In [1]:
```python
import os
import kagglehub
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from scipy.special import inv_boxcox
from scipy.stats import boxcox, shapiro
from statsmodels.tsa.stattools import adfuller
from statsmodels.tsa.statespace.sarimax import SARIMAX
from statsmodels.stats.diagnostic import acorr_ljungbox
from statsmodels.tsa.seasonal import seasonal_decompose
from pmdarima.preprocessing import BoxCoxEndogTransformer
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
```

Get Data

In [2]:
```python
path = kagglehub.dataset_download("vikramamin/arima-time-series-mumbai-temperature")
print("Path to dataset files:", path)
```

```
Path to dataset files: /Users/carlosmayorga/.cache/kagglehub/datasets/vikramamin/arima-t
ime-series-mumbai-temperature/versions/1
```

In [3]:
```python
print(os.listdir(path))
```

```
['rainfall.csv']
```

In [4]:
```python
file_path = os.path.join(path, "rainfall.csv")  # adjust name if needed
data = pd.read_csv(file_path)
print(data.info())
```

```
<class 'pandas.DataFrame'>
RangeIndex: 1781 entries, 0 to 1780
Data columns (total 10 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   datetime          1781 non-null   str    
 1   temp              1781 non-null   float64
 2   dew               1781 non-null   float64
 3   humidity          1781 non-null   float64
 4   sealevelpressure  1781 non-null   float64
 5   winddir           1781 non-null   float64
 6   solarradiation    1781 non-null   float64
 7   windspeed         1781 non-null   float64
 8   precipprob        1781 non-null   int64  
 9   preciptype        1781 non-null   int64  
dtypes: float64(7), int64(2), str(1)
memory usage: 156.7 KB
None
```

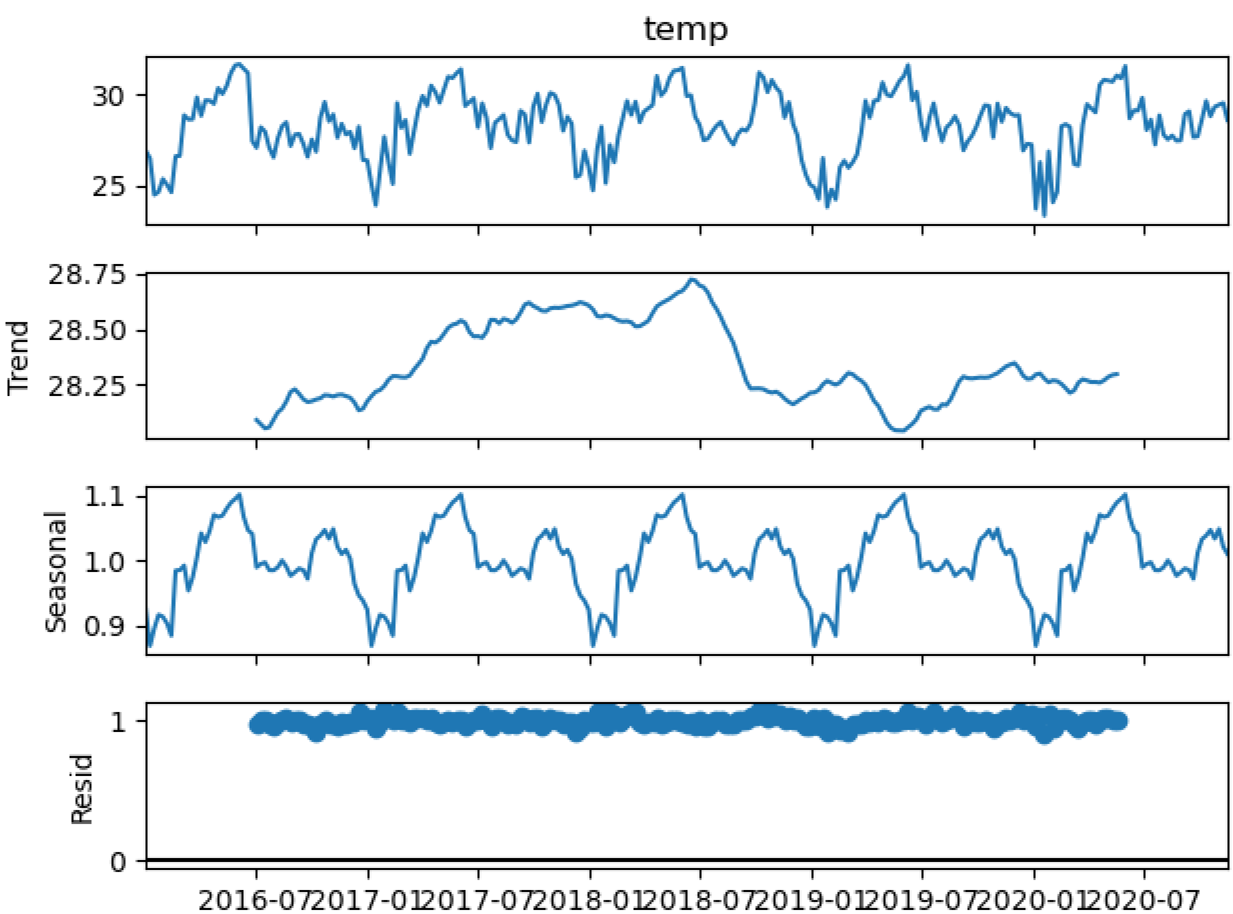
In [5]:
```python
data['date'] = pd.to_datetime(data['datetime'], dayfirst=True)

ts = data.set_index("date")["temp"]
ts = ts.resample("W").mean()
print(ts.info())
print('\n')
print(ts.head());
```

```
<class 'pandas.Series'>
DatetimeIndex: 255 entries, 2016-01-03 to 2020-11-15
Freq: W-SUN
Series name: temp
```

```
Non-Null Count  Dtype
--------------  -----
255 non-null    float64
dtypes: float64(1)
memory usage: 4.0 KB
None


date
2016-01-03    26.900000
2016-01-10    26.485714
2016-01-17    24.485714
2016-01-24    24.642857
2016-01-31    25.357143
Freq: W-SUN, Name: temp, dtype: float64
```

