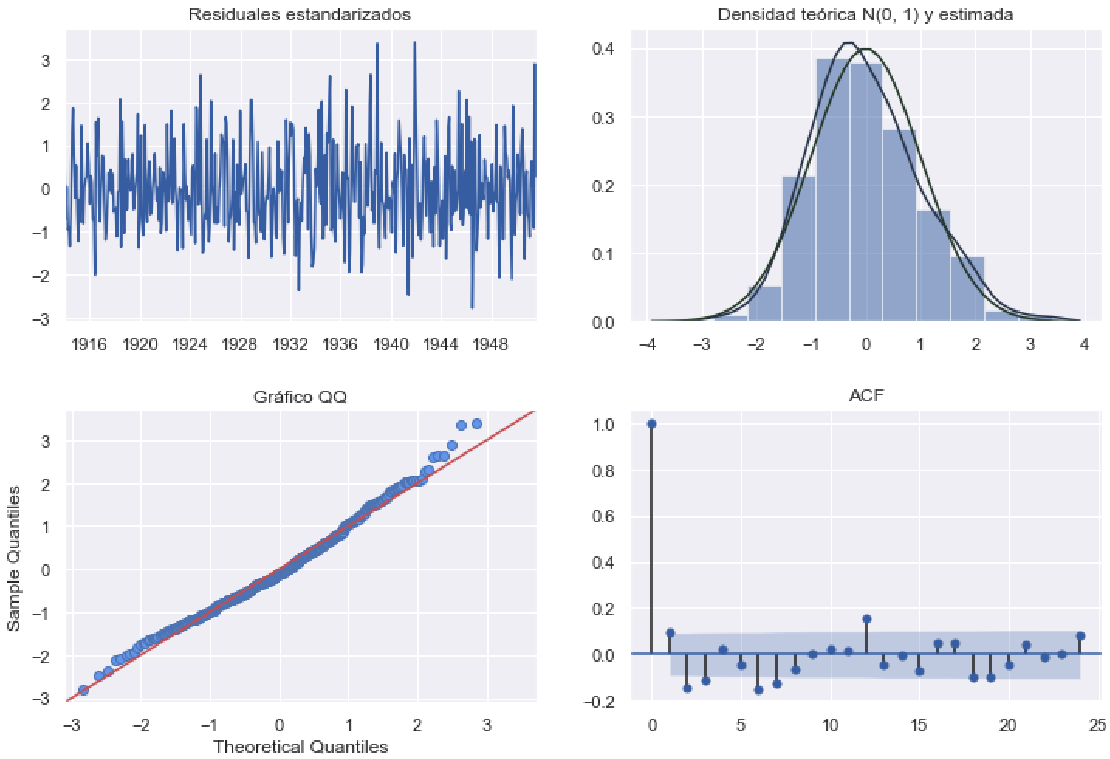


Suavizado Exponencial Triple

```
In [27]: hw = ExponentialSmoothing(bc_train, trend = "add",
                                   seasonal = "add", seasonal_periods = 12)
         hw_model = hw.fit()

         hw_alpha = hw_model.params["smoothing_level"]
         hw_beta = hw_model.params["smoothing_slope"]
         hw_delta = hw_model.params["smoothing_seasonal"]
```

```
        hw_aic = hw_model.aic

        hw_fitted = hw_model.fittedvalues
        hw_resid = (hw_model.resid - hw_model.resid.mean()) / hw_model.resid.std()
        hw_jb_test = jb(hw_resid)
        hw_lb_test = lb(hw_resid)

        hw_forecast = hw_model.predict(split_date, end_date)
        hw_box_forecast = (bc_param * hw_forecast + 1) ** (1 / bc_param)
```

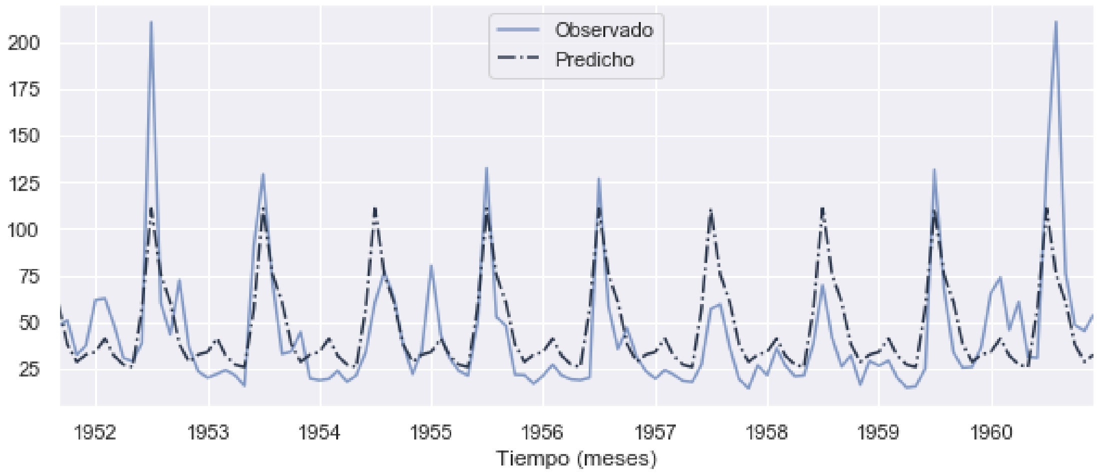
```
In [28]: resid_diag(hw_resid)
         plt.show()
```



```
In [29]: print("Suavizado Exponencial Triple")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("Parámetro alfa de suavizado: " + str(round(hw_alpha, 4)))
         print("Parámetro beta de suavizado: " + str(round(hw_beta, 4)))
         print("Parámetro delta de suavizado: " + str(round(hw_delta, 4)))
         print("")
         print("AIC: " + str(round(hw_aic, 2)))
         print("Test de Jarque-Bera (p-valor): " +
               str(round(hw_jb_test[1], 6)))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(round(hw_lb_test[1][6], 6)))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(round(hw_lb_test[1][12], 6)))
         print("")
         print("RMSE (test):   " + str(round(sqrt(mse(test, hw_box_forecast)), 2)))
         print("MAE (test):    " + str(round(mae(test, hw_box_forecast), 2)))
         print("sMAPE (test):  " + str(round(smape(test, hw_box_forecast), 2)))
```

```
Suavizado Exponencial Triple

Observaciones ajustadas: 452
Observaciones predichas: 112

Parámetro alfa de suavizado: 0.5461
Parámetro beta de suavizado: 0.0
Parámetro delta de suavizado: 0.0

AIC: -2292.11
Test de Jarque-Bera (p-valor): 0.001383
Test de Ljung-Box para k =  6 (p-valor): 3e-06
Test de Ljung-Box para k = 12 (p-valor): 1e-06

RMSE (test):   24.4
MAE (test):    16.84
sMAPE (test):  36.9
```

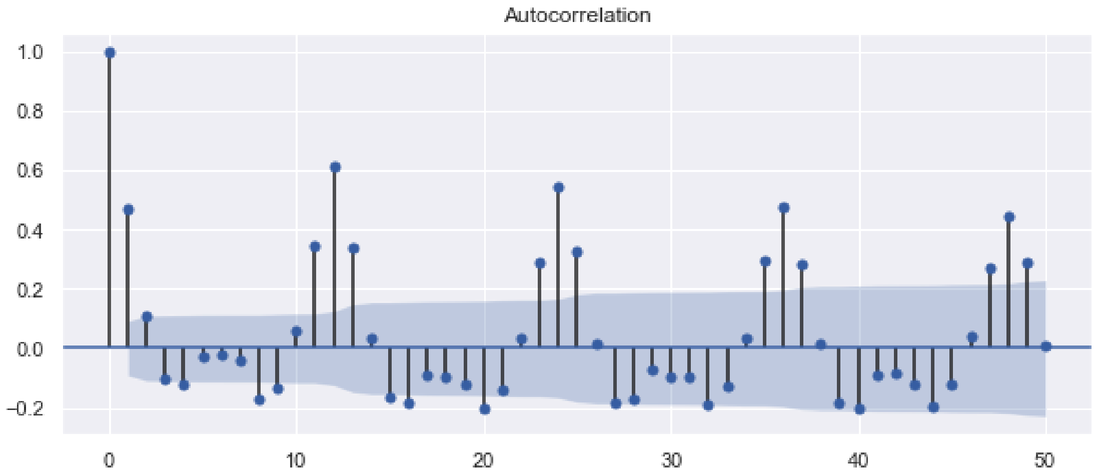
```
In [30]: forecast_plot(test, hw_box_forecast)
         plt.show()
```

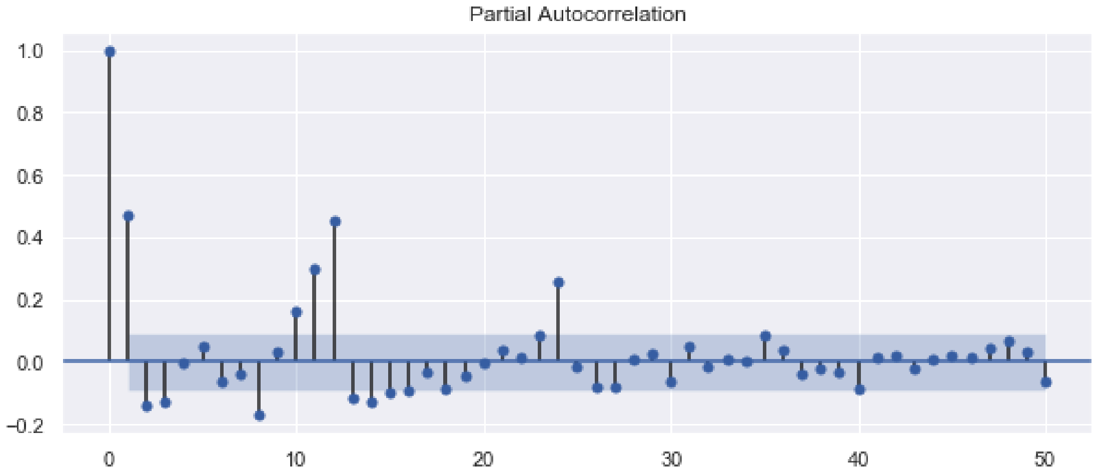


0.0.4 2. Metodología Box-Jenkins

Estacionariedad en media en la estructura regular y/o estacional

```
In [31]: tsaplots.plot_acf(train, lags = 50)
         tsaplots.plot_pacf(train, lags = 50)
         plt.show()
```





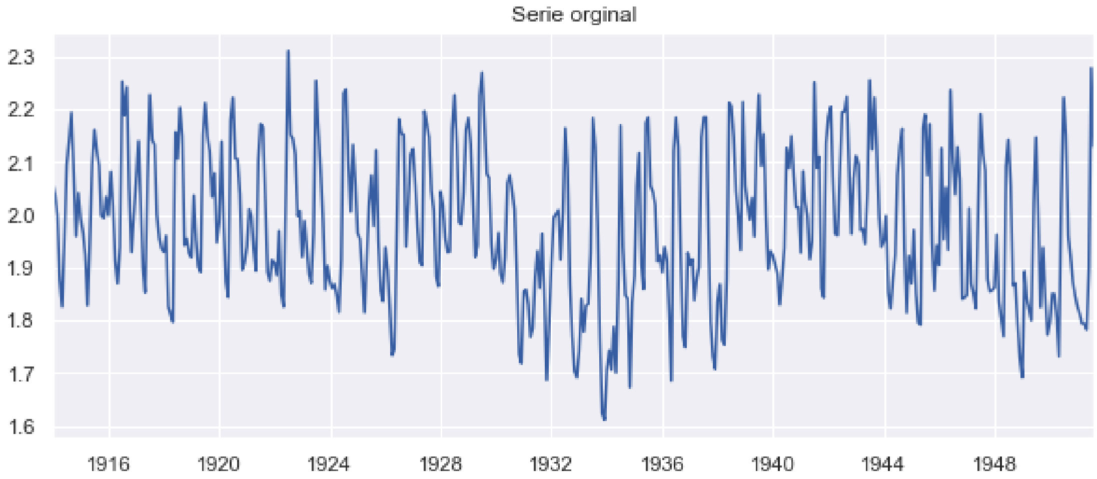
Test de Canova-Hansen de existencia de raíz unitaria estacional

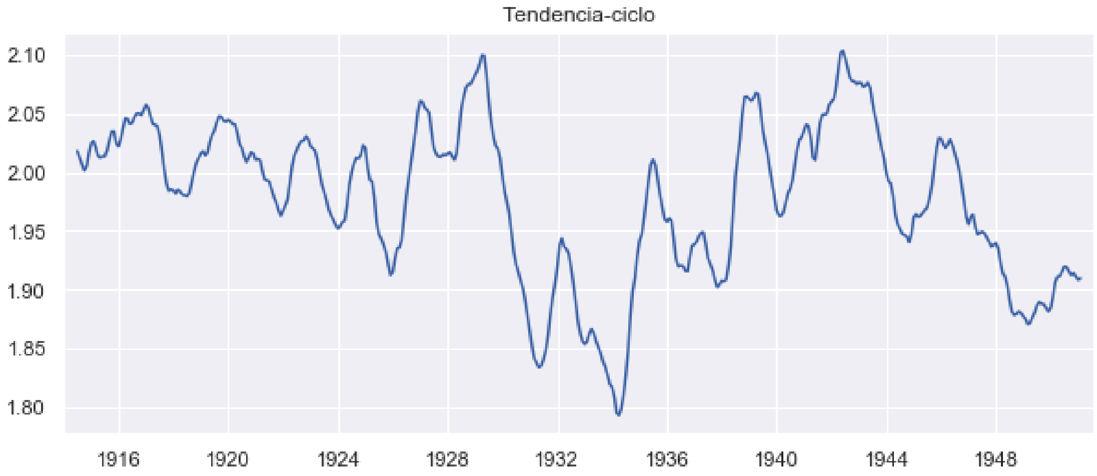
```
In [32]: D = nsdiffs(train, m = 12, test = "ch")
         print(D)
```

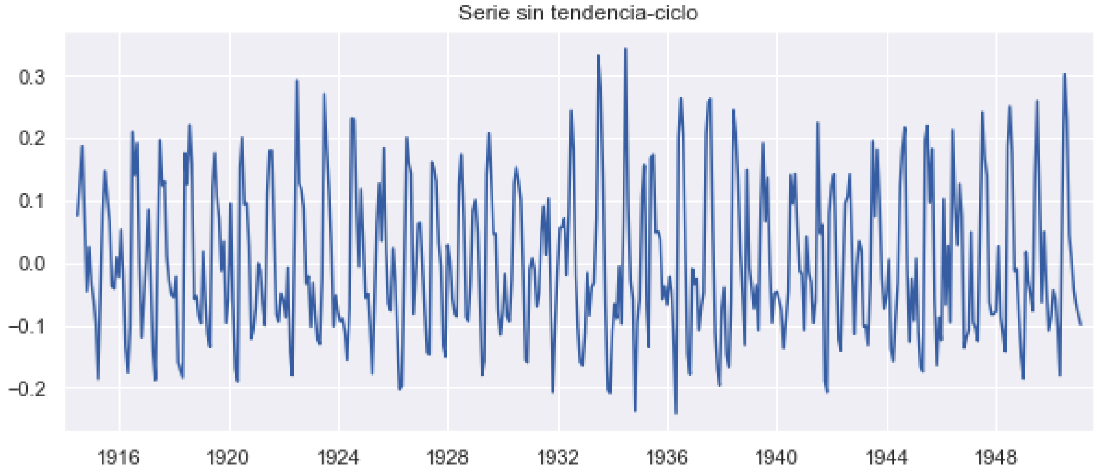
```
0
```

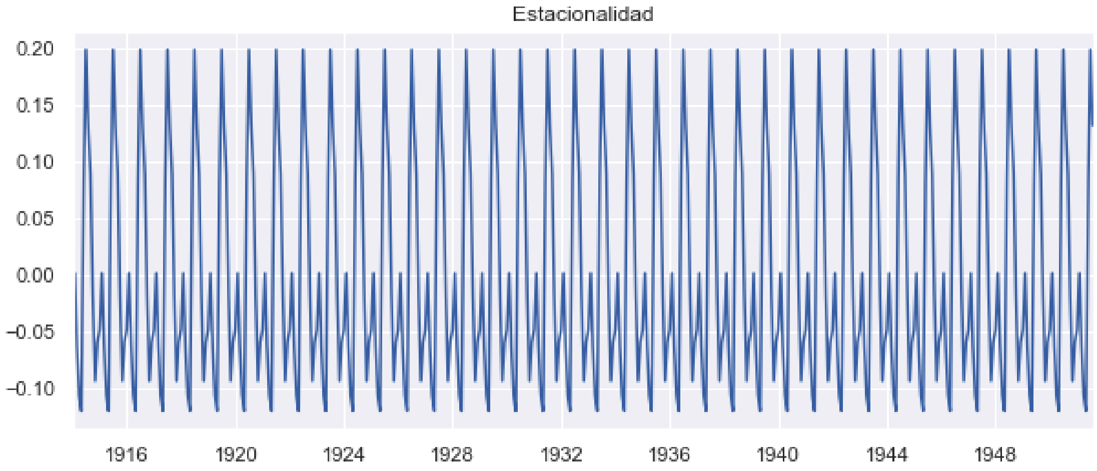
Opción 1. Estimación de la estacionalidad por variables dummy

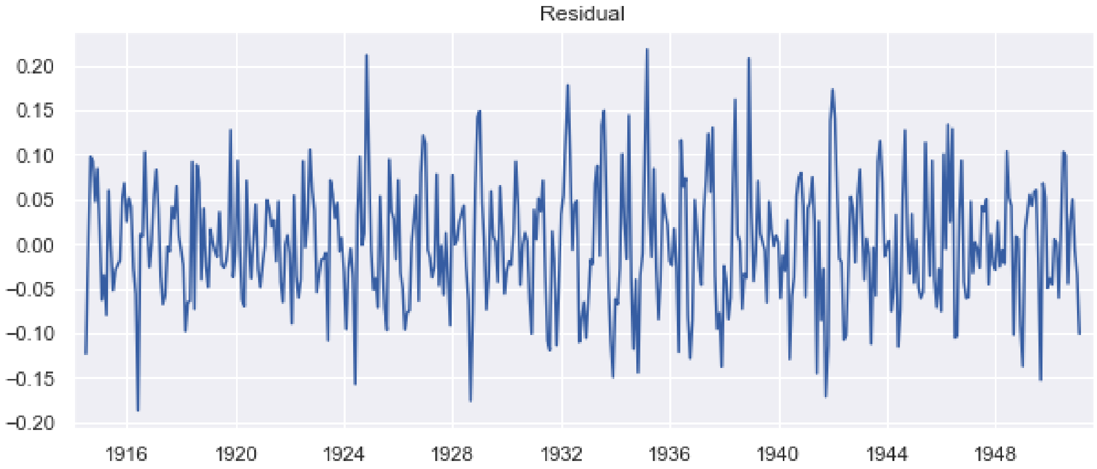
```
In [33]: ts_components = seasonal_decompose(bc_train, "add")

         bc_trend    = ts_components.trend
         bc_seasonal = ts_components.seasonal
         bc_residual = ts_components.resid

         bc_deseas = bc_train - bc_seasonal
         bc_demean = bc_train - bc_trend

         plt.plot(bc_train)
         plt.title("Serie orginal")
         plt.xlim([train.index[0], train.index[-1]])
         plt.show()
         plt.plot(bc_trend)
         plt.title("Tendencia-ciclo")
         plt.xlim([train.index[0], train.index[-1]])
         plt.show()
         plt.plot(bc_demean)
         plt.title("Serie sin tendencia-ciclo")
         plt.xlim([train.index[0], train.index[-1]])
         plt.show()
         plt.plot(bc_seasonal)
         plt.title("Estacionalidad")
         plt.xlim([train.index[0], train.index[-1]])
         plt.show()
         plt.plot(bc_residual)
         plt.title("Residual")
         plt.xlim([train.index[0], train.index[-1]])
         plt.show()
         plt.plot(bc_deseas)
         plt.title("Serie desestacionalizada")
         plt.xlim([train.index[0], train.index[-1]])
         plt.show()
```