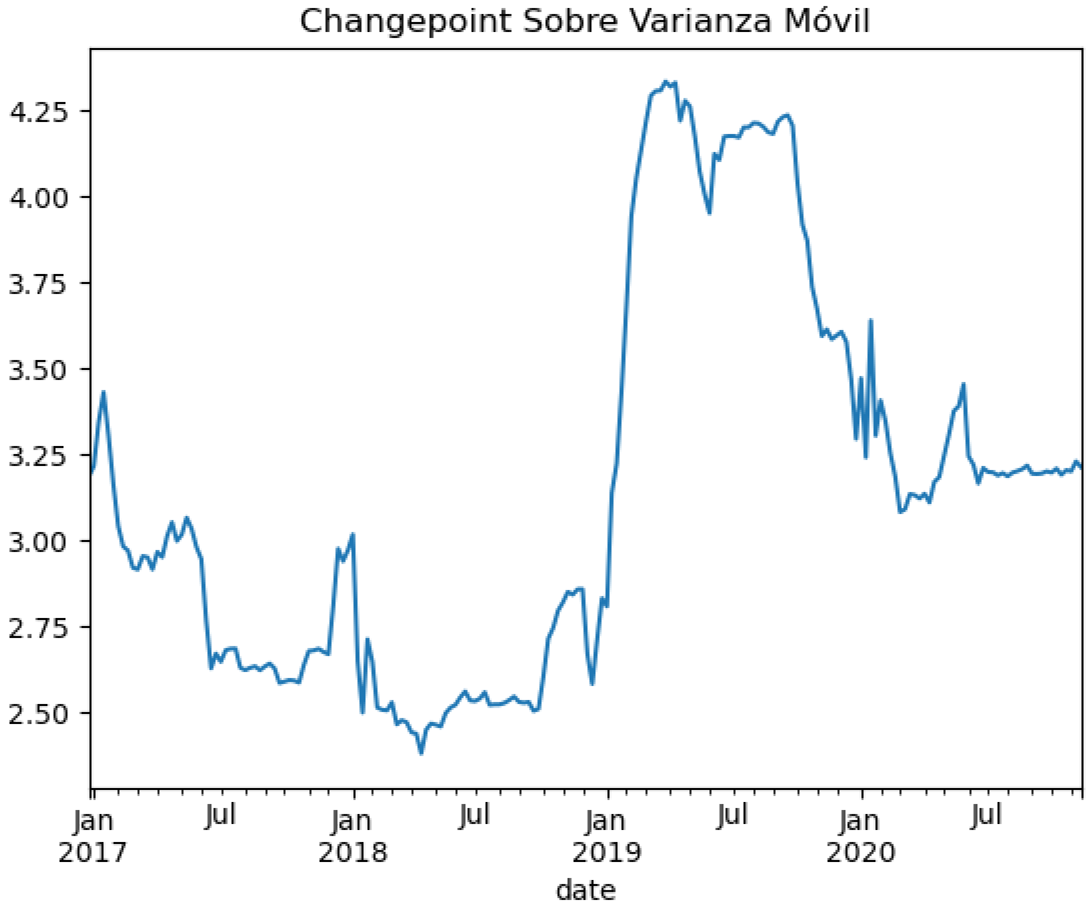
Descomposición de la Serie

In [6]:
```
decomp = seasonal_decompose(ts, model="multiplicative", period=52)
decomp.plot();
```