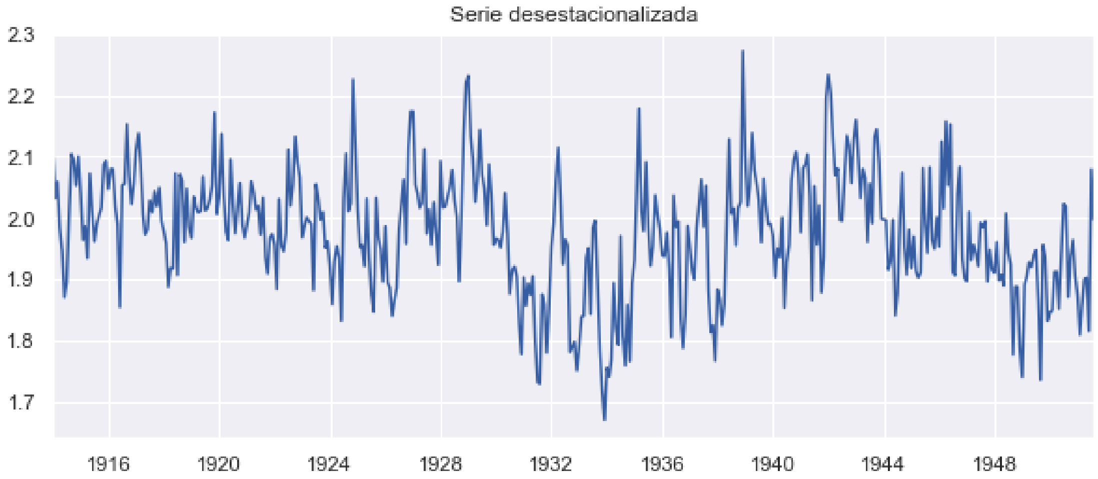

Serie orginal
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1916
1920
1924
1928
1932
1936
1940
1944
1948


Tendencia-ciclo
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1916
1920
1924
1928
1932
1936
1940
1944
1948


Serie sin tendencia-ciclo
0.3
0.2
0.1
0.0
−0.1
−0.2
1916
1920
1924
1928
1932
1936
1940
1944
1948


Estacionalidad
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
1916
1920
1924
1928
1932
1936
1940
1944
1948

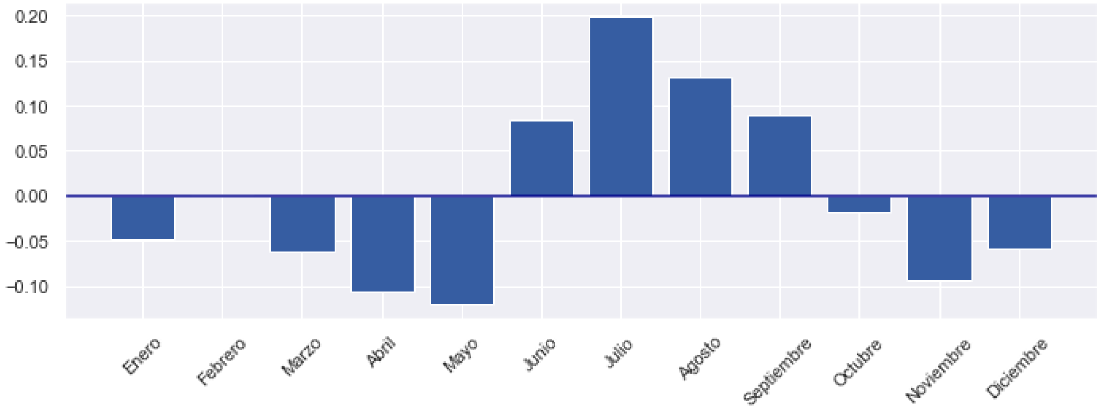

Residual
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
1916
1920
1924
1928
1932
1936
1940
1944
1948



Índices estacionales

```
In [34]: months = ["Enero", "Febrero", "Marzo", "Abril",
                   "Mayo", "Junio", "Julio", "Agosto",
                   "Septiembre", "Octubre", "Noviembre", "Diciembre"]
```

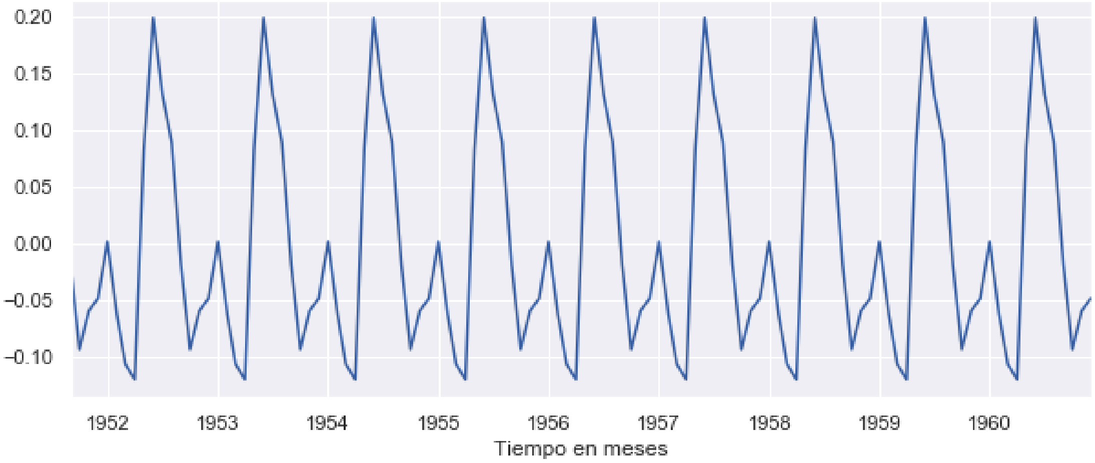
```
In [35]: plt.xticks(rotation=45)
         plt.axhline(0, color='darkblue')
         plt.bar(months, height = bc_seasonal.iloc[:12,0].values)
         plt.tight_layout()
         plt.savefig("seasonal_index.png", dpi=400)
         plt.show()
```



Predicción de la estacionalidad con el método ingenuo estacional

```
In [36]: bc_seasonality_forecast = snaive(bc_seasonal, test)
```

```
In [37]: tsplot(bc_seasonality_forecast)
         plt.show()
```



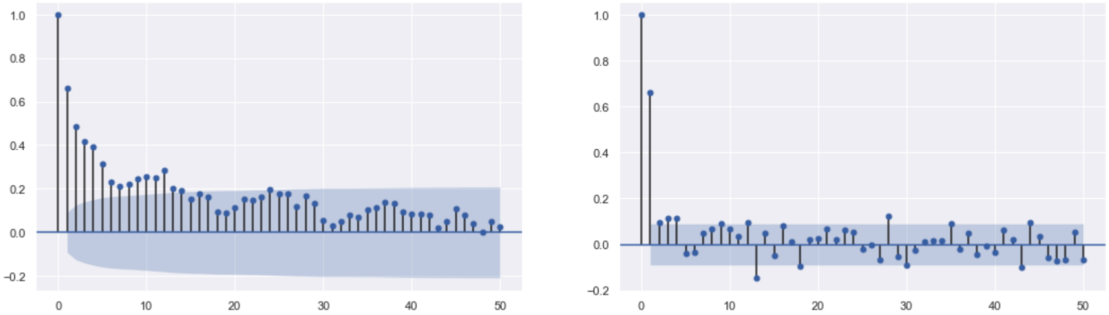
Modelización de la serie desestacionalizada

Test ADF y KPSS para determinar el tratamiento de la tendencia-ciclo

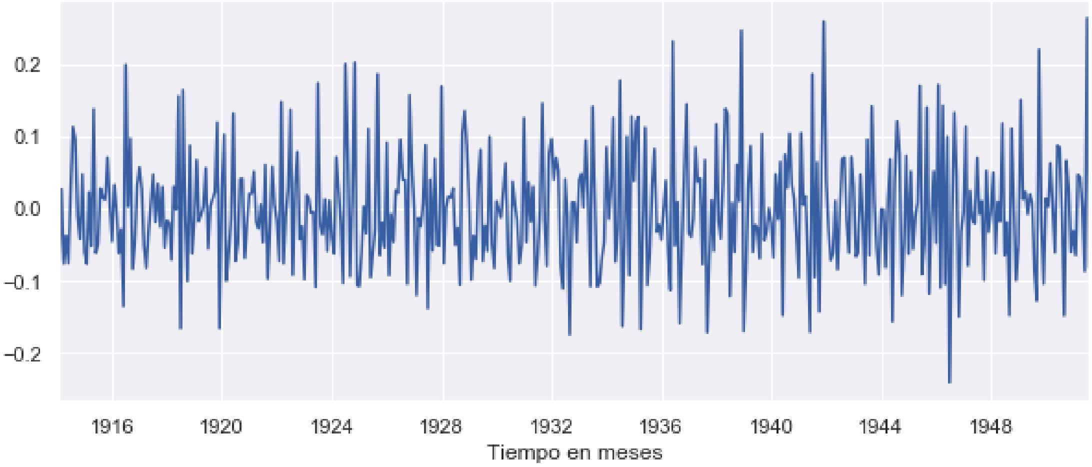
```
In [38]: adf_test = stationarity_test(bc_deseas)[0]
         kpss_test = stationarity_test(bc_deseas)[1]

         print("RESULTADOS DEL TEST AUMENTADO DE DICKEY FULLER")
         print("Estadístico de contraste: " + str(adf_test[0]))
         print("P-valor: " + str(adf_test[1]))
         print("")
         print("RESULTADOS DEL TEST KPSS")
         print("Estadístico de contraste: " + str(kpss_test[0]))
         print("P-valor: " + str(kpss_test[1]))
```

```
RESULTADOS DEL TEST AUMENTADO DE DICKEY FULLER
Estadístico de contraste: -3.6635385092817327
P-valor: 0.004656249355488653

RESULTADOS DEL TEST KPSS
Estadístico de contraste: 0.34855555965899915
P-valor: 0.09932950014698312
```

```
In [39]: fig, ax = plt.subplots(1, 2, figsize=(18, 5))

         tsaplots.plot_acf(bc_deseas, lags = 50, title = "", ax=ax[0])
         tsaplots.plot_pacf(bc_deseas, lags = 50, title = "", ax=ax[1])


         plt.savefig("facs_deseas.png", dpi = 400)
         plt.show()
```



```
In [40]: bc_diff_deseas = bc_deseas.diff(1).iloc[1:]

In [41]: tsplot(bc_diff_deseas)
```

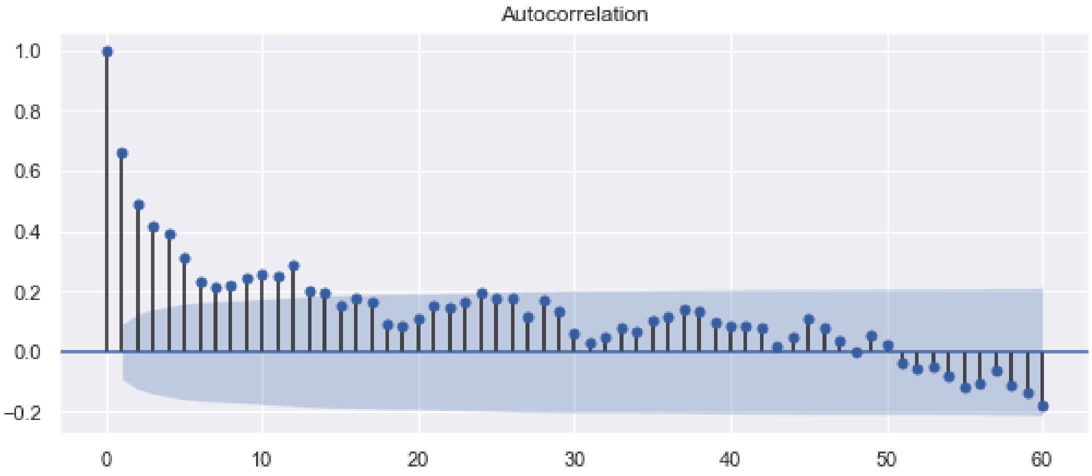


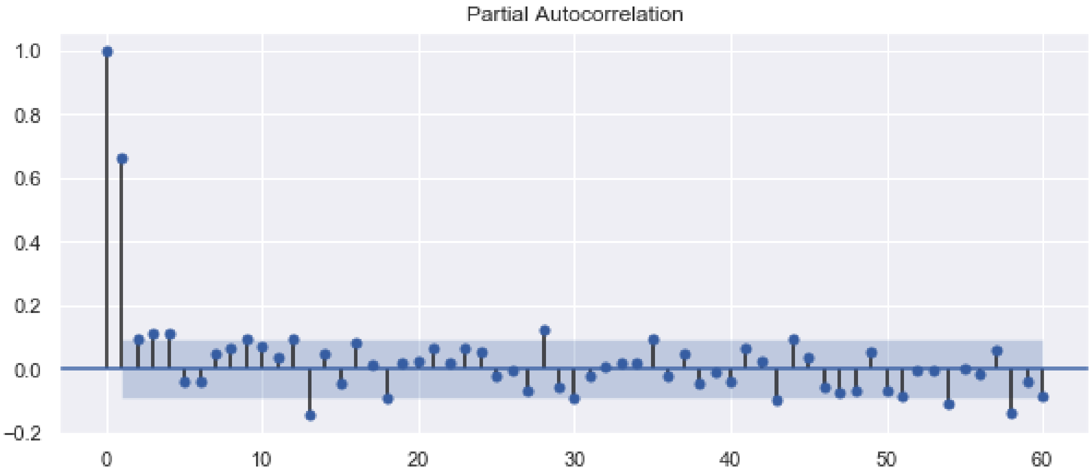
```
In [42]: bc_diff_deseas_adf_test = stationarity_test(bc_diff_deseas)[0]
         print("RESULTADOS DEL TEST AUMENTADO DE DICKEY FULLER")
         print("Estadístico de contraste: " + str(bc_diff_deseas_adf_test[0]))
         print("P-valor: " + str(bc_diff_deseas_adf_test[1]))
```

```
RESULTADOS DEL TEST AUMENTADO DE DICKEY FULLER
Estadístico de contraste: -7.858234299254451
P-valor: 5.3705132937936725e-12
```

Asumiendo estacionariedad en media en la estructura regualar

```
In [43]: tsaplots.plot_acf(bc_deseas, lags = 60)
         plt.show()
         tsaplots.plot_pacf(bc_deseas, lags = 60)
         plt.show()
```



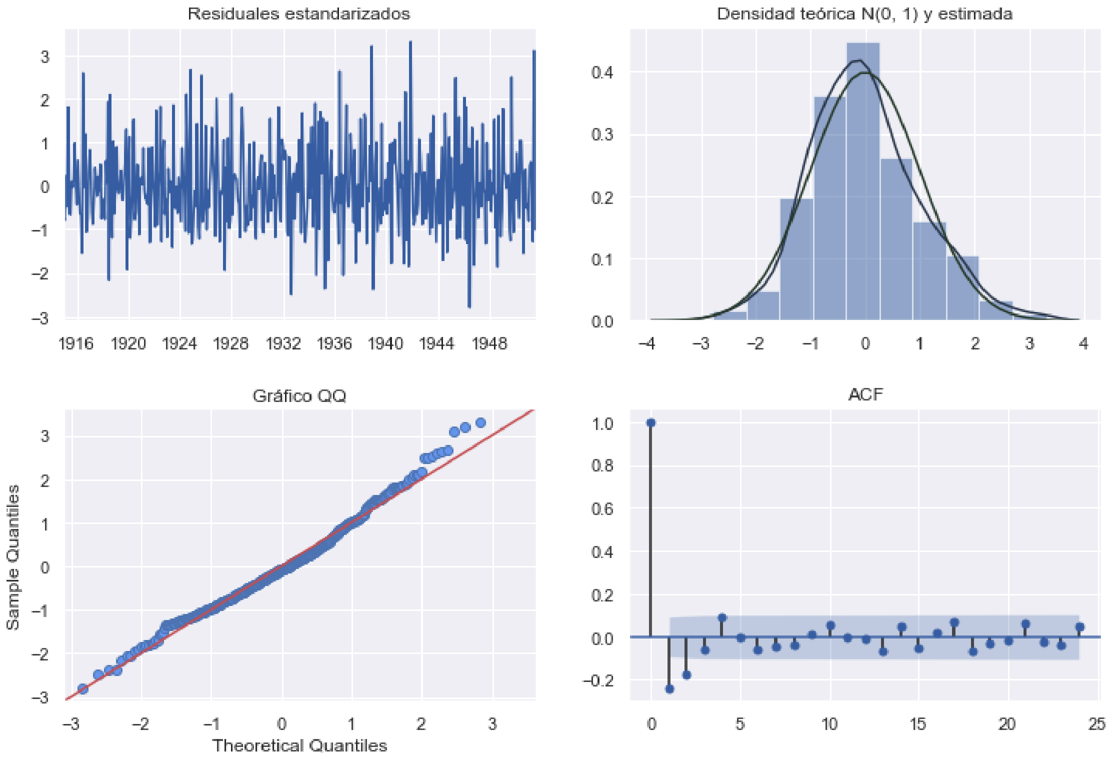


Identificación de ordenes Procesos candidatos a generar la serie desestacionalizada: - **SARIMA (1, 0, 0) x (1, 0, 0)12** - **SARIMA (2, 0, 0) x (1, 0, 0)12** - **SARIMA (3, 0, 0) x (1, 0, 0)12** - **SARIMA (1, 0, 0) x (1, 0, 0)12**

SARIMA (1, 0, 0) x (1, 0, 0)12

```
In [44]: sarima1 = SARIMAX(bc_deseas, order = (1, 0, 0), seasonal_order = (1, 0, 0, 12))
         sarima1_model = sarima1.fit()

         sarima1_aic = sarima1_model.aic
         sarima1_fitted = sarima1_model.fittedvalues
         sarima1_resid = (sarima1_model.resid[12:] -
                          sarima1_model.resid[12:].mean()) / sarima1_model.resid[12:].std()
         sarima1_jb_test = jb(sarima1_resid)
         sarima1_lb_test = lb(sarima1_resid)

         sarima1_forecast = sarima1_model.predict(split_date, end_date)
```

```
In [45]: resid_diag(sarima1_resid)
         plt.show()
```



```
In [46]: print(sarima1_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(1, 0, 0)x(1, 0, 0, 12)   Log Likelihood                 498.122
Date:                            Thu, 04 Jul 2019   AIC                           -990.244
```

```
Time:                                    18:45:01   BIC                            -977.903
Sample:                                01-01-1914   HQIC                           -985.381
                                     - 08-01-1951                                         
Covariance Type:                              opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.9989      0.002    412.426      0.000       0.994       1.004
ar.S.L12       0.1817      0.046      3.931      0.000       0.091       0.272
sigma2         0.0064      0.000     15.704      0.000       0.006       0.007
===================================================================================
Ljung-Box (Q):                       92.22   Jarque-Bera (JB):                14.48
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):               1.29   Skew:                             0.41
Prob(H) (two-sided):                  0.12   Kurtosis:                         3.31
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

Incluímos la componente estacional en la predicción

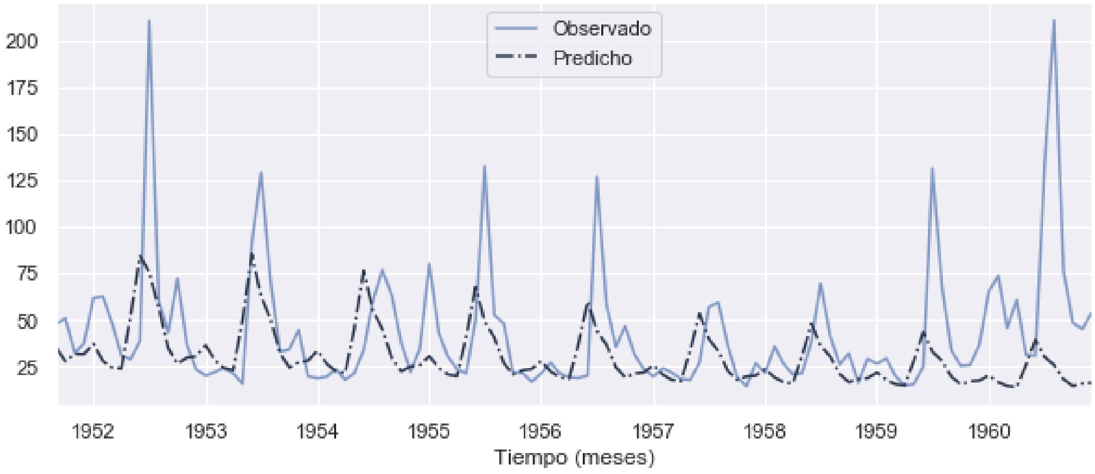
```
In [47]: sarima1_seas_forecast = sarima1_forecast + bc_seasonality_forecast
         sarima1_box_forecast = (bc_param *
                                 sarima1_seas_forecast + 1) ** (1 / bc_param)
```

```
In [48]: print("SARIMA (1, 0, 0) x (1, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima1_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima1_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima1_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima1_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima1_box_forecast))))
         print("MAE (test):  " + str(mae(test, sarima1_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, sarima1_box_forecast)))
```

```
SARIMA (1, 0, 0) x (1, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112
```

```
AIC: -990.2436857349406
Test de Jarque-Bera (p-valor): 0.000703689799407352
Test de Ljung-Box para k =  6 (p-valor): 9.348364038617179e-08
Test de Ljung-Box para k = 12 (p-valor): 3.02612164703319e-06

RMSE (test): 35.01214652563524
MAE (test):  21.426091309467676
sMAPE (test):  47.82440889998852
```

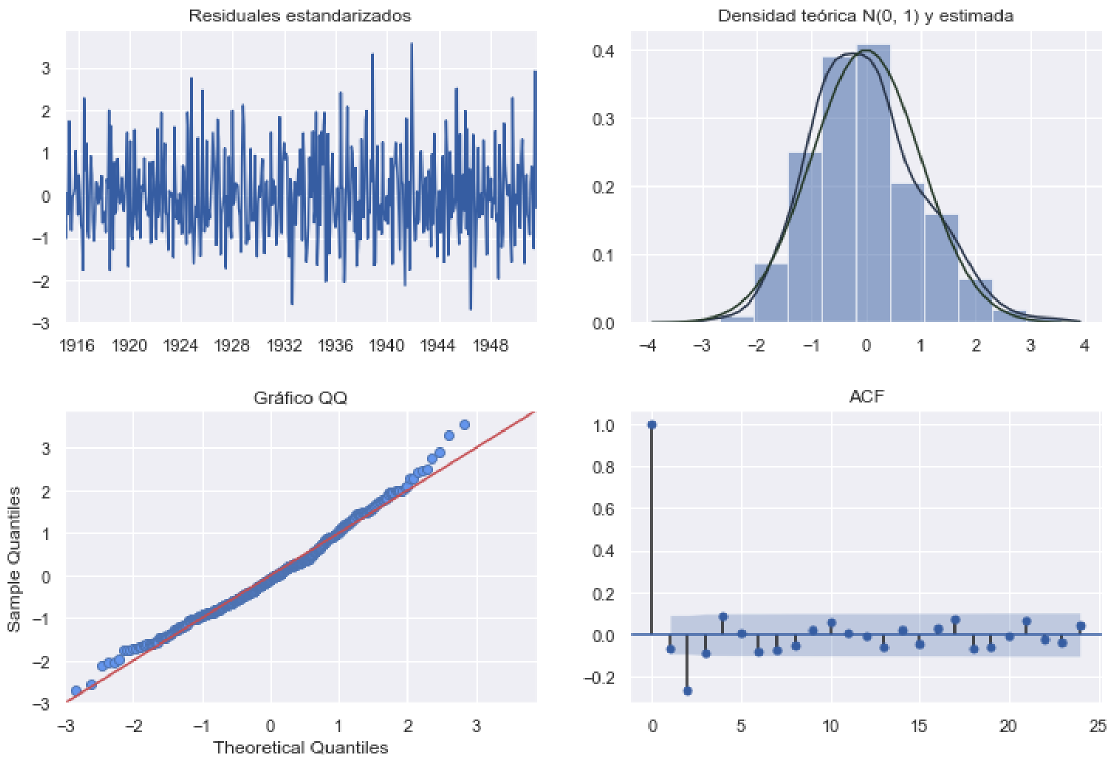
```
In [49]: forecast_plot(test, sarima1_box_forecast)
         plt.show()
```



SARIMA (2, 0, 0) x (1, 0, 0)12

```
In [50]: sarima2 = SARIMAX(bc_deseas, order = (2, 0, 0), seasonal_order = (1, 0, 0, 12))
         sarima2_model = sarima2.fit()

         sarima2_aic = sarima2_model.aic
         sarima2_fitted = sarima2_model.fittedvalues
         sarima2_resid = (sarima2_model.resid[12:] -
                          sarima2_model.resid[12:].mean()) / sarima2_model.resid[12:].std()
         sarima2_jb_test = jb(sarima2_resid)
         sarima2_lb_test = lb(sarima2_resid)

         sarima2_forecast = sarima2_model.predict(split_date, end_date)
```

```
In [51]: resid_diag(sarima2_resid)
         plt.show()
```



```
In [52]: print(sarima2_model.summary())
```

```
                           Statespace Model Results
==========================================================================================
Dep. Variable:                             value   No. Observations:                  452
Model:             SARIMAX(2, 0, 0)x(1, 0, 0, 12)   Log Likelihood                 510.562
Date:                           Thu, 04 Jul 2019   AIC                          -1013.125
Time:                                   18:45:02   BIC                           -996.670
Sample:                               01-01-1914   HQIC                         -1006.641
                                    - 08-01-1951
Covariance Type:                             opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.7665      0.045     17.075      0.000       0.679       0.855
ar.L2          0.2327      0.045      5.181      0.000       0.145       0.321
ar.S.L12       0.1612      0.047      3.432      0.001       0.069       0.253
sigma2         0.0060      0.000     14.968      0.000       0.005       0.007
===================================================================================
Ljung-Box (Q):                       86.87   Jarque-Bera (JB):                15.04
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):               1.29   Skew:                             0.44
Prob(H) (two-sided):                  0.12   Kurtosis:                         3.17
```

```
====================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

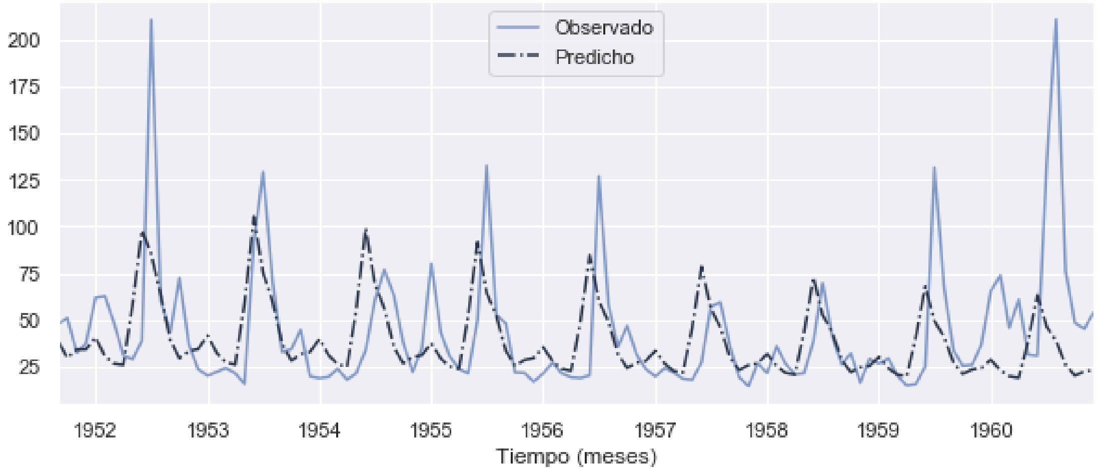
Incluímos la componente estacional en la predicción

```
In [53]: sarima2_seas_forecast = sarima2_forecast + bc_seasonality_forecast
         sarima2_box_forecast = (bc_param *
                                 sarima2_seas_forecast + 1) ** (1 / bc_param)
```

```
In [54]: print("SARIMA (2, 0, 0) x (1, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima2_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima2_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima2_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima2_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima2_box_forecast))))
         print("MAE (test):  " + str(mae(test, sarima2_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, sarima2_box_forecast)))
```

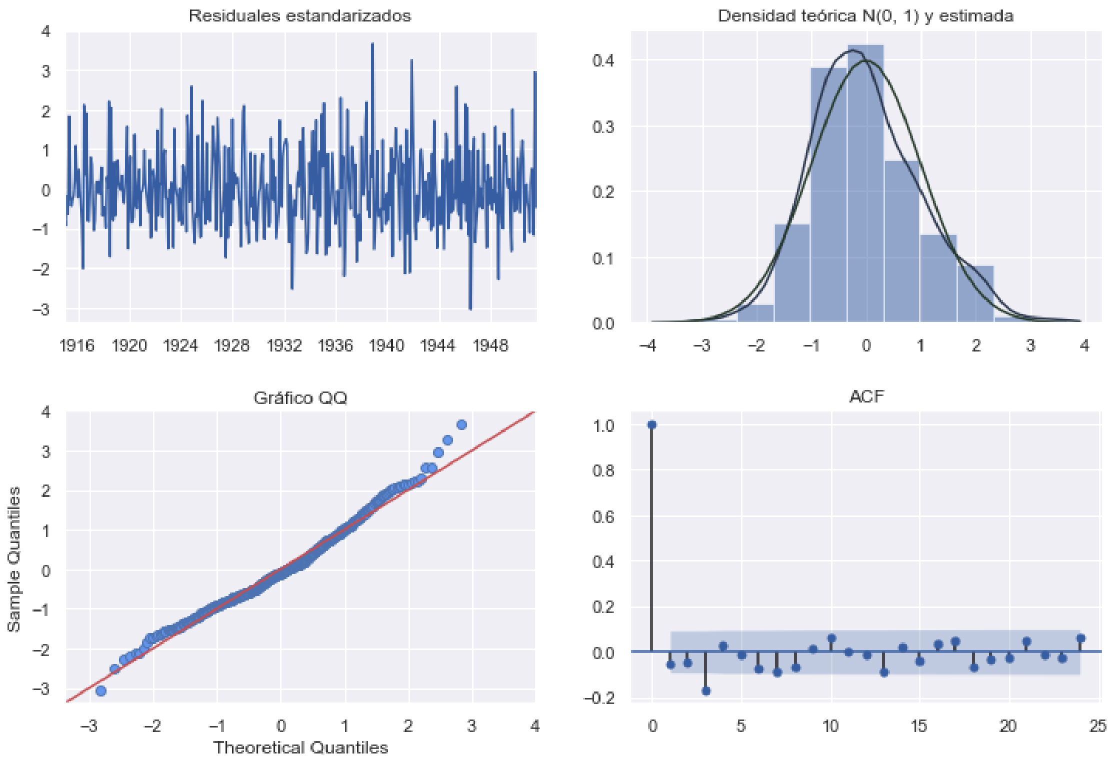
```
SARIMA (2, 0, 0) x (1, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1013.1247970732632
Test de Jarque-Bera (p-valor): 0.0005838844848180709
Test de Ljung-Box para k =  6 (p-valor): 1.7859542088064174e-07
Test de Ljung-Box para k = 12 (p-valor): 4.306284481982204e-06

RMSE (test): 33.36204984253718
MAE (test):  20.93837409539871
sMAPE (test):  43.256423677042946
```

```
In [55]: forecast_plot(test, sarima2_box_forecast)
         plt.show()
```



SARIMA (3, 0, 0) x (1, 0, 0)12

```
In [56]: sarima3 = SARIMAX(bc_deseas, order = (3, 0, 0), seasonal_order = (1, 0, 0, 12))
         sarima3_model = sarima3.fit()

         sarima3_aic = sarima3_model.aic
         sarima3_fitted = sarima3_model.fittedvalues
         sarima3_resid = (sarima3_model.resid[12:] -
                          sarima3_model.resid[12:].mean()) / sarima3_model.resid[12:].std()
         sarima3_jb_test = jb(sarima3_resid)
         sarima3_lb_test = lb(sarima3_resid)

         sarima3_forecast = sarima3_model.predict(split_date, end_date)

In [57]: resid_diag(sarima3_resid)
         plt.show()
```



```
In [58]: print(sarima3_model.summary())

                                 Statespace Model Results
==========================================================================================
Dep. Variable:                             value   No. Observations:                  452
Model:             SARIMAX(3, 0, 0)x(1, 0, 0, 12)   Log Likelihood                 523.653
Date:                           Thu, 04 Jul 2019   AIC                          -1037.306
Time:                                   18:45:03   BIC                          -1016.738
Sample:                               01-01-1914   HQIC                         -1029.201
                                    - 08-01-1951
Covariance Type:                             opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.7143      0.044     16.397      0.000       0.629       0.800
ar.L2          0.0443      0.060      0.742      0.458      -0.073       0.161
ar.L3          0.2407      0.047      5.154      0.000       0.149       0.332
ar.S.L12       0.1845      0.047      3.928      0.000       0.092       0.277
sigma2         0.0057      0.000     15.434      0.000       0.005       0.006
===================================================================================
Ljung-Box (Q):                       63.64   Jarque-Bera (JB):                16.30
Prob(Q):                              0.01   Prob(JB):                         0.00
Heteroskedasticity (H):               1.31   Skew:                             0.44
```

```
Prob(H) (two-sided):                  0.10   Kurtosis:                         3.32
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

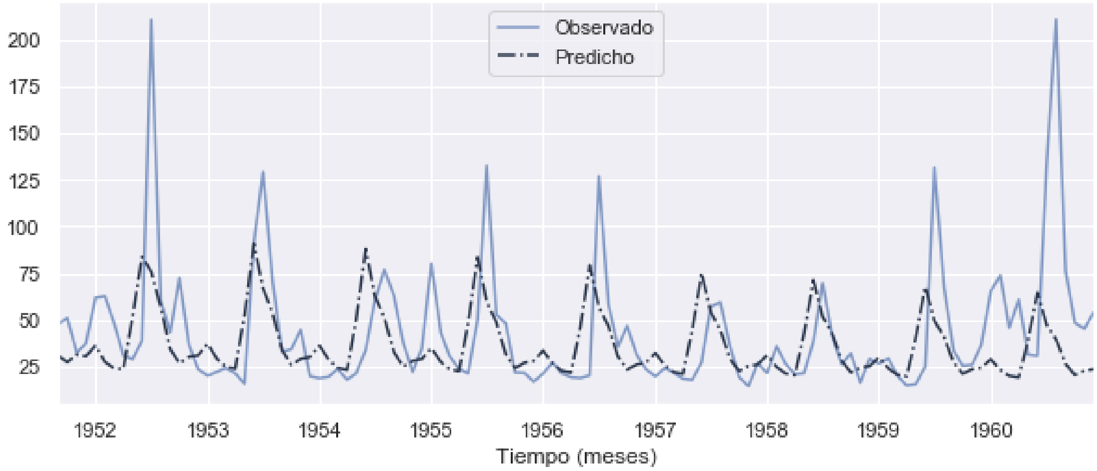
Incluímos la componente estacional en la predicción

```
In [59]: sarima3_seas_forecast = sarima3_forecast + bc_seasonality_forecast
         sarima3_box_forecast = (bc_param *
                                 sarima3_seas_forecast + 1) ** (1 / bc_param)
```

```
In [60]: print("SARIMA (3, 0, 0) x (1, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima3_aic))
         print("Test de Jarque-Bera (p-valor): " +
               str(sarima3_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima3_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima3_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima3_box_forecast))))
         print("MAE (test):  " + str(mae(test, sarima3_box_forecast)))
         print("sMAPE (test):  " + str(smape(test, sarima3_box_forecast)))
```

```
SARIMA (3, 0, 0) x (1, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1037.3059844862905
Test de Jarque-Bera (p-valor): 0.0002395300271233465
Test de Ljung-Box para k =  6 (p-valor): 0.0030782005468447606
Test de Ljung-Box para k = 12 (p-valor): 0.007953950814358884

RMSE (test): 33.264475246335486
MAE (test):  20.640906133344604
sMAPE (test):  43.17662717478427
```

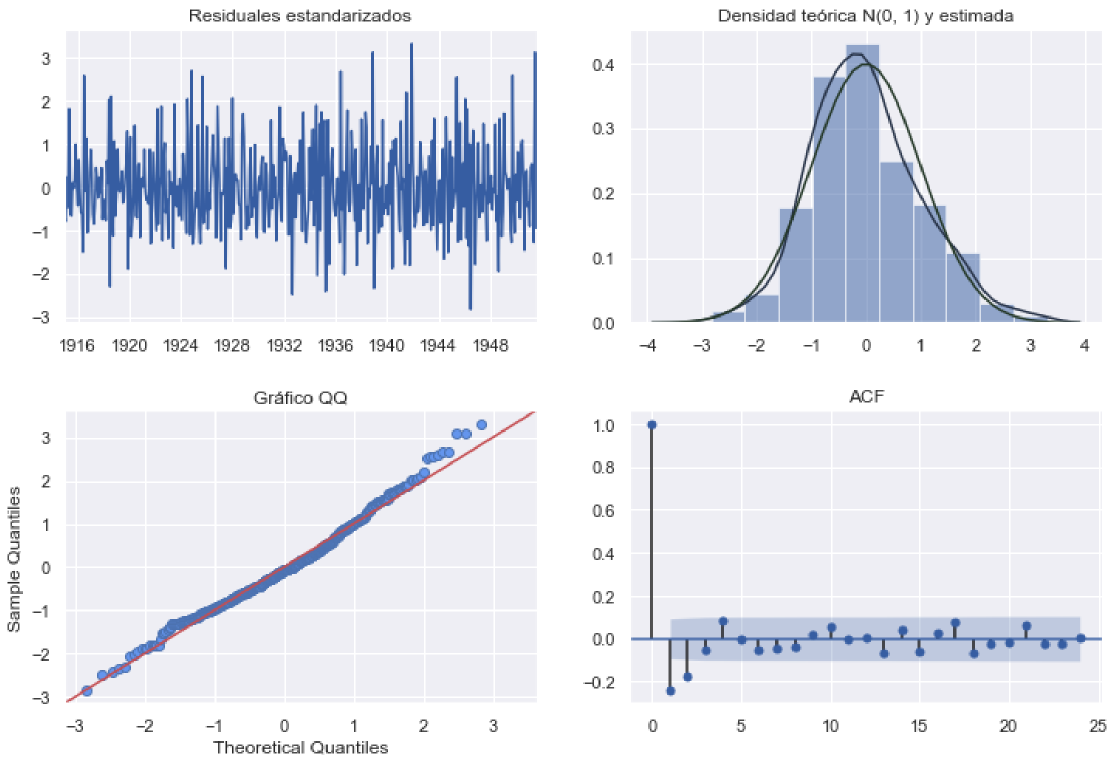
```
In [61]: forecast_plot(test, sarima3_box_forecast)
         plt.show()
```



SARIMA (1, 0, 0) x (2, 0, 0)12

```
In [62]: sarima4 = SARIMAX(bc_deseas, order = (1, 0, 0), seasonal_order = (2, 0, 0, 12))
         sarima4_model = sarima4.fit()

         sarima4_aic = sarima4_model.aic
         sarima4_fitted = sarima4_model.fittedvalues
         sarima4_resid = (sarima4_model.resid[12:] -
                          sarima4_model.resid[12:].mean()) / sarima4_model.resid[12:].std()
         sarima4_jb_test = jb(sarima4_resid)
         sarima4_lb_test = lb(sarima4_resid)

         sarima4_forecasted = sarima4_model.predict(split_date, end_date)
```

```
In [63]: resid_diag(sarima4_resid)
         plt.show()
```



```
In [64]: print(sarima4_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(1, 0, 0)x(2, 0, 0, 12)   Log Likelihood                 498.760
Date:                            Thu, 04 Jul 2019   AIC                           -989.521
Time:                                    18:45:05   BIC                           -973.066
Sample:                                01-01-1914   HQIC                          -983.036
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.9990      0.003    395.285      0.000       0.994       1.004
ar.S.L12       0.1721      0.047      3.692      0.000       0.081       0.263
ar.S.L24       0.0545      0.045      1.225      0.221      -0.033       0.142
sigma2         0.0063      0.000     15.775      0.000       0.006       0.007
===================================================================================
Ljung-Box (Q):                       89.25   Jarque-Bera (JB):                14.19
Prob(Q):                              0.00   Prob(JB):                         0.00
Heteroskedasticity (H):               1.29   Skew:                             0.40
Prob(H) (two-sided):                  0.12   Kurtosis:                         3.32
```