Estabilización de la Varianza

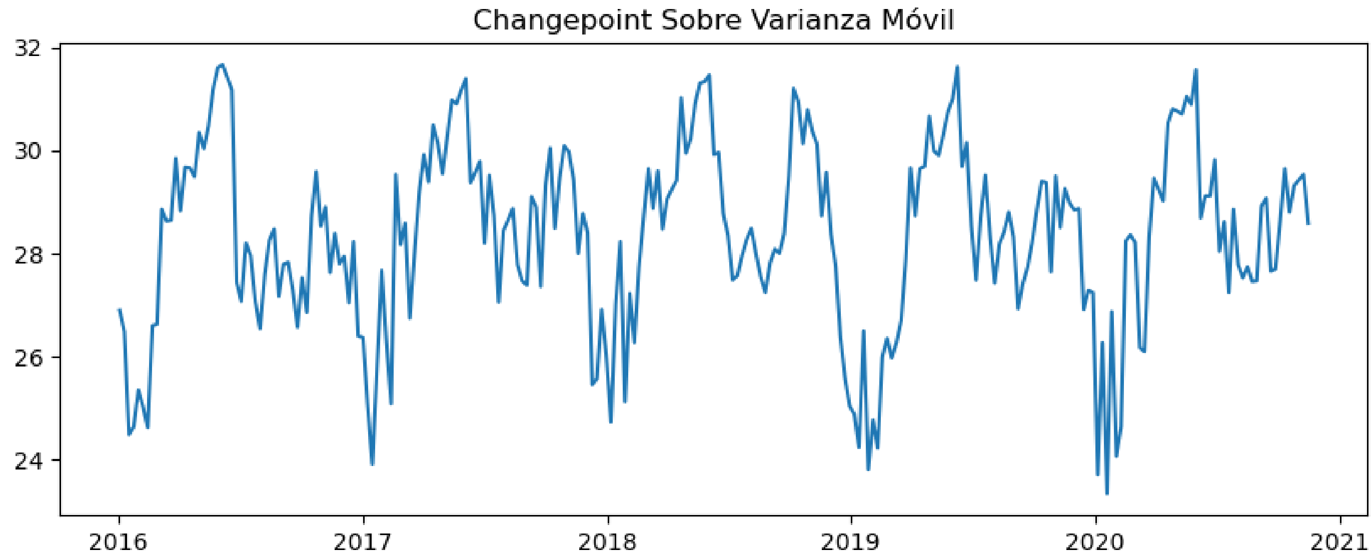
In [7]:
```
rolling_var = ts.rolling(window=52).var().dropna()
rolling_var.plot().set_title("Changepoint Sobre Varianza Móvil");
```

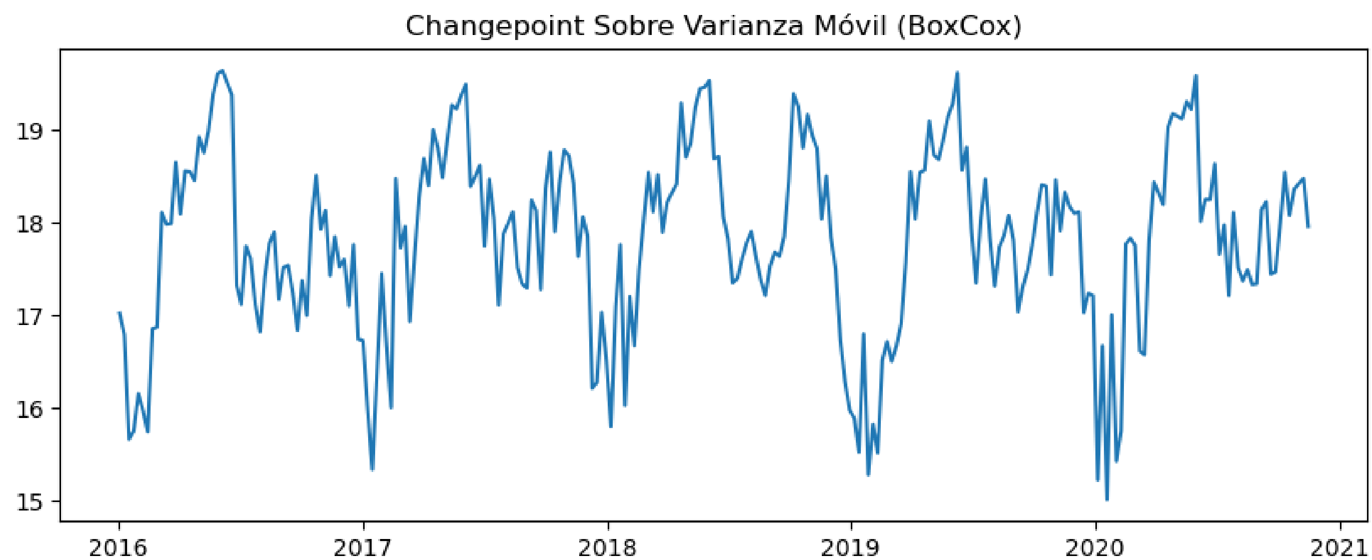


In [8]:
```
def guerrero_lambda(ts, m=52, lambdas=np.linspace(-2, 2, 300)):
    ts = ts.dropna().values
    ts = ts[ts > 0]   # Box-Cox requiere positivos

    blocks = np.array_split(ts, len(ts)//m)
    scores = []

    for lam in lambdas:
        stds = []
        for b in blocks:
            bt = boxcox(b, lam)
            stds.append(np.std(bt, ddof=1))

        stds = np.array(stds)
        score = np.std(np.log(stds)) / np.mean(np.log(stds))
        scores.append(score)

    return lambdas[np.argmin(scores)]

lam = guerrero_lambda(ts, m=52)
print('Lambda que minimiza CV (Gerrero): ' + lam.astype(str))
```

```
Lambda que minimiza CV (Gerrero): 0.8227424749163879
```

In [9]:
```
ts_bc = boxcox(ts, lam)
ts_bc = pd.Series(ts_bc, index=ts.index)
fig, axes = plt.subplots(2, 1, figsize=(10, 8))
axes[0].plot(ts); axes[0].set_title("Changepoint Sobre Varianza Móvil")
axes[1].plot(ts_bc); axes[1].set_title("Changepoint Sobre Varianza Móvil (BoxCox)");
```



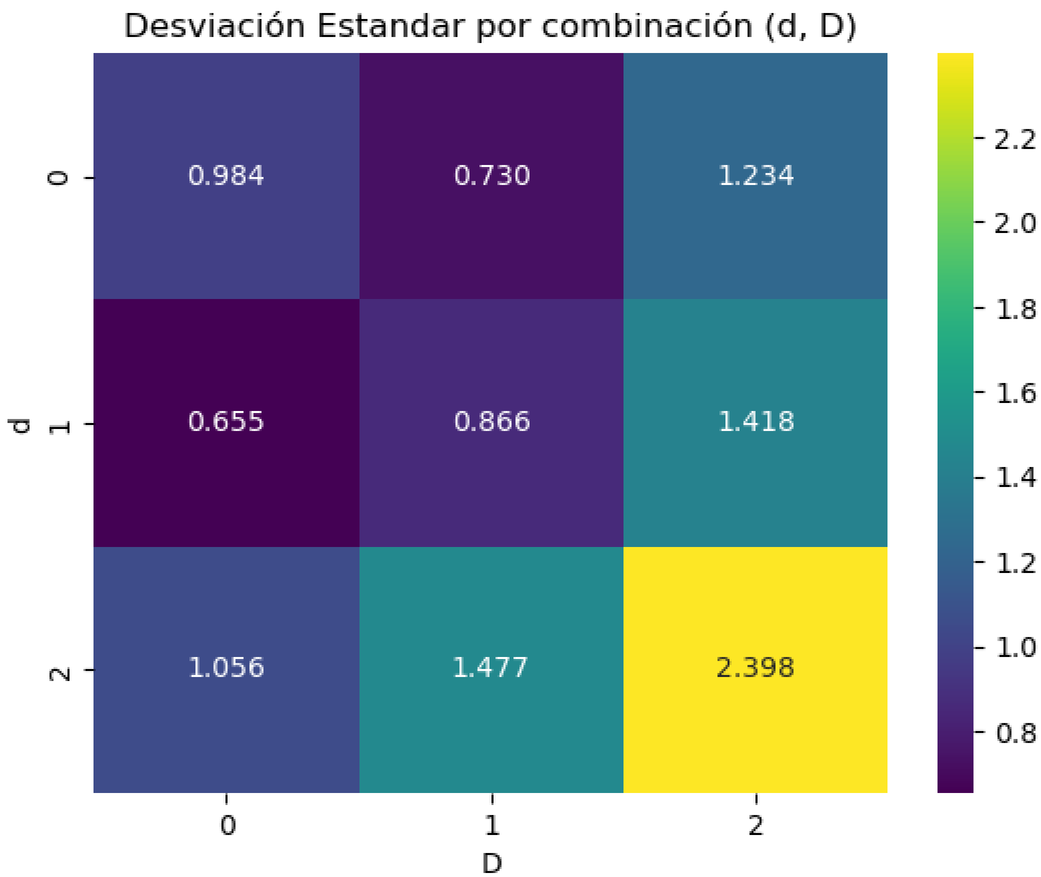


Estabilización de la Media

In [10]:
```
def difference_series(ts, d=0, D=0, s=52):
    ts_diff = ts.copy()

    for _ in range(d):
        ts_diff = ts_diff.diff()

    for _ in range(D):
        ts_diff = ts_diff.diff(s)

    return ts_diff.dropna()

def find_best_diff(ts, max_d=2, max_D=2, s=52):
    results = []

    for d in range(max_d + 1):
        for D in range(max_D + 1):
            ts_d = difference_series(ts, d=d, D=D, s=s)
            std = ts_d.std()
            results.append({"d": d, "D": D, "standar deviation": std})

    df_results = pd.DataFrame(results).sort_values("standar deviation")

    best = df_results.loc[df_results["standar deviation"].idxmin()]
```

```
    return int(best["d"]), int(best["D"]), df_results

best_d, best_D, df_results = find_best_diff(ts_bc, s=52)
print(f"Best d = {best_d}, Best D = {best_D}")

pivot = df_results.pivot(index="d", columns="D", values="standar deviation")

sns.heatmap(pivot, annot=True, fmt=".3f", cmap="viridis")
plt.title("Desviación Estandar por combinación (d, D)")
plt.show()
```

```
Best d = 1, Best D = 0
```