```
====================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

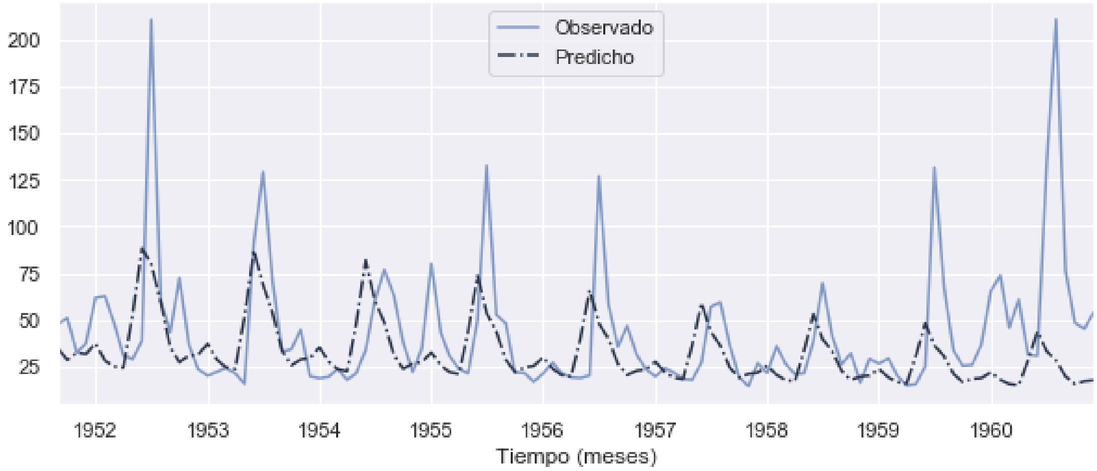
Incluímos la componente estacional en la predicción

```
In [65]: sarima4_seas_fore = sarima4_forecasted + bc_seasonality_forecast
         sarima4_box_forecasted = (bc_param *
                                   sarima4_seas_fore + 1) ** (1 / bc_param)
```

```
In [66]: print("SARIMA (1, 0, 0) x (2, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima4_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima4_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima4_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima4_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima4_box_forecasted))))
         print("MAE (test):  " + str(mae(test, sarima4_box_forecasted)))
         print("sMAPE (test):  " + str(smape(test, sarima4_box_forecasted)))
```

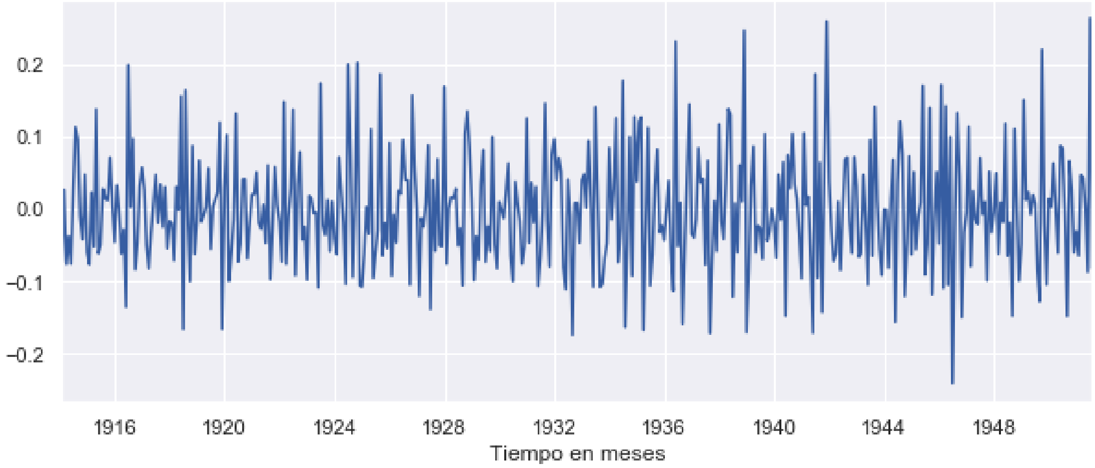
```
SARIMA (1, 0, 0) x (2, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -989.5205192525689
Test de Jarque-Bera (p-valor): 0.0008326123323562449
Test de Ljung-Box para k =  6 (p-valor): 1.1234026340419993e-07
Test de Ljung-Box para k = 12 (p-valor): 3.231483301275644e-06

RMSE (test): 34.30400787973258
MAE (test):  20.96971443804415
sMAPE (test):  45.8176427427
```

```
In [67]: forecast_plot(test, sarima4_box_forecasted)
         plt.show()
```

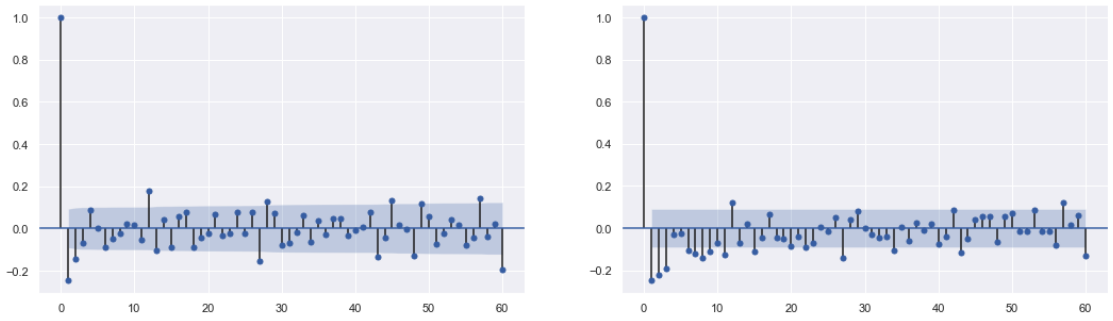


Considerando procesos integrados

```
In [68]: tsplot(bc_diff_deseas)
         plt.savefig("diff_deseas.png")
         plt.show()
```



```
In [69]: fig, ax = plt.subplots(1, 2, figsize=(18, 5))

         tsaplots.plot_acf(bc_diff_deseas, lags = 60, title = "", ax=ax[0])
         tsaplots.plot_pacf(bc_diff_deseas, lags = 60, title = "", ax=ax[1])


         plt.savefig("diff_deseas_facs.png", dpi = 400)
         plt.show()
```

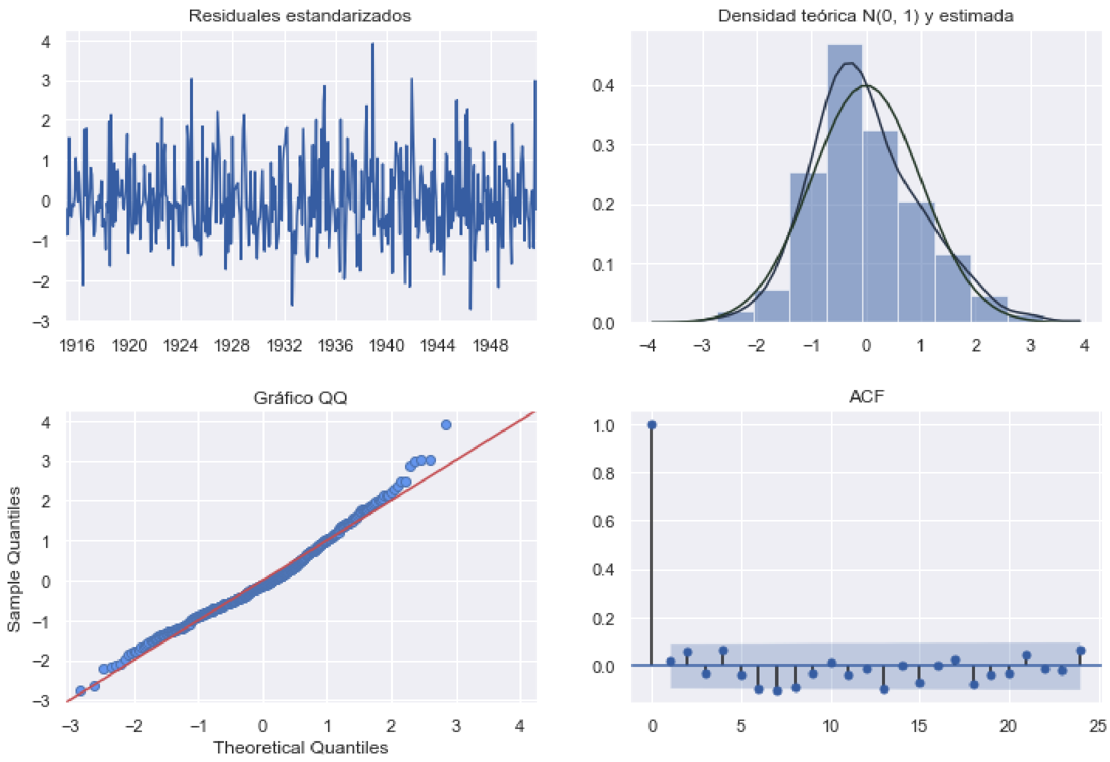


Identificación de ordenes Procesos candidatos a generar la serie desestacionalizada: - **SARIMA (0, 1, 2) x (1, 0, 0)12 - SARIMA (0, 1, 2) x (1, 0, 1)12 - SARIMA (0, 1, 2) x (2, 0, 0)12**

SARIMA (0, 1, 2) x (1, 0, 0)12

```
In [70]: sarima5 = SARIMAX(bc_deseas, order = (0, 1, 2), seasonal_order = (1, 0, 0, 12))
         sarima5_model = sarima5.fit()

         sarima5_aic = sarima5_model.aic
         sarima5_fitted = sarima5_model.fittedvalues
         sarima5_resid = (sarima5_model.resid[12:] -
                          sarima5_model.resid[12:].mean()) / sarima5_model.resid[12:].std()
         sarima5_jb_test = jb(sarima5_resid)
         sarima5_lb_test = lb(sarima5_resid)

         sarima5_forecasted = sarima5_model.predict(split_date, end_date)
```

```
In [71]: resid_diag(sarima5_resid)
         plt.show()
```



```
In [72]: print(sarima5_model.summary())
```

```
                                 Statespace Model Results                                 
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(0, 1, 2)x(1, 0, 0, 12)   Log Likelihood                 536.624
Date:                            Thu, 04 Jul 2019   AIC                          -1065.247
Time:                                    18:45:07   BIC                          -1048.801
Sample:                                01-01-1914   HQIC                         -1058.766
                                     - 08-01-1951                                         
Covariance Type:                              opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ma.L1         -0.3946      0.042     -9.307      0.000      -0.478      -0.312
ma.L2         -0.2621      0.048     -5.464      0.000      -0.356      -0.168
ar.S.L12       0.1595      0.046      3.488      0.000       0.070       0.249
sigma2         0.0054      0.000     16.477      0.000       0.005       0.006
===================================================================================
Ljung-Box (Q):                       60.02   Jarque-Bera (JB):                23.75
Prob(Q):                              0.02   Prob(JB):                         0.00
Heteroskedasticity (H):               1.29   Skew:                             0.51
Prob(H) (two-sided):                  0.12   Kurtosis:                         3.48
```

```
====================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

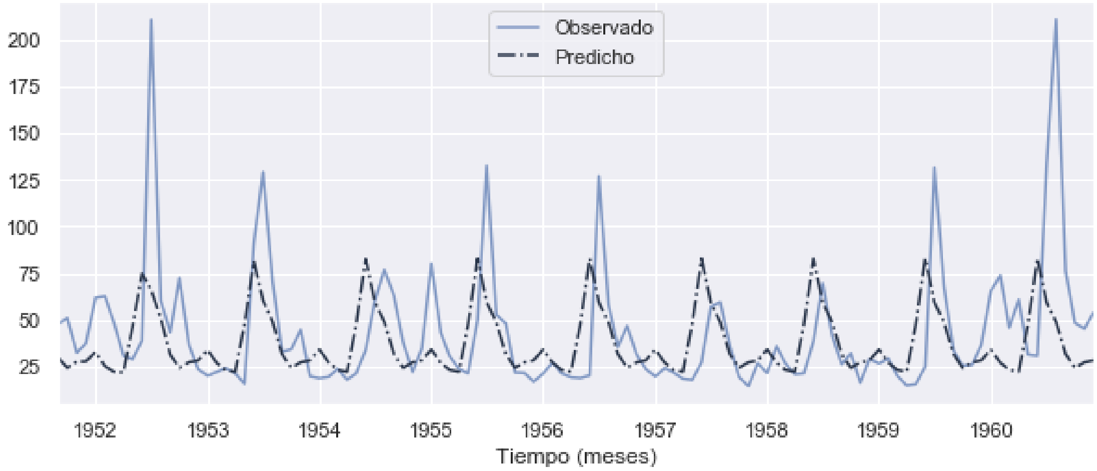
Incluímos la componente estacional en la predicción

```
In [73]: sarima5_seas_fore = sarima5_forecasted + bc_seasonality_forecast
         sarima5_box_forecasted = (bc_param * sarima5_seas_fore + 1) ** (1 / bc_param)
```

```
In [74]: print("SARIMA (0, 1, 2) x (1, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima5_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima5_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima5_lb_test[1][6]))
         print("   Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima5_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima5_box_forecasted))))
         print("MAE (test):  " + str(mae(test, sarima5_box_forecasted)))
         print("sMAPE (test):  " + str(smape(test, sarima5_box_forecasted)))
```

```
SARIMA (0, 1, 2) x (1, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1065.247025938098
Test de Jarque-Bera (p-valor): 4.899060158882278e-06
Test de Ljung-Box para k =  6 (p-valor): 0.06930557174720219
   Test de Ljung-Box para k = 12 (p-valor): 0.0567054705610174

RMSE (test): 33.22208969056615
MAE (test):  20.90303492438331
sMAPE (test):  43.176709437271505
```

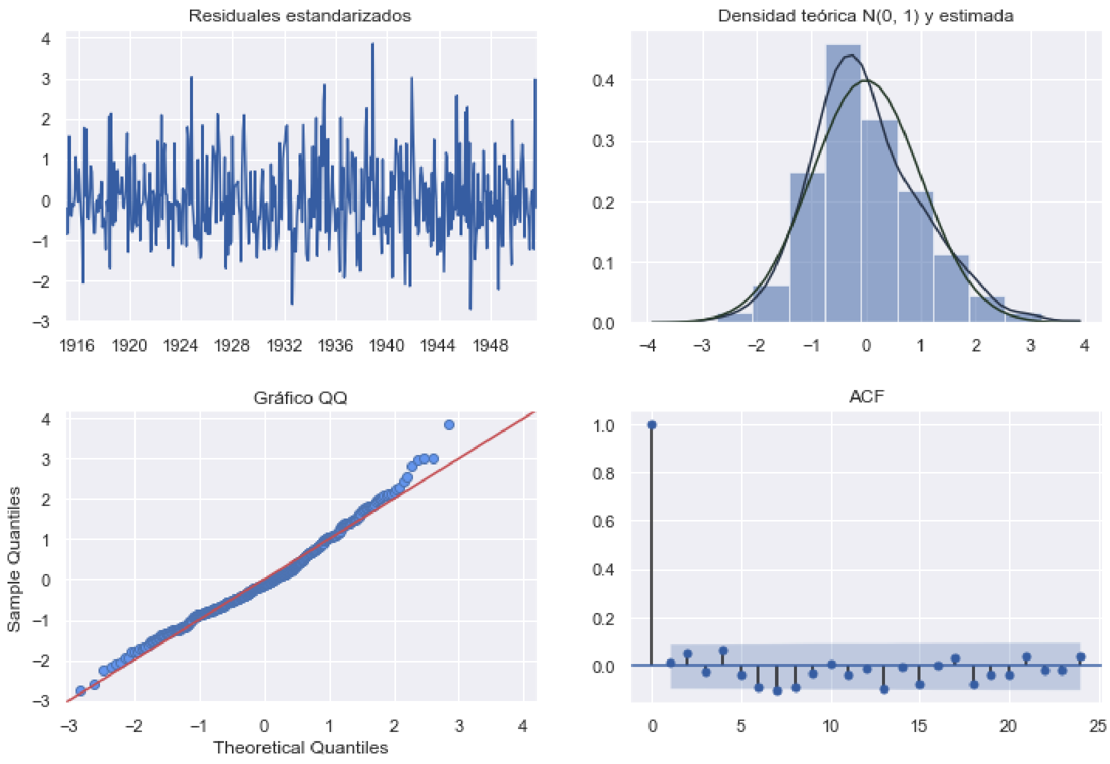
```
In [75]: forecast_plot(test, sarima5_box_forecasted)
         plt.show()
```



SARIMA (0, 1, 2) x (1, 0, 1)12

```
In [76]: sarima6 = SARIMAX(bc_deseas, order = (0, 1, 2), seasonal_order = (1, 0, 1, 12))
         sarima6_model = sarima6.fit()

         sarima6_aic = sarima6_model.aic
         sarima6_fitted = sarima6_model.fittedvalues
         sarima6_resid = (sarima6_model.resid[12:] -
                          sarima6_model.resid[12:].mean()) / sarima6_model.resid[12:].std()
         sarima6_jb_test = jb(sarima6_resid)
         sarima6_lb_test = lb(sarima6_resid)

         sarima6_forecasted = sarima6_model.predict(split_date, end_date)
```

```
In [77]: resid_diag(sarima6_resid)
         plt.show()
```


Residuales estandarizados

Densidad teórica N(0, 1) y estimada

Gráfico QQ

ACF

```
In [78]: print(sarima6_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(0, 1, 2)x(1, 0, 1, 12)   Log Likelihood                 537.410
Date:                            Thu, 04 Jul 2019   AIC                          -1064.820
Time:                                    18:45:08   BIC                          -1044.263
Sample:                                01-01-1914   HQIC                         -1056.719
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ma.L1         -0.3958      0.043     -9.293      0.000      -0.479      -0.312
ma.L2         -0.2629      0.048     -5.499      0.000      -0.357      -0.169
ar.S.L12       0.3981      0.227      1.753      0.080      -0.047       0.843
ma.S.L12      -0.2392      0.239     -1.001      0.317      -0.707       0.229
sigma2         0.0054      0.000     16.326      0.000       0.005       0.006
===================================================================================
Ljung-Box (Q):                       55.85   Jarque-Bera (JB):                22.84
Prob(Q):                              0.05   Prob(JB):                         0.00
Heteroskedasticity (H):               1.29   Skew:                             0.50
```

```
Prob(H) (two-sided):                  0.12   Kurtosis:                         3.46
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

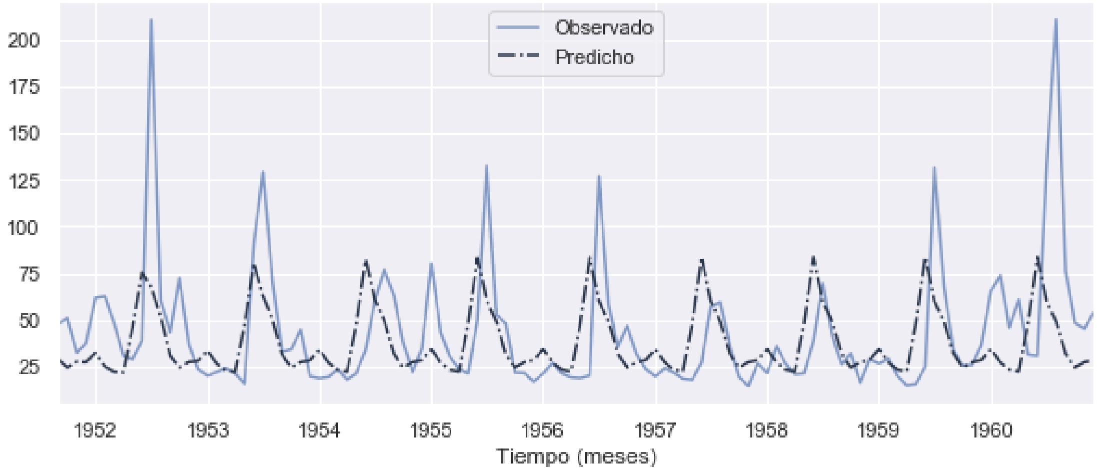
Incluímos la componente estacional en la predicción

```
In [79]: sarima6_seas_fore = sarima6_forecasted + bc_seasonality_forecast
         sarima6_box_forecasted = (bc_param *
                                   sarima6_seas_fore + 1) ** (1 / bc_param)
```

```
In [80]: print("SARIMA (0, 1, 2) x (1, 0, 1) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima6_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima6_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima6_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima6_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima6_box_forecasted))))
         print("MAE (test):  " + str(mae(test, sarima6_box_forecasted)))
         print("sMAPE (test):  " + str(smape(test, sarima6_box_forecasted)))
```

```
SARIMA (0, 1, 2) x (1, 0, 1) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1064.8202474740951
Test de Jarque-Bera (p-valor): 7.840339372635264e-06
Test de Ljung-Box para k =  6 (p-valor): 0.09660711986874868
Test de Ljung-Box para k = 12 (p-valor): 0.0715205434558047

RMSE (test): 33.097596059360754
MAE (test):  20.862229508696394
sMAPE (test):  43.08602581853967
```