In [11]:
```
def apply_differencing(ts, d=0, D=0, s=52):
    ts_diff = ts.copy()

    for _ in range(d):
        ts_diff = ts_diff.diff()

    for _ in range(D):
        ts_diff = ts_diff.diff(s)

    return ts_diff.dropna()

ts_final = apply_differencing(ts_bc, d=best_d, D=best_D, s=52)
```

Chequeo de Estacionariedad De Media

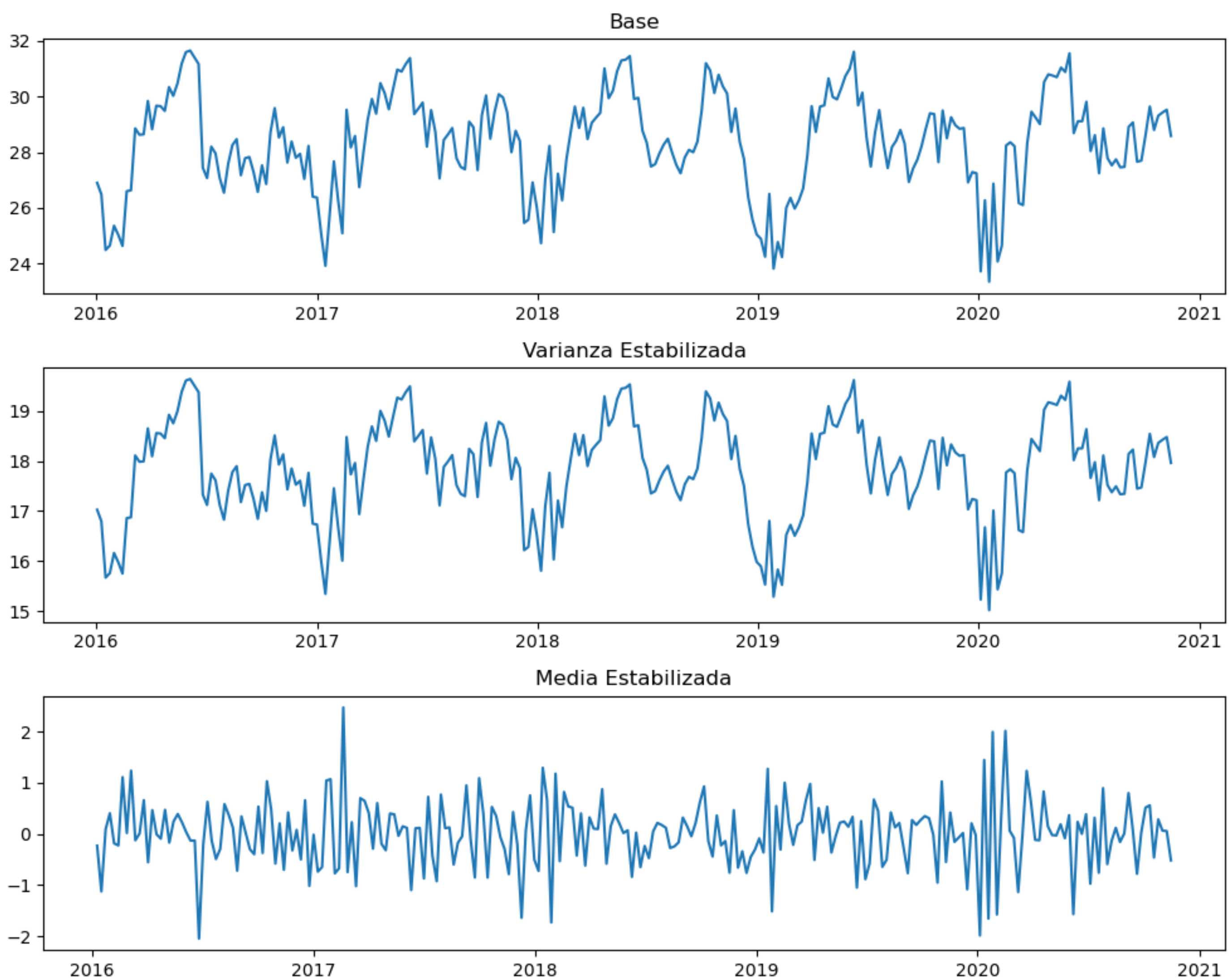
In [12]:
```
def check_stationarity(x, name="serie", alpha=0.05):
    adf = adfuller(x.dropna())
    p_value = adf[1]

    print(f"--- {name} ---")
    print(f"ADF p-value: {p_value:.4f}")
```

```python
    if p_value < alpha:
        print("La serie ES estacionaria (rechazamos H0 de raíz unitaria)")
    else:
        print("La serie NO es estacionaria (no podemos rechazar H0)")

check_stationarity(ts_final, 'Serie estabilizada en varianza y media')
```

```
--- Serie estabilizada en varianza y media ---
ADF p-value: 0.0000
La serie ES estacionaria (rechazamos H0 de raíz unitaria)
```