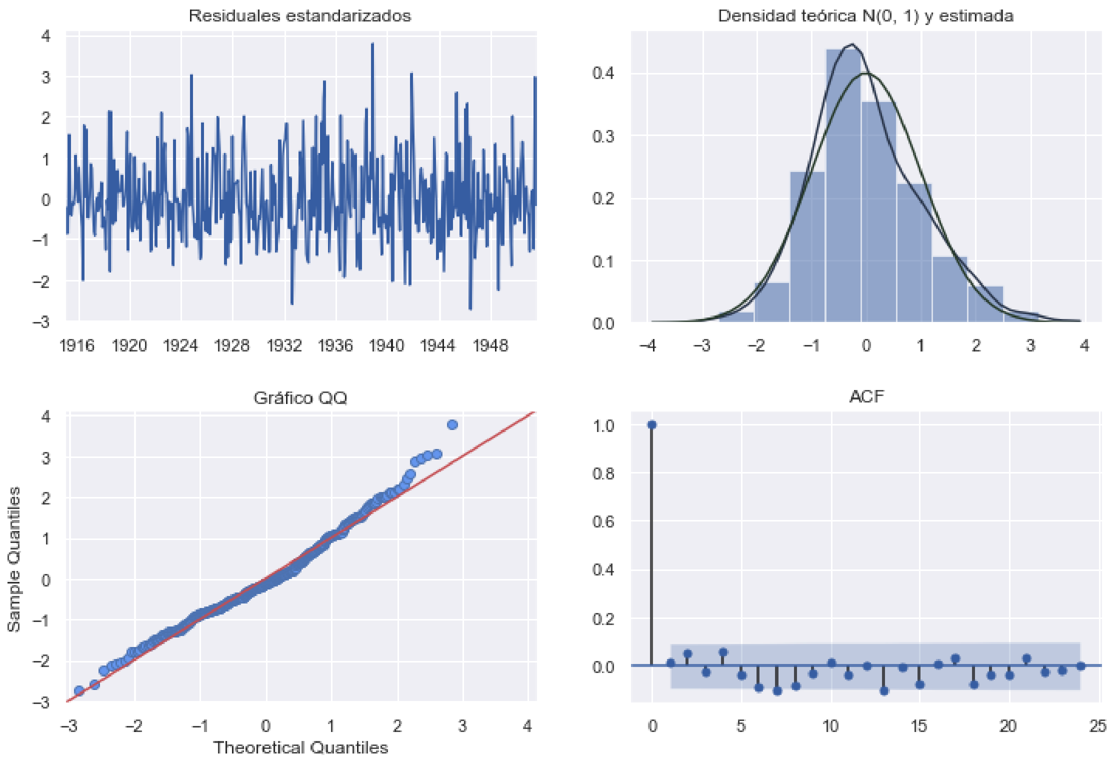
```
In [81]: forecast_plot(test, sarima6_box_forecasted)
         plt.show()
```



SARIMA (0, 1, 2) x (2, 0, 0)12

```
In [82]: sarima7 = SARIMAX(bc_deseas, order = (0, 1, 2), seasonal_order = (2, 0, 0, 12))
         sarima7_model = sarima7.fit()

         sarima7_aic = sarima7_model.aic
         sarima7_fitted = sarima7_model.fittedvalues
         sarima7_resid = (sarima7_model.resid[12:] -
                          sarima7_model.resid[12:].mean()) / sarima7_model.resid[12:].std()
         sarima7_jb_test = jb(sarima7_resid)
         sarima7_lb_test = lb(sarima7_resid)

         sarima7_forecasted = sarima7_model.predict(split_date, end_date)
```

```
In [83]: resid_diag(sarima7_resid)
         plt.show()
```



```
In [84]: print(sarima7_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                          value   No. Observations:                    452
Model:             SARIMAX(0, 1, 2)x(2, 0, 0, 12)   Log Likelihood                 538.021
Date:                        Thu, 04 Jul 2019   AIC                          -1066.042
Time:                                18:45:09   BIC                          -1045.484
Sample:                            01-01-1914   HQIC                         -1057.940
                                 - 08-01-1951
Covariance Type:                          opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ma.L1         -0.3965      0.042     -9.452      0.000      -0.479      -0.314
ma.L2         -0.2650      0.047     -5.592      0.000      -0.358      -0.172
ar.S.L12       0.1474      0.046      3.214      0.001       0.058       0.237
ar.S.L24       0.0802      0.045      1.800      0.072      -0.007       0.168
sigma2         0.0054      0.000     16.338      0.000       0.005       0.006
===================================================================================
Ljung-Box (Q):                       53.27   Jarque-Bera (JB):                 22.21
Prob(Q):                              0.08   Prob(JB):                          0.00
Heteroskedasticity (H):               1.30   Skew:                              0.50
```

```
Prob(H) (two-sided):                  0.11   Kurtosis:                         3.45
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

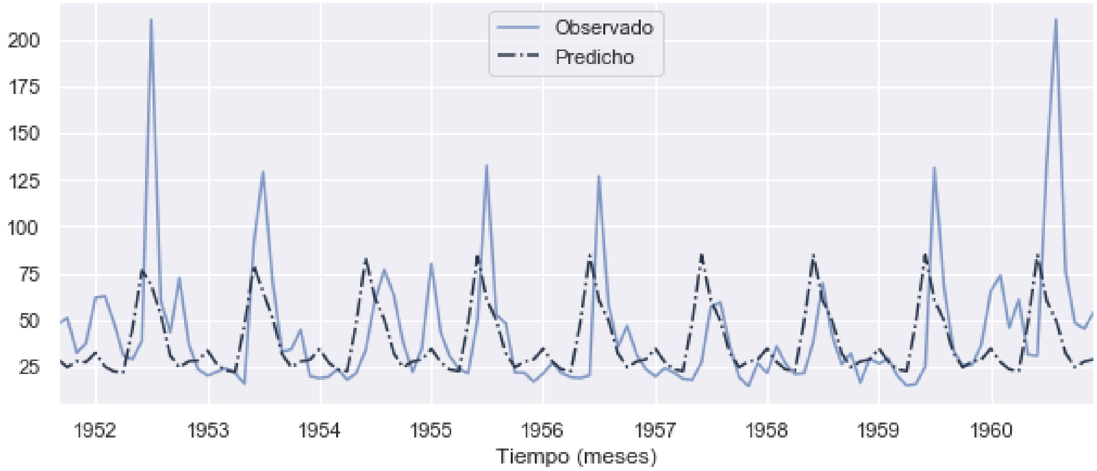
Incluímos la componente estacional en la predicción

```
In [85]: sarima7_seas_fore = sarima7_forecasted + bc_seasonality_forecast
         sarima7_box_forecasted = (bc_param *
                                   sarima7_seas_fore + 1) ** (1 / bc_param)
```

```
In [86]: print("SARIMA (0, 1, 2) x (2, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima7_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima7_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima7_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima7_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima7_box_forecasted))))
         print("MAE (test):  " + str(mae(test, sarima7_box_forecasted)))
         print("sMAPE (test):  " + str(smape(test, sarima7_box_forecasted)))
```

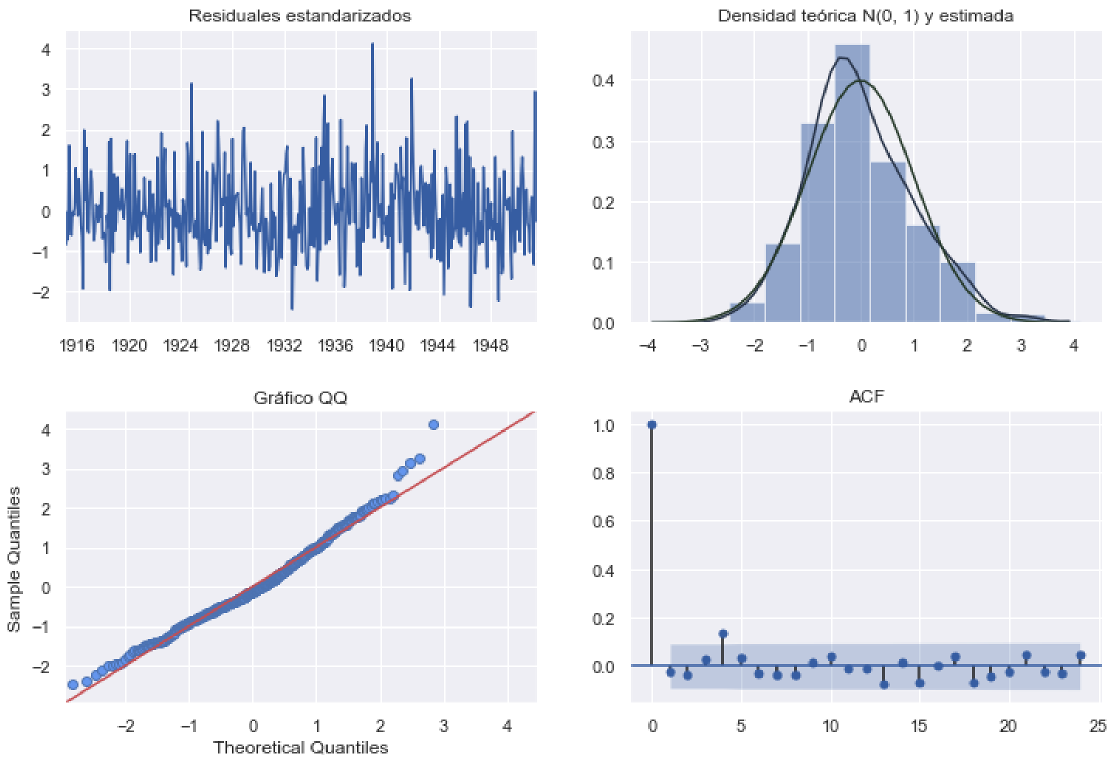
```
SARIMA (0, 1, 2) x (2, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1066.0415922868567
Test de Jarque-Bera (p-valor): 1.0860050176790743e-05
Test de Ljung-Box para k =  6 (p-valor): 0.11830845647215742
Test de Ljung-Box para k = 12 (p-valor): 0.09063065320021838

RMSE (test): 33.0379053381173
MAE (test):  20.871418150460133
sMAPE (test):  43.03383094851058
```

```
In [87]: forecast_plot(test, sarima7_box_forecasted)
         plt.show()
```



Autoarima

```
In [88]: auto = auto_arima(bc_deseas, m=12, seasonal=True)
         auto

Out[88]: ARIMA(callback=None, disp=0, maxiter=None, method=None, order=(1, 1, 2),
            out_of_sample_size=0, scoring='mse', scoring_args={},
            seasonal_order=(1, 0, 0, 12), solver='lbfgs', start_params=None,
            suppress_warnings=False, transparams=True, trend=None,
            with_intercept=True)

In [89]: autosarima1 = SARIMAX(bc_deseas, order = (1, 1, 1), seasonal_order = (1, 0, 0, 12))
         autosarima1_model = autosarima1.fit()

         autosarima1_aic = autosarima1_model.aic
         autosarima1_fitted = autosarima1_model.fittedvalues
         autosarima1_resid = (autosarima1_model.resid[12:] -
                              autosarima1_model.resid[12:].mean()) / autosarima1_model.resid[12:
         autosarima1_jb_test = jb(autosarima1_resid)
         autosarima1_lb_test = lb(autosarima1_resid)

         autosarima1_forecasted = autosarima1_model.predict(split_date, end_date)

In [90]: resid_diag(autosarima1_resid)
         plt.show()
```



```
In [91]: print(autosarima1_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(1, 1, 1)x(1, 0, 0, 12)   Log Likelihood                 544.272
Date:                            Thu, 04 Jul 2019   AIC                          -1080.545
Time:                                    18:45:37   BIC                          -1064.099
Sample:                                01-01-1914   HQIC                         -1074.064
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.5705      0.043     13.176      0.000       0.486       0.655
ma.L1         -0.9548      0.017    -55.649      0.000      -0.988      -0.921
ar.S.L12       0.1694      0.048      3.546      0.000       0.076       0.263
sigma2         0.0052      0.000     16.586      0.000       0.005       0.006
===================================================================================
Ljung-Box (Q):                       47.67   Jarque-Bera (JB):                26.63
Prob(Q):                              0.19   Prob(JB):                         0.00
Heteroskedasticity (H):               1.31   Skew:                             0.53
Prob(H) (two-sided):                  0.10   Kurtosis:                         3.55
```

```
==================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

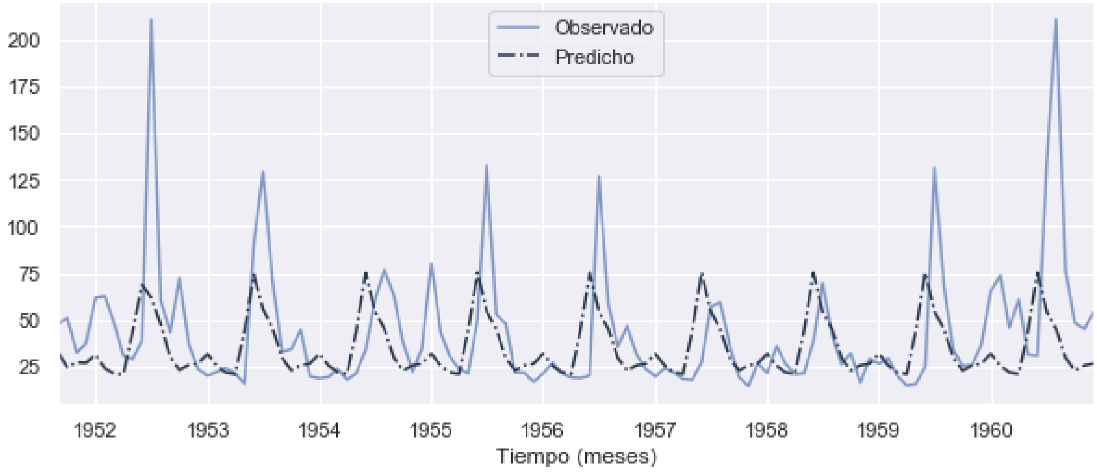
Incluímos la componente estacional en la predicción

```
In [92]: autosarima1_seas_fore = autosarima1_forecasted + bc_seasonality_forecast
         autosarima1_box_forecasted = (bc_param * autosarima1_seas_fore + 1) ** (1 / bc_param)
```

```
In [93]: print("SARIMA (1, 1, 1) x (2, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(autosarima1_aic))
         print("Test de Jarque-Bera (p-valor): " + str(autosarima1_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(autosarima1_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(autosarima1_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, autosarima1_box_forecasted))))
         print("MAE (test):  " + str(mae(test, autosarima1_box_forecasted)))
         print("sMAPE (test):  " + str(smape(test, autosarima1_box_forecasted)))
```

```
SARIMA (1, 1, 1) x (2, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1080.5448933279936
Test de Jarque-Bera (p-valor): 1.7693001979751832e-06
Test de Ljung-Box para k =  6 (p-valor): 0.15311810790555627
Test de Ljung-Box para k = 12 (p-valor): 0.3333204025803236

RMSE (test): 33.451003456851836
MAE (test):  20.846279715383275
sMAPE (test):  43.5275472737031
```

```
In [94]: forecast_plot(test, autosarima1_box_forecasted)
         plt.show()
```



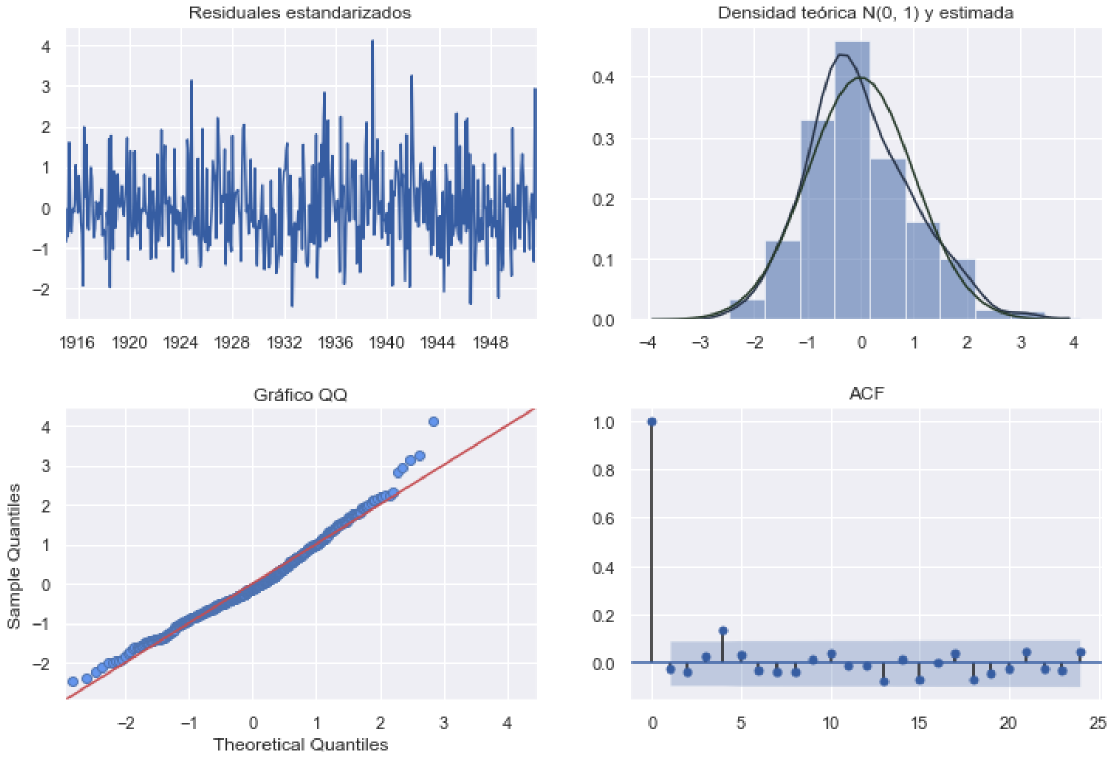
Procesos finales candidatos a generar la serie desestacionalizada: - **SARIMA (0, 1, 2) x (1, 0, 0)12** - **SARIMA (1, 1, 1) x (1, 0, 0)12**

SARIMA (0, 1, 2) x (1, 0, 0)12 Véase sarima5

SARIMA (1, 1, 1) x (1, 0, 0)12

```
In [95]: sarima8 = SARIMAX(bc_deseas, order = (1, 1, 1), seasonal_order = (1, 0, 0, 12))
         sarima8_model = sarima8.fit()

         sarima8_aic = sarima8_model.aic
         sarima8_fitted = sarima8_model.fittedvalues
         sarima8_resid = (sarima8_model.resid[12:] -
                          sarima8_model.resid[12:].mean()) / sarima8_model.resid[12:].std()
         sarima8_jb_test = jb(sarima8_resid)
         sarima8_lb_test = lb(sarima8_resid)

         sarima8_forecasted = sarima8_model.predict(split_date, end_date)
```

```
In [96]: resid_diag(sarima8_resid)
         plt.show()
```



```
In [97]: print(sarima8_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(1, 1, 1)x(1, 0, 0, 12)   Log Likelihood                 544.272
Date:                            Thu, 04 Jul 2019   AIC                          -1080.545
Time:                                    18:45:38   BIC                          -1064.099
Sample:                                01-01-1914   HQIC                         -1074.064
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.5705      0.043     13.176      0.000       0.486       0.655
ma.L1         -0.9548      0.017    -55.649      0.000      -0.988      -0.921
ar.S.L12       0.1694      0.048      3.546      0.000       0.076       0.263
sigma2         0.0052      0.000     16.586      0.000       0.005       0.006
===================================================================================
Ljung-Box (Q):                       47.67   Jarque-Bera (JB):                26.63
Prob(Q):                              0.19   Prob(JB):                         0.00
Heteroskedasticity (H):               1.31   Skew:                             0.53
Prob(H) (two-sided):                  0.10   Kurtosis:                         3.55
```

```
====================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

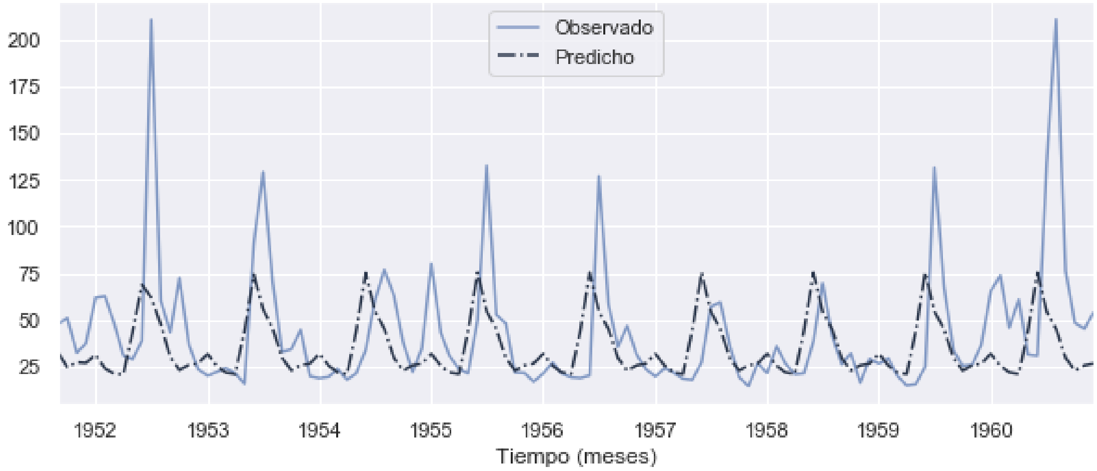
Incluímos la componente estacional en la predicción