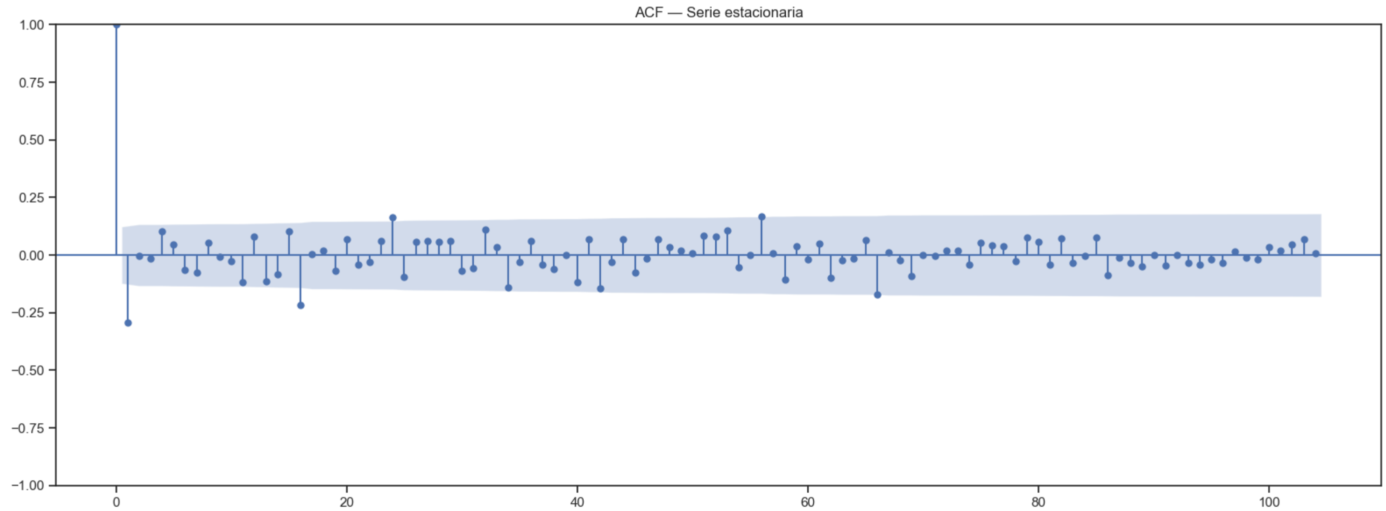
Evolución de la Serie

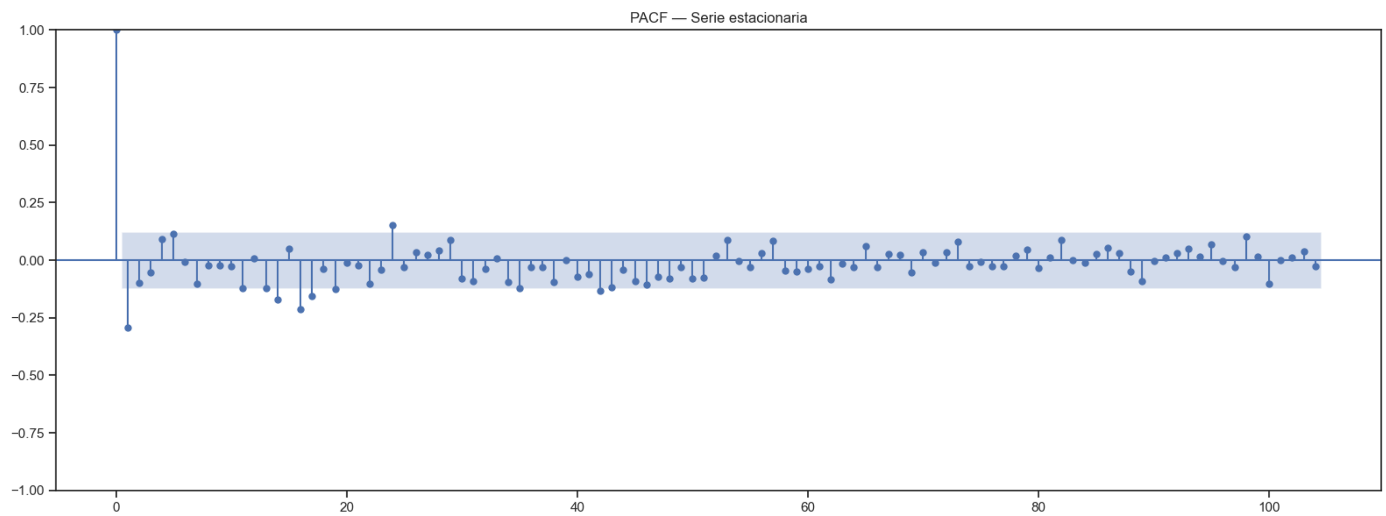
In [13]:
```python
fig, axes = plt.subplots(3, 1, figsize=(10, 8))
axes[0].plot(ts); axes[0].set_title("Base")
axes[1].plot(ts_bc); axes[1].set_title("Varianza Estabilizada")
axes[2].plot(ts_final); axes[2].set_title("Media Estabilizada")
plt.tight_layout()
```