```
In [98]: sarima8_seas_fore = sarima8_forecasted + bc_seasonality_forecast
         sarima8_box_forecasted = (bc_param *
                                   sarima8_seas_fore + 1) ** (1 / bc_param)
```

```
In [99]: print("SARIMA (1, 1, 1) x (1, 0, 0) (serie desestacionalizada)")
         print("")
         print("Observaciones ajustadas: " + str(len(train)))
         print("Observaciones predichas: " + str(len(test)))
         print("")
         print("AIC: " + str(sarima8_aic))
         print("Test de Jarque-Bera (p-valor): " + str(sarima8_jb_test[1]))
         print("Test de Ljung-Box para k =  6 (p-valor): " +
               str(sarima8_lb_test[1][6]))
         print("Test de Ljung-Box para k = 12 (p-valor): " +
               str(sarima8_lb_test[1][12]))
         print("")
         print("RMSE (test): " + str(sqrt(mse(test, sarima8_box_forecasted))))
         print("MAE (test):  " + str(mae(test, sarima8_box_forecasted)))
         print("sMAPE (test):  " + str(smape(test, sarima8_box_forecasted)))
```

```
SARIMA (1, 1, 1) x (1, 0, 0) (serie desestacionalizada)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1080.5448933279936
Test de Jarque-Bera (p-valor): 1.7693001979751832e-06
Test de Ljung-Box para k =  6 (p-valor): 0.15311810790555627
Test de Ljung-Box para k = 12 (p-valor): 0.3333204025803236

RMSE (test): 33.451003456851836
MAE (test):  20.846279715383275
sMAPE (test):  43.5275472737031
```

```
In [100]: forecast_plot(test, sarima8_box_forecasted)
          plt.show()
```



Opción 2. Modelo SARIMA.

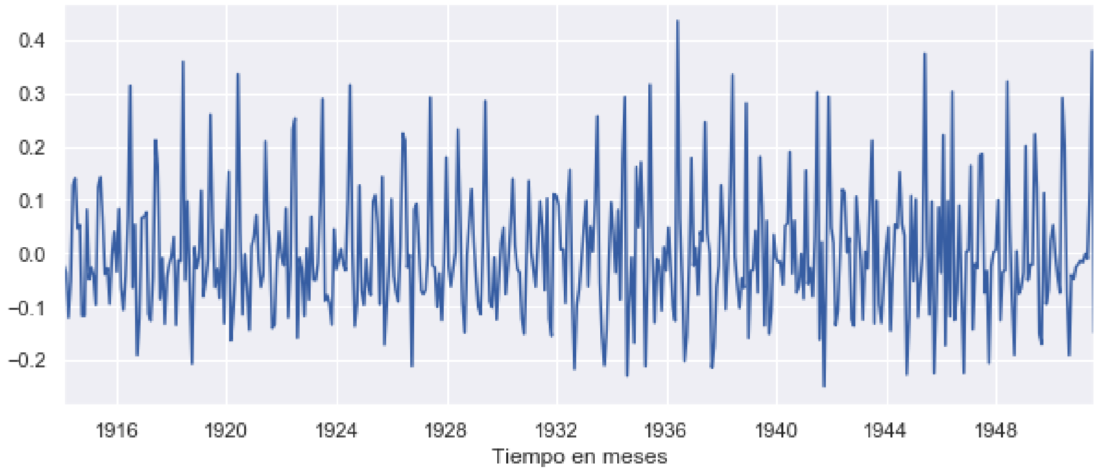
Test ADF y KPSS para determinar el tratamiento de la tendencia-ciclo

```
In [101]: adf_test = stationarity_test(bc_train)[0]
          kpss_test = stationarity_test(bc_train)[1]

          print("RESULTADOS DEL TEST AUMENTADO DE DICKEY FULLER")
          print("Estadístico de contraste: " + str(adf_test[0]))
          print("P-valor: " + str(adf_test[1]))
          print("")
          print("RESULTADOS DEL TEST KPSS")
          print("Estadístico de contraste: " + str(kpss_test[0]))
          print("P-valor: " + str(kpss_test[1]))
```

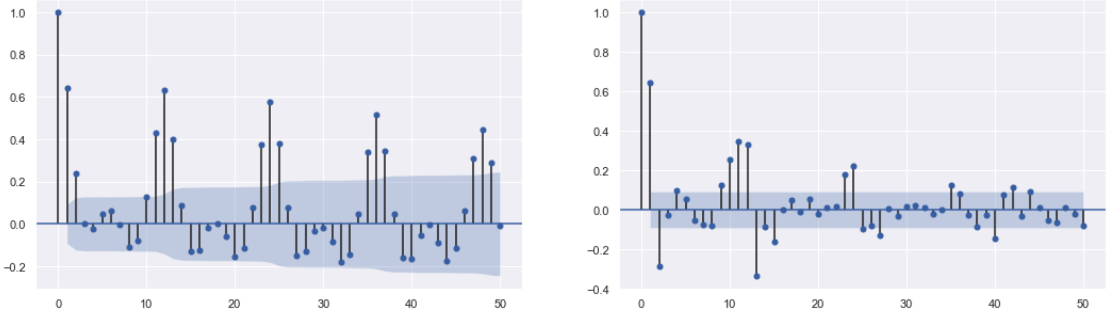
```
RESULTADOS DEL TEST AUMENTADO DE DICKEY FULLER
Estadístico de contraste: -3.812926799047772
P-valor: 0.0027777917233248674

RESULTADOS DEL TEST KPSS
Estadístico de contraste: 0.31804791289067974
P-valor: 0.1
```

```
In [102]: diff_bc_train = bc_train.diff(1).iloc[1:]
```

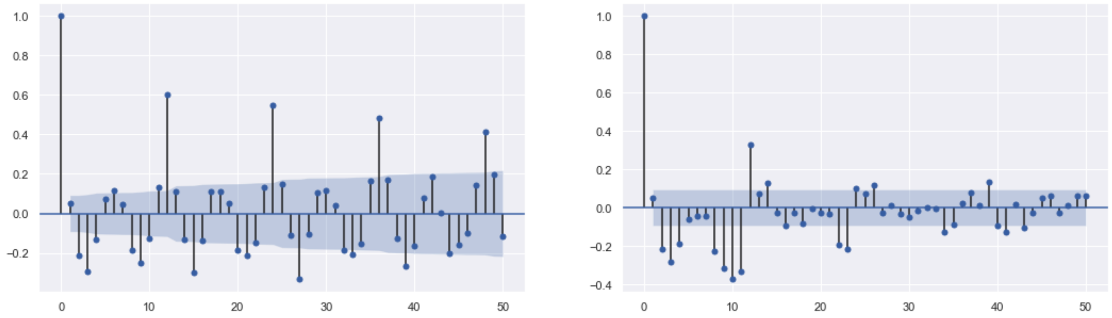
```
In [103]: tsplot(diff_bc_train)
```



```
In [104]: fig, ax = plt.subplots(1, 2, figsize=(18, 5))

          tsaplots.plot_acf(bc_train, lags = 50, title = "", ax=ax[0])
          tsaplots.plot_pacf(bc_train, lags = 50, title = "", ax=ax[1])


          plt.savefig("facs.png", dpi = 400)
          plt.show()
```



```
In [105]: fig, ax = plt.subplots(1, 2, figsize=(18, 5))

          tsaplots.plot_acf(diff_bc_train, lags = 50, title = "", ax=ax[0])
          tsaplots.plot_pacf(diff_bc_train, lags = 50, title = "", ax=ax[1])


          plt.savefig("facs_diff.png", dpi = 400)
          plt.show()
```

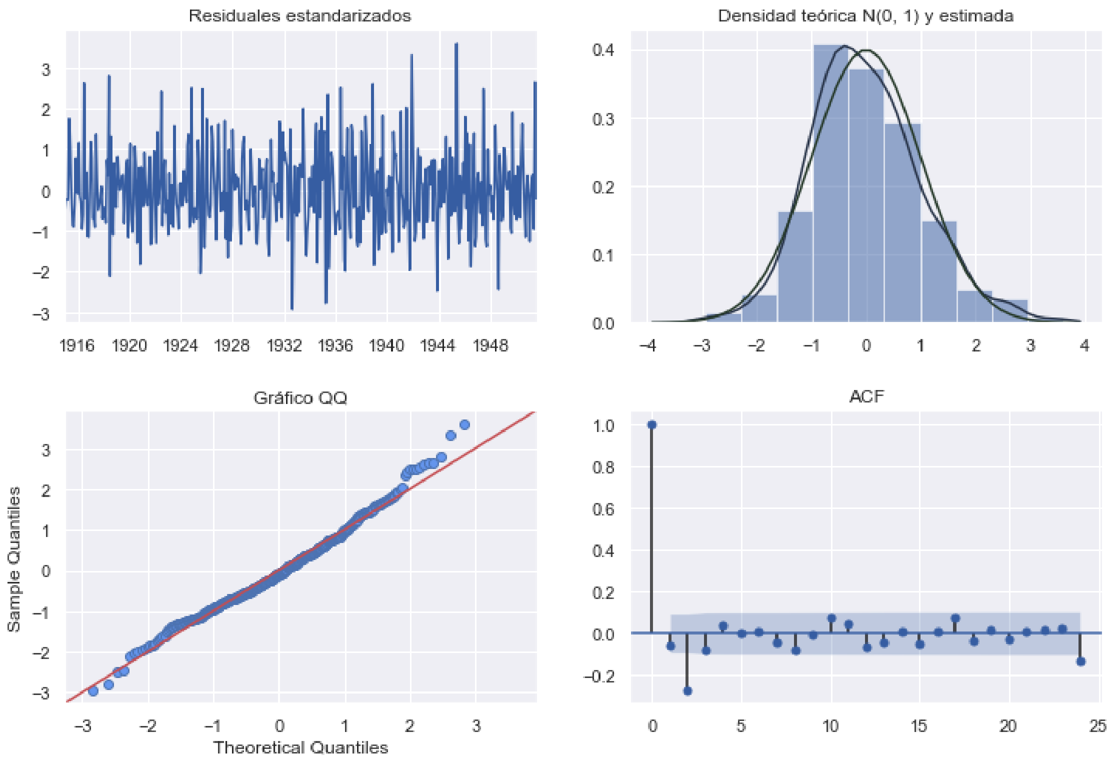


Identificación de ordenes Procesos candidatos a generar la serie: - **SARIMA (2, 0, 0) x (2, 0, 0)12 - SARIMA (1, 0, 1) x (2, 0, 0)12 - SARIMA (1, 0, 2) x (2, 0, 0)12 - SARIMA (3, 1, 0) x (2, 0, 0)12 - SARIMA (2, 1, 2) x (2, 0, 0)12**

SARIMA (2, 0, 0) x (2, 0, 0)12

```
In [106]: sarima9 = SARIMAX(bc_train, order = (2, 0, 0), seasonal_order = (2, 0, 0, 12))
          sarima9_model = sarima9.fit()

          sarima9_aic = sarima9_model.aic
          sarima9_fitted = sarima9_model.fittedvalues
          sarima9_resid = (sarima9_model.resid[12:] -
                           sarima9_model.resid[12:].mean()) / sarima9_model.resid[12:].std()
          sarima9_jb_test = jb(sarima9_resid)
          sarima9_lb_test = lb(sarima9_resid)

          sarima9_forecasted = sarima9_model.predict(split_date, end_date)
          sarima9_box_forecasted = (bc_param * sarima9_forecasted + 1) ** (1 / bc_param)
```

```
In [107]: resid_diag(sarima9_resid)
          plt.show()
```



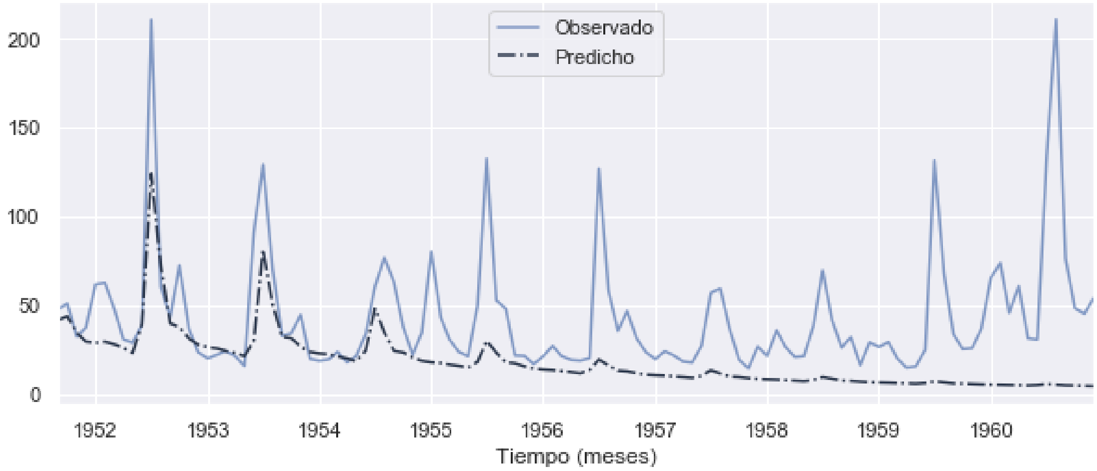
```
In [108]: print(sarima9_model.summary())

                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(2, 0, 0)x(2, 0, 0, 12)   Log Likelihood                 456.353
Date:                            Thu, 04 Jul 2019   AIC                           -902.707
Time:                                    18:45:42   BIC                           -882.138
Sample:                                01-01-1914   HQIC                          -894.601
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.8028      0.049     16.306      0.000       0.706       0.899
ar.L2          0.1824      0.049      3.736      0.000       0.087       0.278
ar.S.L12       0.4422      0.042     10.457      0.000       0.359       0.525
ar.S.L24       0.3433      0.043      8.063      0.000       0.260       0.427
sigma2         0.0075      0.000     16.334      0.000       0.007       0.008
===================================================================================
Ljung-Box (Q):                       90.02   Jarque-Bera (JB):                 15.65
Prob(Q):                              0.00   Prob(JB):                          0.00
Heteroskedasticity (H):               1.22   Skew:                              0.39
```

```
Prob(H) (two-sided):                  0.22   Kurtosis:                         3.47
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [109]: print("SARIMA (2, 0, 0) x (2, 0, 0)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(sarima9_aic))
          print("Test de Jarque-Bera (p-valor): " +
                str(sarima9_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(sarima9_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(sarima9_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, sarima9_box_forecasted))))
          print("MAE (test):  " + str(mae(test, sarima9_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, sarima9_box_forecasted)))
```

```
SARIMA (2, 0, 0) x (2, 0, 0)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -902.7066634500046
Test de Jarque-Bera (p-valor): 0.00035697719434374587
Test de Ljung-Box para k =  6 (p-valor): 2.089838109582137e-06
Test de Ljung-Box para k = 12 (p-valor): 6.379352048463386e-06

RMSE (test): 40.02521988513189
MAE (test):  25.897865650314316
sMAPE (test):  79.37610123282874
```

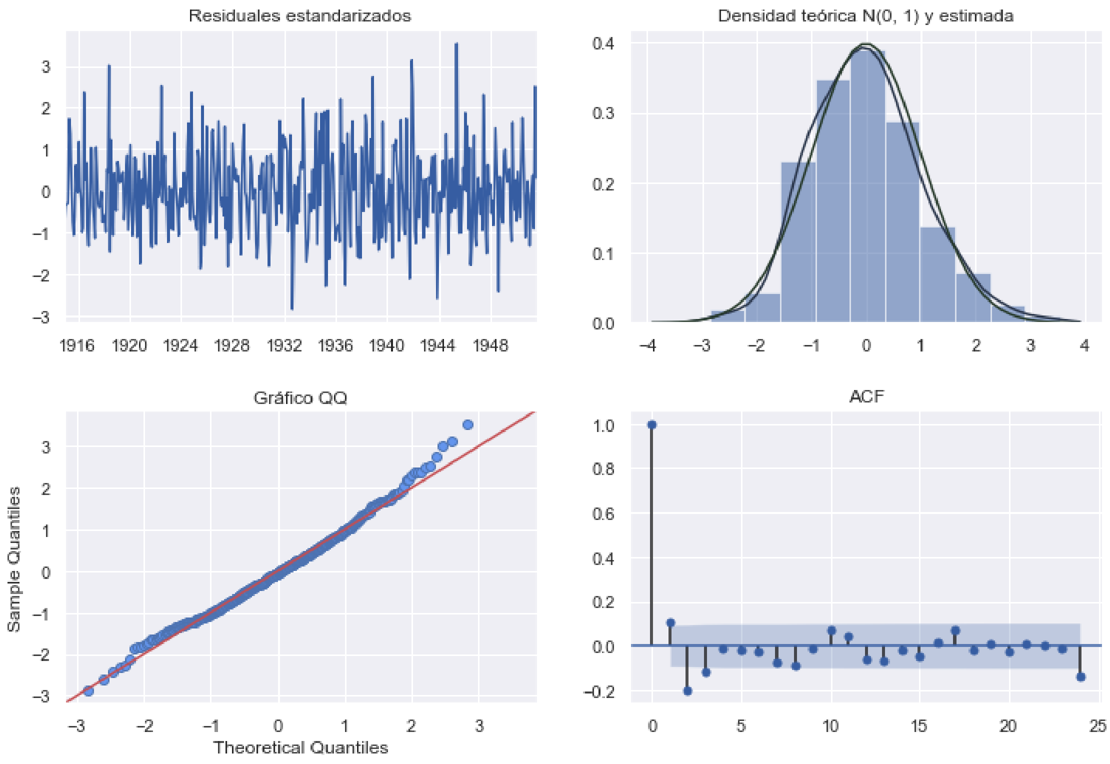
```
In [110]: forecast_plot(test, sarima9_box_forecasted)
          plt.show()
```



SARIMA (1, 0, 1) x (2, 0, 0)12

```
In [111]: sarima10 = SARIMAX(bc_train, order = (1, 0, 1), seasonal_order = (2, 0, 0, 12))
          sarima10_model = sarima10.fit()

          sarima10_aic = sarima10_model.aic
          sarima10_fitted = sarima10_model.fittedvalues
          sarima10_resid = (sarima10_model.resid[12:] -
                            sarima10_model.resid[12:].mean()) / sarima10_model.resid[12:].std()
          sarima10_jb_test = jb(sarima10_resid)
          sarima10_lb_test = lb(sarima10_resid)

          sarima10_forecasted = sarima10_model.predict(split_date, end_date)
          sarima10_box_forecasted = (bc_param * sarima10_forecasted + 1) ** (1 / bc_param)
```

```
In [112]: resid_diag(sarima10_resid)
          plt.show()
```



```
In [113]: print(sarima10_model.summary())
```

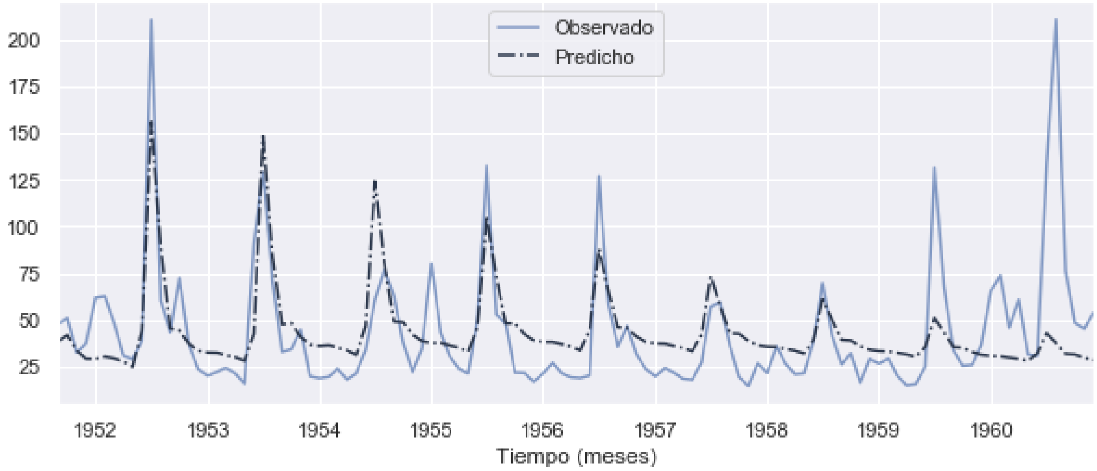
```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(1, 0, 1)x(2, 0, 0, 12)   Log Likelihood                 464.686
Date:                            Thu, 04 Jul 2019   AIC                           -919.373
Time:                                    18:45:44   BIC                           -898.804
Sample:                                01-01-1914   HQIC                          -911.268
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.9977      0.004    223.033      0.000       0.989       1.006
ma.L1         -0.4223      0.042    -10.079      0.000      -0.504      -0.340
ar.S.L12       0.4405      0.040     10.976      0.000       0.362       0.519
ar.S.L24       0.3570      0.041      8.677      0.000       0.276       0.438
sigma2         0.0072      0.000     15.738      0.000       0.006       0.008
===================================================================================
Ljung-Box (Q):                       85.42   Jarque-Bera (JB):                 10.18
Prob(Q):                              0.00   Prob(JB):                          0.01
Heteroskedasticity (H):               1.28   Skew:                              0.34
```

```
Prob(H) (two-sided):                  0.13   Kurtosis:                         3.28
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [114]: print("SARIMA (1, 0, 1) x (2, 0, 0)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(sarima10_aic))
          print("Test de Jarque-Bera (p-valor): " + str(sarima10_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(sarima10_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(sarima10_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, sarima10_box_forecasted))))
          print("MAE (test):  " + str(mae(test, sarima10_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, sarima10_box_forecasted)))
```

```
SARIMA (1, 0, 1) x (2, 0, 0)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -919.3728280518599
Test de Jarque-Bera (p-valor): 0.005843389176126087
Test de Ljung-Box para k =  6 (p-valor): 5.763337363937166e-05
Test de Ljung-Box para k = 12 (p-valor): 7.224410996546479e-05

RMSE (test): 27.449553412296037
MAE (test):  17.665500442180765
sMAPE (test):  39.854219835874
```

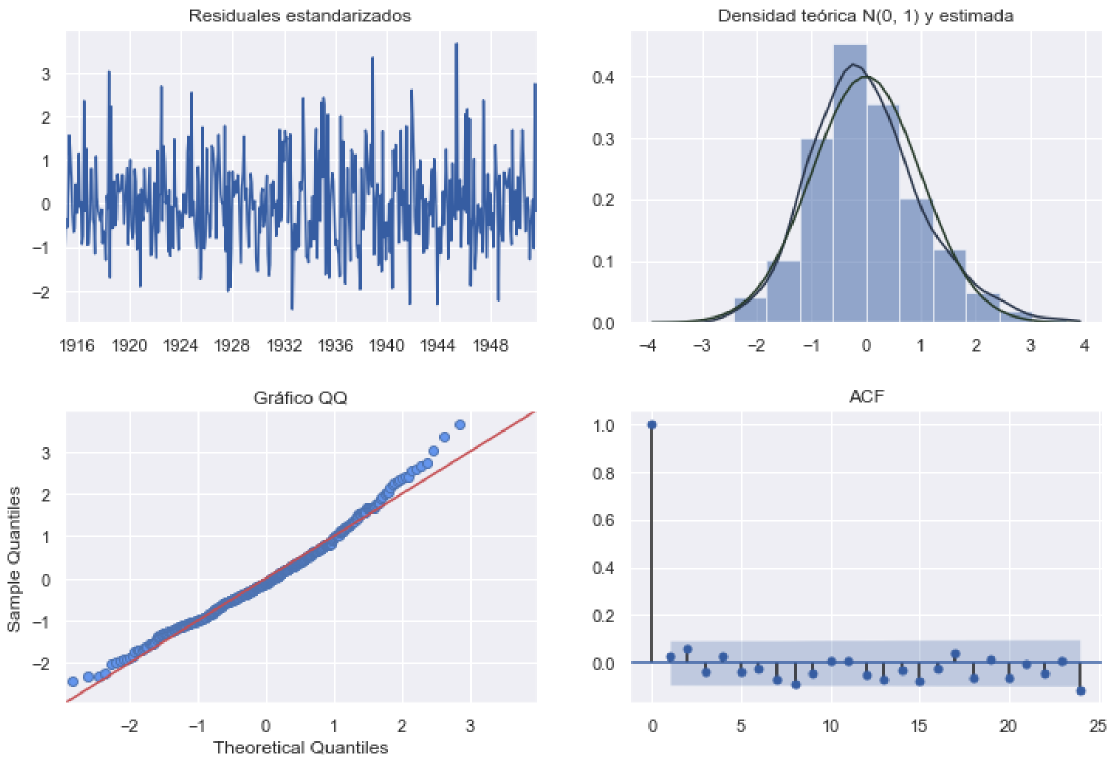
```
In [115]: forecast_plot(test, sarima10_box_forecasted)
          plt.show()
```



SARIMA (1, 0, 2) x (2, 0, 0)12

```
In [116]: sarima11 = SARIMAX(bc_train, order = (1, 0, 2), seasonal_order = (2, 0, 0, 12))
          sarima11_model = sarima11.fit()

          sarima11_aic = sarima11_model.aic
          sarima11_fitted = sarima11_model.fittedvalues
          sarima11_resid = (sarima11_model.resid[12:] -
                            sarima11_model.resid[12:].mean()) / sarima11_model.resid[12:].std()
          sarima11_jb_test = jb(sarima11_resid)
          sarima11_lb_test = lb(sarima11_resid)

          sarima11_forecasted = sarima11_model.predict(split_date, end_date)
          sarima11_box_forecasted = (bc_param * sarima11_forecasted + 1) ** (1 / bc_param)
```

```
In [117]: resid_diag(sarima11_resid)
          plt.show()
```



```
In [118]: print(sarima11_model.summary())
```

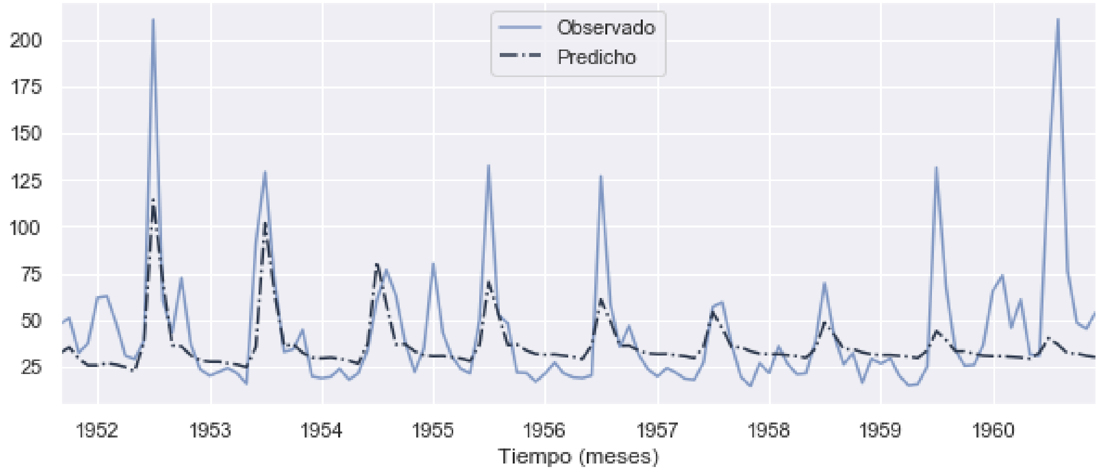
```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                                 value   No. Observations:              452
Model:             SARIMAX(1, 0, 2)x(2, 0, 0, 12)   Log Likelihood             482.315
Date:                               Thu, 04 Jul 2019   AIC                       -952.630
Time:                                       18:45:47   BIC                       -927.948
Sample:                                   01-01-1914   HQIC                      -942.903
                                        - 08-01-1951
Covariance Type:                                 opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.9993      0.002    505.130      0.000       0.995       1.003
ma.L1         -0.3539      0.043     -8.244      0.000      -0.438      -0.270
ma.L2         -0.3131      0.046     -6.816      0.000      -0.403      -0.223
ar.S.L12       0.4166      0.039     10.556      0.000       0.339       0.494
ar.S.L24       0.3422      0.042      8.216      0.000       0.261       0.424
sigma2         0.0067      0.000     16.242      0.000       0.006       0.007
===================================================================================
Ljung-Box (Q):                       52.13   Jarque-Bera (JB):                23.12
Prob(Q):                              0.09   Prob(JB):                         0.00
```

```
Heteroskedasticity (H):               1.28   Skew:                             0.50
Prob(H) (two-sided):                  0.13   Kurtosis:                         3.47
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [119]: print("SARIMA (1, 0, 2) x (3, 0, 0)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(sarima11_aic))
          print("Test de Jarque-Bera (p-valor): " + str(sarima11_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(sarima11_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(sarima11_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, sarima11_box_forecasted))))
          print("MAE (test):  " + str(mae(test, sarima11_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, sarima11_box_forecasted)))
```

```
SARIMA (1, 0, 2) x (3, 0, 0)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -952.6298121517603
Test de Jarque-Bera (p-valor): 9.727564739286202e-06
Test de Ljung-Box para k =  6 (p-valor): 0.5646576512181141
Test de Ljung-Box para k = 12 (p-valor): 0.3835095315373295

RMSE (test): 28.661457482477648
MAE (test):  16.488395863188817
sMAPE (test):  35.81959586469082
```

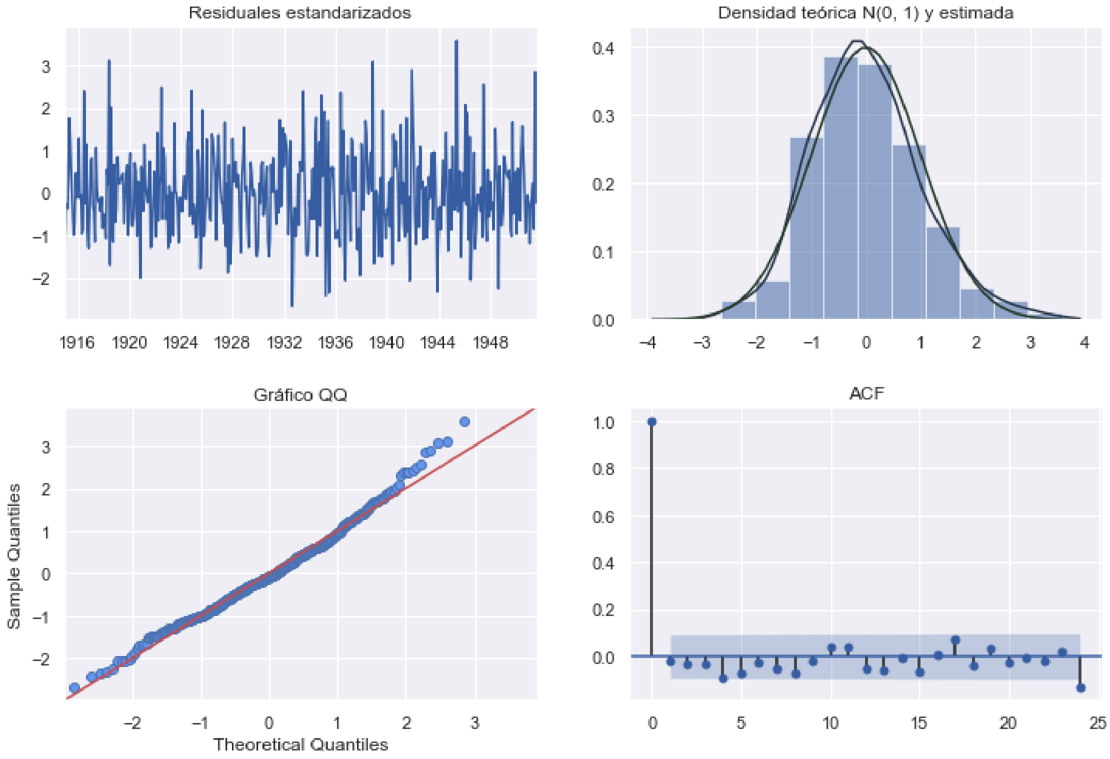
```
In [120]: forecast_plot(test, sarima11_box_forecasted)
          plt.show()
```



SARIMA (3, 1, 0) x (2, 0, 0)12

```
In [121]: sarima12 = SARIMAX(bc_train, order = (3, 1, 0), seasonal_order = (2, 0, 0, 12))
          sarima12_model = sarima12.fit()

          sarima12_aic = sarima12_model.aic
          sarima12_fitted = sarima12_model.fittedvalues
          sarima12_resid = (sarima12_model.resid[12:] -
                            sarima12_model.resid[12:].mean()) / sarima12_model.resid[12:].std()
          sarima12_jb_test = jb(sarima12_resid)
          sarima12_lb_test = lb(sarima12_resid)

          sarima12_forecasted = sarima12_model.predict(split_date, end_date)
          sarima12_box_forecasted = (bc_param * sarima12_forecasted + 1) ** (1 / bc_param)
```

```
In [122]: resid_diag(sarima12_resid)
          plt.show()
```



```
In [123]: print(sarima12_model.summary())
```

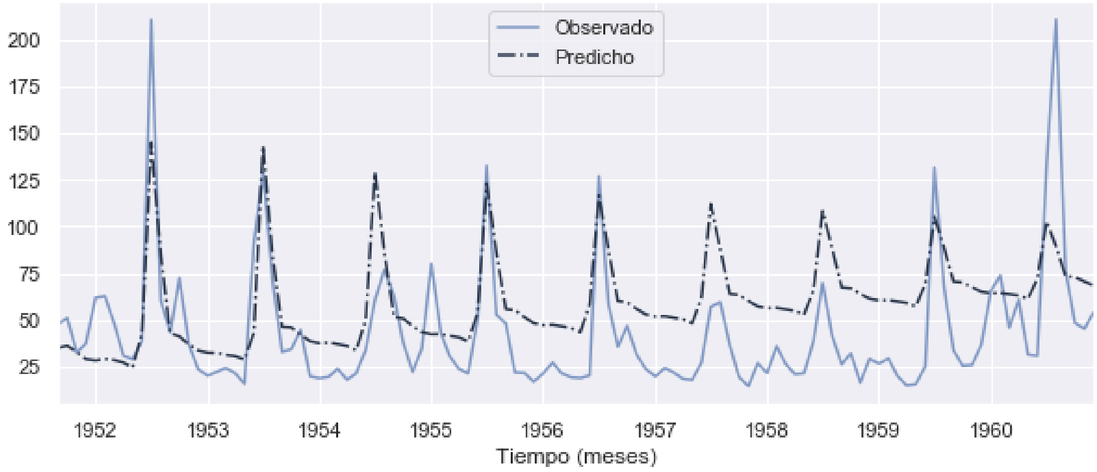
```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(3, 1, 0)x(2, 0, 0, 12)   Log Likelihood                 478.387
Date:                            Thu, 04 Jul 2019   AIC                           -944.773
Time:                                    18:45:49   BIC                           -920.104
Sample:                                01-01-1914   HQIC                          -935.051
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.2784      0.047     -5.892      0.000      -0.371      -0.186
ar.L2         -0.2951      0.046     -6.468      0.000      -0.384      -0.206
ar.L3         -0.1674      0.048     -3.514      0.000      -0.261      -0.074
ar.S.L12       0.4443      0.041     10.775      0.000       0.364       0.525
ar.S.L24       0.3332      0.043      7.734      0.000       0.249       0.418
sigma2         0.0069      0.000     16.246      0.000       0.006       0.008
===================================================================================
Ljung-Box (Q):                       62.17   Jarque-Bera (JB):                16.70
Prob(Q):                              0.01   Prob(JB):                         0.00
```

```
Heteroskedasticity (H):              1.25   Skew:                             0.42
Prob(H) (two-sided):                 0.17   Kurtosis:                         3.44
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [124]: print("SARIMA (3, 1, 0) x (3, 0, 0)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(sarima12_aic))
          print("Test de Jarque-Bera (p-valor): " + str(sarima12_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(sarima12_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(sarima12_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, sarima12_box_forecasted))))
          print("MAE (test):  " + str(mae(test, sarima12_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, sarima12_box_forecasted)))
```

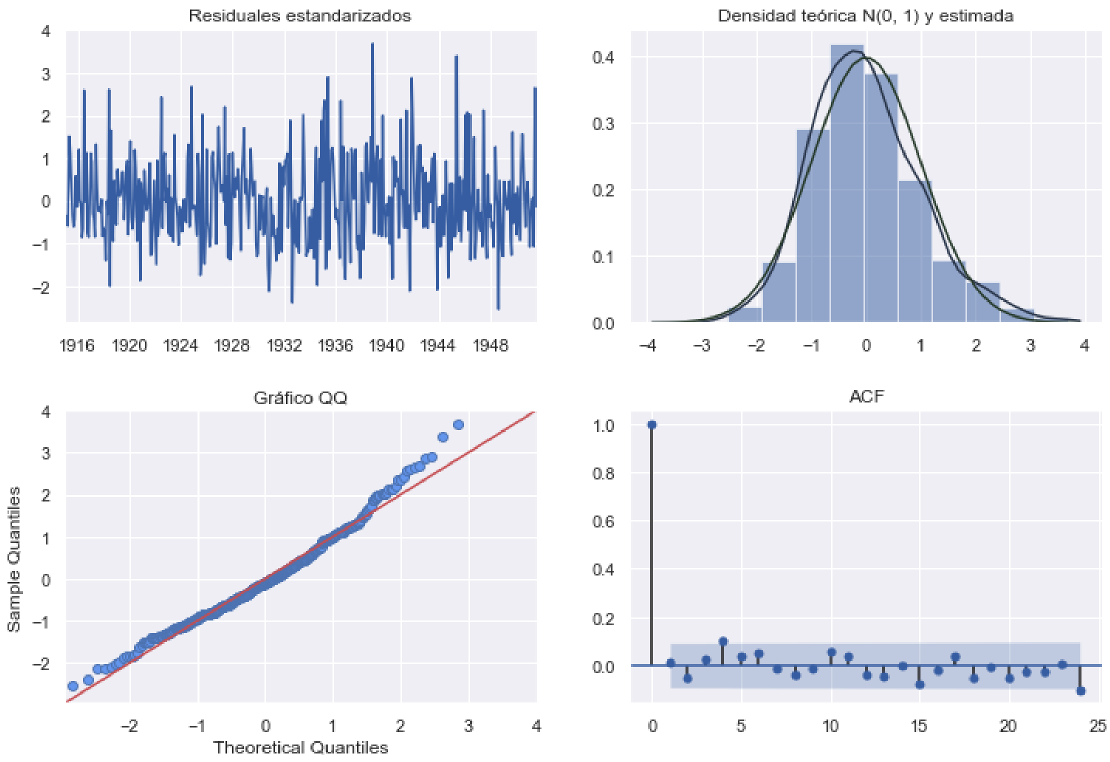
```
SARIMA (3, 1, 0) x (3, 0, 0)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -944.7731123922366
Test de Jarque-Bera (p-valor): 0.00026187824992419 82
Test de Ljung-Box para k =  6 (p-valor): 0.24156163398839642
Test de Ljung-Box para k = 12 (p-valor): 0.2557396125217794

RMSE (test): 30.131423011307717
MAE (test):  24.87668745101635
sMAPE (test):  53.169159504076674
```

```
In [125]: forecast_plot(test, sarima12_box_forecasted)
          plt.show()
```



SARIMA (2, 1, 2) x (2, 0, 0)12

```
In [126]: sarima13 = SARIMAX(bc_train, order = (2, 1, 2), seasonal_order = (2, 0, 0, 12))
          sarima13_model = sarima13.fit()

          sarima13_aic = sarima13_model.aic
          sarima13_fitted = sarima13_model.fittedvalues
          sarima13_resid = (sarima13_model.resid[12:] -
                            sarima13_model.resid[12:].mean()) / sarima13_model.resid[12:].std()
          sarima13_jb_test = jb(sarima13_resid)
          sarima13_lb_test = lb(sarima13_resid)

          sarima13_forecasted = sarima13_model.predict(split_date, end_date)
          sarima13_box_forecasted = (bc_param * sarima13_forecasted + 1) ** (1 / bc_param)