In [14]:
```python
sns.set_theme(style="ticks")

fig, axes = plt.subplots(2, 1, figsize=(16,12))

plot_acf(ts_final, lags=104, ax=axes[0])
axes[0].set_title("ACF — Serie estacionaria")

plot_pacf(ts_final, lags=104, ax=axes[1], method="ywm")
axes[1].set_title("PACF — Serie estacionaria")
```

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





In [89]:
```python
def evaluate_model(ts, order, seasonal_order, name):

    model = SARIMAX(ts,
                    order=order,
                    seasonal_order=seasonal_order,
                    enforce_stationarity=False,
                    enforce_invertibility=False)

    results = model.fit(disp=False)
    resid = results.resid.dropna()

    lb_p = acorr_ljungbox(resid, lags=[20], return_df=True)["lb_pvalue"].iloc[0]
    shapiro_p = shapiro(resid.sample(min(len(resid), 500)))[1]

    return {
        "name": name,
        "order": order,
        "seasonal_order": seasonal_order,
        "aic": results.aic,
        "bic": results.bic,
        "lb_p": lb_p,
        "shapiro_p": shapiro_p,
        "results": results
    }

models = []

# models.append(evaluate_model(ts_final, (1,0,0), (0,0,0,52), "SARIMA(1,0,0)(0,0,0)"))
```

```
# models.append(evaluate_model(ts_final, (2,0,0), (0,0,0,52), "SARIMA(2,0,0)(0,0,0)"))
# models.append(evaluate_model(ts_final, (0,0,1), (0,0,0,52), "SARIMA(0,0,1)(0,0,0)"))
# models.append(evaluate_model(ts_final, (0,0,2), (0,0,0,52), "SARIMA(0,0,2)(0,0,0)"))
# models.append(evaluate_model(ts_final, (1,0,1), (0,0,0,52), "SARIMA(1,0,1)(0,0,0)"))
# models.append(evaluate_model(ts_final, (2,0,1), (0,0,0,52), "SARIMA(2,0,1)(0,0,0)"))
# models.append(evaluate_model(ts_final, (1,0,2), (0,0,0,52), "SARIMA(1,0,2)(0,0,0)"))

# models.append(evaluate_model(ts_final, (1,0,0), (1,0,0,52), "SARIMA(1,0,0)(1,0,0)"))
# models.append(evaluate_model(ts_final, (2,0,0), (1,0,0,52), "SARIMA(2,0,0)(1,0,0)"))
# models.append(evaluate_model(ts_final, (0,0,1), (1,0,0,52), "SARIMA(0,0,1)(1,0,0)"))
# models.append(evaluate_model(ts_final, (0,0,2), (1,0,0,52), "SARIMA(0,0,2)(1,0,0)"))
# models.append(evaluate_model(ts_final, (1,0,1), (1,0,0,52), "SARIMA(1,0,1)(1,0,0)"))
# models.append(evaluate_model(ts_final, (2,0,1), (1,0,0,52), "SARIMA(2,0,1)(1,0,0)"))
# models.append(evaluate_model(ts_final, (1,0,2), (1,0,0,52), "SARIMA(1,0,2)(1,0,0)"))

# models.append(evaluate_model(ts_final, (1,0,0), (0,0,1,52), "SARIMA(1,0,0)(0,0,1)"))
# models.append(evaluate_model(ts_final, (2,0,0), (0,0,1,52), "SARIMA(2,0,0)(0,0,1)"))
# models.append(evaluate_model(ts_final, (0,0,1), (0,0,1,52), "SARIMA(0,0,1)(0,0,1)"))
# models.append(evaluate_model(ts_final, (0,0,2), (0,0,1,52), "SARIMA(0,0,2)(0,0,1)"))
# models.append(evaluate_model(ts_final, (1,0,1), (0,0,1,52), "SARIMA(2,0,1)(0,0,1)"))
# models.append(evaluate_model(ts_final, (2,0,1), (0,0,1,52), "SARIMA(2,0,1)(0,0,1)"))
# models.append(evaluate_model(ts_final, (1,0,2), (0,0,1,52), "SARIMA(1,0,2)(0,0,1)"))

models.append(evaluate_model(ts_final, (1,0,0), (1,0,1,52), "SARIMA(1,0,0)(1,0,1)"))
models.append(evaluate_model(ts_final, (2,0,0), (1,0,1,52), "SARIMA(2,0,0)(1,0,1)"))