In [127]: resid_diag(sarima13_resid)
          plt.show()
```



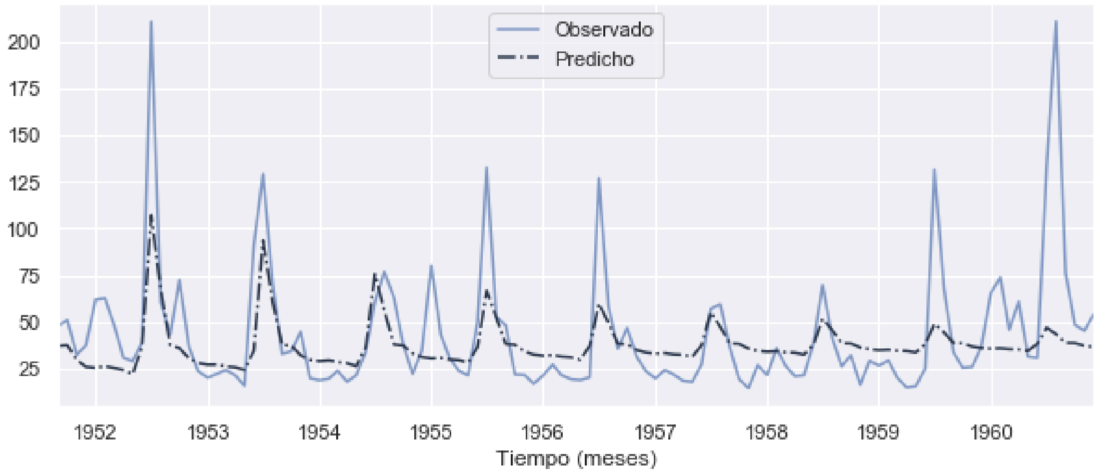
```
In [128]: print(sarima13_model.summary())

                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(2, 1, 2)x(2, 0, 0, 12)   Log Likelihood                 497.181
Date:                            Thu, 04 Jul 2019   AIC                           -980.363
Time:                                    18:45:52   BIC                           -951.582
Sample:                                01-01-1914   HQIC                          -969.020
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.3731      0.073     -5.104      0.000      -0.516      -0.230
ar.L2          0.5758      0.059      9.731      0.000       0.460       0.692
ma.L1         -0.0203      0.145     -0.140      0.888      -0.304       0.263
ma.L2         -0.9793      0.143     -6.838      0.000      -1.260      -0.699
ar.S.L12       0.4327      0.042     10.420      0.000       0.351       0.514
ar.S.L24       0.3139      0.042      7.415      0.000       0.231       0.397
sigma2         0.0063      0.001      6.368      0.000       0.004       0.008
===================================================================================
Ljung-Box (Q):                       47.39   Jarque-Bera (JB):                 26.08
```

```
Prob(Q):                              0.20   Prob(JB):                         0.00
Heteroskedasticity (H):               1.26   Skew:                             0.53
Prob(H) (two-sided):                  0.15   Kurtosis:                         3.50
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [129]: print("SARIMA (2, 1, 2) x (2, 0, 0)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(sarima9_aic))
          print("Test de Jarque-Bera (p-valor): " + str(sarima13_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(sarima13_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(sarima13_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, sarima13_box_forecasted))))
          print("MAE (test):  " + str(mae(test, sarima13_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, sarima13_box_forecasted)))
```

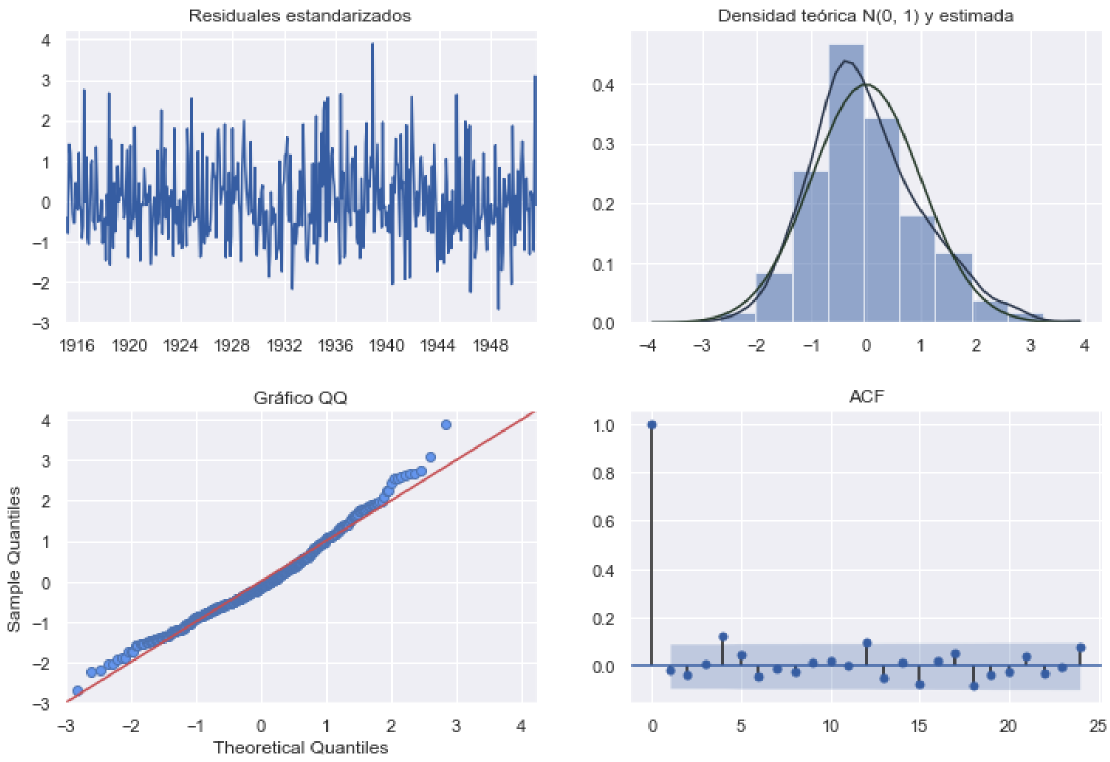
```
SARIMA (2, 1, 2) x (2, 0, 0)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -902.7066634500046
Test de Jarque-Bera (p-valor): 2.416370941312278e-06
Test de Ljung-Box para k =  6 (p-valor): 0.34316962540957
Test de Ljung-Box para k = 12 (p-valor): 0.48554474723781593

RMSE (test): 28.209171874266634
MAE (test):  16.694862572380313
sMAPE (test):  36.412646030162946
```

```
In [130]: forecast_plot(test, sarima13_box_forecasted)
          plt.show()
```



Autoarima

```
In [131]: auto = auto_arima(bc_train, m = 12, seasonal = True)
          auto

Out[131]: ARIMA(callback=None, disp=0, maxiter=None, method=None, order=(2, 1, 2),
             out_of_sample_size=0, scoring='mse', scoring_args={},
             seasonal_order=(2, 0, 2, 12), solver='lbfgs', start_params=None,
             suppress_warnings=False, transparams=True, trend=None,
             with_intercept=True)

In [132]: autosarima2 = SARIMAX(bc_train, order = (2, 1, 2), seasonal_order = (2, 0, 2, 12))
          autosarima2_model = autosarima2.fit()

          autosarima2_aic = autosarima2_model.aic
          autosarima2_fitted = autosarima2_model.fittedvalues
          autosarima2_resid = (autosarima2_model.resid[12:] -
                               autosarima2_model.resid[12:].mean()) / autosarima2_model.resid[12
          autosarima2_jb_test = jb(autosarima2_resid)
          autosarima2_lb_test = lb(autosarima2_resid)

          autosarima2_forecasted = autosarima2_model.predict(split_date, end_date)
          autosarima2_box_forecasted = (bc_param * autosarima2_forecasted + 1) ** (1 / bc_param)

In [133]: resid_diag(autosarima2_resid)
          plt.savefig("resid_best.png", dpi=400)
          plt.show()
```



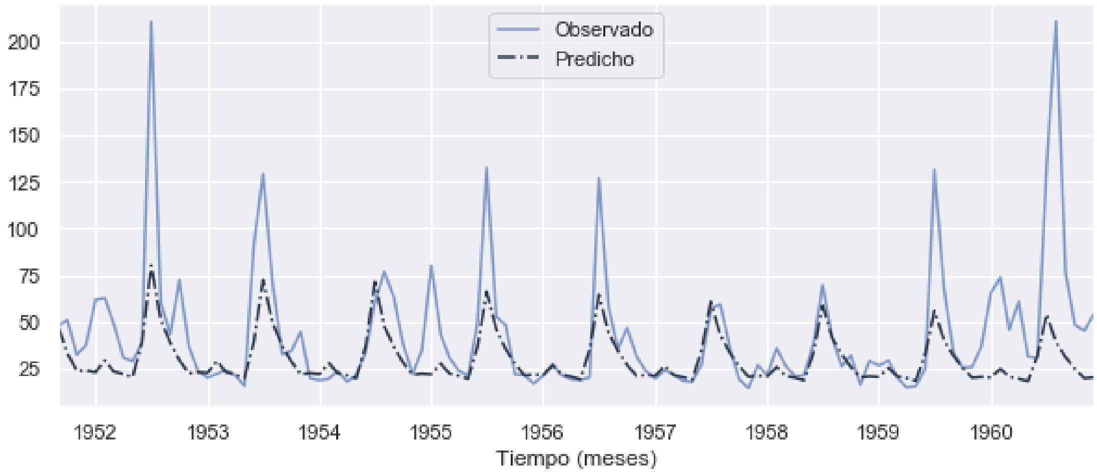
```
In [134]: print(autosarima2_model.summary())

                                 Statespace Model Results
==========================================================================================
Dep. Variable:                            value   No. Observations:                  452
Model:             SARIMAX(2, 1, 2)x(2, 0, 2, 12)   Log Likelihood                 508.362
Date:                          Thu, 04 Jul 2019   AIC                           -998.724
Time:                                  18:47:08   BIC                           -961.721
Sample:                              01-01-1914   HQIC                          -984.141
                                   - 08-01-1951
Covariance Type:                            opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.0699     16.423      0.004      0.997     -32.118      32.258
ar.L2          0.2944      9.546      0.031      0.975     -18.416      19.004
ma.L1         -0.4520     16.408     -0.028      0.978     -32.610      31.706
ma.L2         -0.4921     15.802     -0.031      0.975     -31.463      30.478
ar.S.L12       0.2502      0.371      0.675      0.500      -0.476       0.977
ar.S.L24       0.7220      0.365      1.978      0.048       0.007       1.437
ma.S.L12      -0.0607      0.350     -0.174      0.862      -0.747       0.625
ma.S.L24      -0.6413      0.285     -2.249      0.024      -1.200      -0.082
sigma2         0.0059      0.000     15.570      0.000       0.005       0.007
```

```
===================================================================================
Ljung-Box (Q):                       57.04   Jarque-Bera (JB):                25.93
Prob(Q):                              0.04   Prob(JB):                         0.00
Heteroskedasticity (H):               1.34   Skew:                             0.55
Prob(H) (two-sided):                  0.08   Kurtosis:                         3.42
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [135]: print("SARIMA (2, 1, 2) x (2, 0, 0)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(autosarima2_aic))
          print("Test de Jarque-Bera (p-valor): " + str(autosarima2_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(autosarima2_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(autosarima2_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, autosarima2_box_forecasted))))
          print("MAE (test):  " + str(mae(test, autosarima2_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, autosarima2_box_forecasted)))
```

```
SARIMA (2, 1, 2) x (2, 0, 0)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -998.7244026526776
Test de Jarque-Bera (p-valor): 1.925192263208415e-06
Test de Ljung-Box para k =  6 (p-valor): 0.21515469923533817
Test de Ljung-Box para k = 12 (p-valor): 0.2760923446894693

RMSE (test): 29.9846699649396
MAE (test):  16.04973322417936
sMAPE (test):  33.00127011320319
```

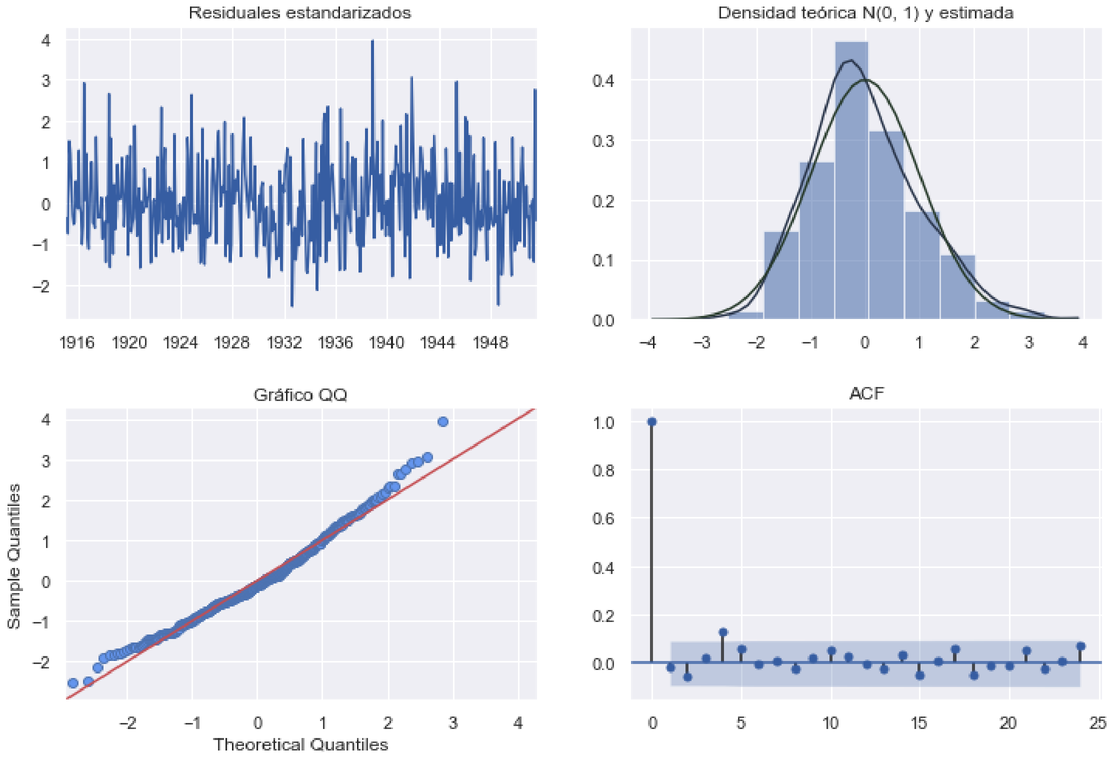
```
In [136]: forecast_plot(test, autosarima2_box_forecasted)
          plt.show()
```



- **SARIMA (2, 1, 2) x (2, 0, 1)12**

```
In [137]: sarima14 = SARIMAX(bc_train, order = (2, 1, 2), seasonal_order = (2, 0, 1, 12))
          sarima14_model = sarima14.fit()

          sarima14_aic = sarima14_model.aic
          sarima14_fitted = sarima14_model.fittedvalues
          sarima14_resid = (sarima14_model.resid[12:] -
                            sarima14_model.resid[12:].mean()) / sarima14_model.resid[12:].std()
          sarima14_jb_test = jb(sarima14_resid)
          sarima14_lb_test = lb(sarima14_resid)

          sarima14_forecasted = sarima14_model.predict(split_date, end_date)
          sarima14_box_forecasted = (bc_param * sarima14_forecasted + 1) ** (1 / bc_param)
```

```
In [138]: resid_diag(sarima14_resid)
          plt.savefig("resid_best.png", dpi=400)
          plt.show()
```



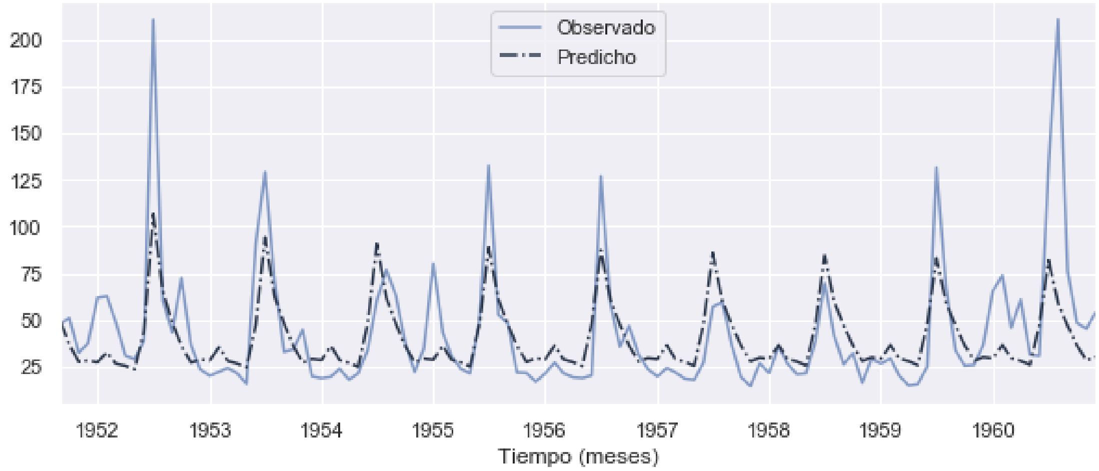
```
In [139]: print(sarima14_model.summary())
```

```
                                 Statespace Model Results
==========================================================================================
Dep. Variable:                              value   No. Observations:                  452
Model:             SARIMAX(2, 1, 2)x(2, 0, 1, 12)   Log Likelihood                 511.934
Date:                            Thu, 04 Jul 2019   AIC                          -1007.869
Time:                                    18:47:13   BIC                           -974.977
Sample:                                01-01-1914   HQIC                          -994.906
                                     - 08-01-1951
Covariance Type:                              opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1         -0.3689      0.050     -7.386      0.000      -0.467      -0.271
ar.L2          0.6247      0.041     15.366      0.000       0.545       0.704
ma.L1         -0.0083      0.104     -0.080      0.936      -0.213       0.196
ma.L2         -0.9916      0.123     -8.043      0.000      -1.233      -0.750
ar.S.L12       1.1777      0.059     20.078      0.000       1.063       1.293
ar.S.L24      -0.1918      0.054     -3.538      0.000      -0.298      -0.086
ma.S.L12      -0.8739      0.049    -17.853      0.000      -0.970      -0.778
sigma2         0.0058      0.001      7.970      0.000       0.004       0.007
===================================================================================
Ljung-Box (Q):                       47.30   Jarque-Bera (JB):                24.65
Prob(Q):                              0.20   Prob(JB):                         0.00
Heteroskedasticity (H):               1.26   Skew:                             0.53
Prob(H) (two-sided):                  0.16   Kurtosis:                         3.42
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

```
In [140]: print("SARIMA (2, 1, 2) x (2, 0, 1)")
          print("")
          print("Observaciones ajustadas: " + str(len(train)))
          print("Observaciones predichas: " + str(len(test)))
          print("")
          print("AIC: " + str(sarima14_aic))
          print("Test de Jarque-Bera (p-valor): " + str(sarima14_jb_test[1]))
          print("Test de Ljung-Box para k =  6 (p-valor): " +
                str(sarima14_lb_test[1][6]))
          print("Test de Ljung-Box para k = 12 (p-valor): " +
                str(sarima14_lb_test[1][12]))
          print("")
          print("RMSE (test): " + str(sqrt(mse(test, sarima14_box_forecasted))))
          print("MAE (test):  " + str(mae(test, sarima14_box_forecasted)))
          print("sMAPE (test):  " + str(smape(test, sarima14_box_forecasted)))
```

```
SARIMA (2, 1, 2) x (2, 0, 1)

Observaciones ajustadas: 452
Observaciones predichas: 112

AIC: -1007.8686734324268
Test de Jarque-Bera (p-valor): 2.8743969410190724e-06
Test de Ljung-Box para k =  6 (p-valor): 0.15446746927782673
Test de Ljung-Box para k = 12 (p-valor): 0.45015879016303895

RMSE (test): 24.823649386547004
MAE (test):  15.352171959400692
sMAPE (test):  33.52102774477333
```

```
In [141]: forecast_plot(test, sarima14_box_forecasted)
          plt.show()
```


Observado
Predicho
200
175
150
125
100
75
50
25
1952
1953
1954
1955
1956
1957
1958
1959
1960
Tiempo (meses)