models.append(evaluate_model(ts_final, (0,0,1), (1,0,1,52), "SARIMA(0,0,1)(1,0,1)"))
models.append(evaluate_model(ts_final, (0,0,2), (1,0,1,52), "SARIMA(0,0,2)(1,0,1)"))
models.append(evaluate_model(ts_final, (1,0,1), (1,0,1,52), "SARIMA(1,0,1)(1,0,1)"))
models.append(evaluate_model(ts_final, (2,0,1), (1,0,1,52), "SARIMA(2,0,1)(1,0,1)"))
models.append(evaluate_model(ts_final, (1,0,2), (1,0,1,52), "SARIMA(1,0,2)(1,0,1)"))

# models.append(evaluate_model(ts_final, (1,0,0), (2,0,0,52), "SARIMA(1,0,0)(2,0,0)"))
# models.append(evaluate_model(ts_final, (2,0,0), (2,0,0,52), "SARIMA(2,0,0)(2,0,0)"))
# models.append(evaluate_model(ts_final, (0,0,1), (2,0,0,52), "SARIMA(0,0,1)(2,0,0)"))
# models.append(evaluate_model(ts_final, (0,0,2), (2,0,0,52), "SARIMA(0,0,2)(2,0,0)"))
# models.append(evaluate_model(ts_final, (1,0,1), (2,0,0,52), "SARIMA(1,0,1)(2,0,0)"))
# models.append(evaluate_model(ts_final, (2,0,1), (2,0,0,52), "SARIMA(2,0,1)(2,0,0)"))
# models.append(evaluate_model(ts_final, (1,0,2), (2,0,0,52), "SARIMA(1,0,2)(2,0,0)"))

# models.append(evaluate_model(ts_final, (1,0,0), (0,0,2,52), "SARIMA(1,0,0)(0,0,2)"))
# models.append(evaluate_model(ts_final, (2,0,0), (0,0,2,52), "SARIMA(2,0,0)(0,0,2)"))
# models.append(evaluate_model(ts_final, (0,0,1), (0,0,2,52), "SARIMA(0,0,1)(0,0,2)"))
# models.append(evaluate_model(ts_final, (0,0,2), (0,0,2,52), "SARIMA(0,0,2)(0,0,2)"))
# models.append(evaluate_model(ts_final, (1,0,1), (0,0,2,52), "SARIMA(2,0,1)(0,0,2)"))
# models.append(evaluate_model(ts_final, (2,0,1), (0,0,2,52), "SARIMA(2,0,1)(0,0,2)"))
# models.append(evaluate_model(ts_final, (1,0,2), (0,0,2,52), "SARIMA(1,0,2)(0,0,2)"))

# models.append(evaluate_model(ts_final, (1,0,0), (2,0,1,52), "SARIMA(1,0,0)(2,0,1)"))
# models.append(evaluate_model(ts_final, (2,0,0), (2,0,1,52), "SARIMA(2,0,0)(2,0,1)"))
# models.append(evaluate_model(ts_final, (0,0,1), (2,0,1,52), "SARIMA(0,0,1)(2,0,1)"))
# models.append(evaluate_model(ts_final, (0,0,2), (2,0,1,52), "SARIMA(0,0,2)(2,0,1)"))
# models.append(evaluate_model(ts_final, (1,0,1), (2,0,1,52), "SARIMA(1,0,1)(2,0,1)"))
# models.append(evaluate_model(ts_final, (2,0,1), (2,0,1,52), "SARIMA(2,0,1)(2,0,1)"))
# models.append(evaluate_model(ts_final, (1,0,2), (2,0,1,52), "SARIMA(1,0,2)(2,0,1)"))

# models.append(evaluate_model(ts_final, (1,0,0), (1,0,2,52), "SARIMA(1,0,0)(1,0,2)"))
# models.append(evaluate_model(ts_final, (2,0,0), (1,0,2,52), "SARIMA(2,0,0)(1,0,2)"))
# models.append(evaluate_model(ts_final, (0,0,1), (1,0,2,52), "SARIMA(0,0,1)(1,0,2)"))
# models.append(evaluate_model(ts_final, (0,0,2), (1,0,2,52), "SARIMA(0,0,2)(1,0,2)"))
# models.append(evaluate_model(ts_final, (1,0,1), (1,0,2,52), "SARIMA(1,0,1)(1,0,2)"))
# models.append(evaluate_model(ts_final, (2,0,1), (1,0,2,52), "SARIMA(2,0,1)(1,0,2)"))
# models.append(evaluate_model(ts_final, (1,0,2), (1,0,2,52), "SARIMA(1,0,2)(1,0,2)"))

# models.append(evaluate_model(ts_final, (1,0,0), (2,0,2,52), "SARIMA(1,0,0)(2,0,2)"))
# models.append(evaluate_model(ts_final, (2,0,0), (2,0,2,52), "SARIMA(2,0,0)(2,0,2)"))
# models.append(evaluate_model(ts_final, (0,0,1), (2,0,2,52), "SARIMA(0,0,1)(2,0,2)"))
```

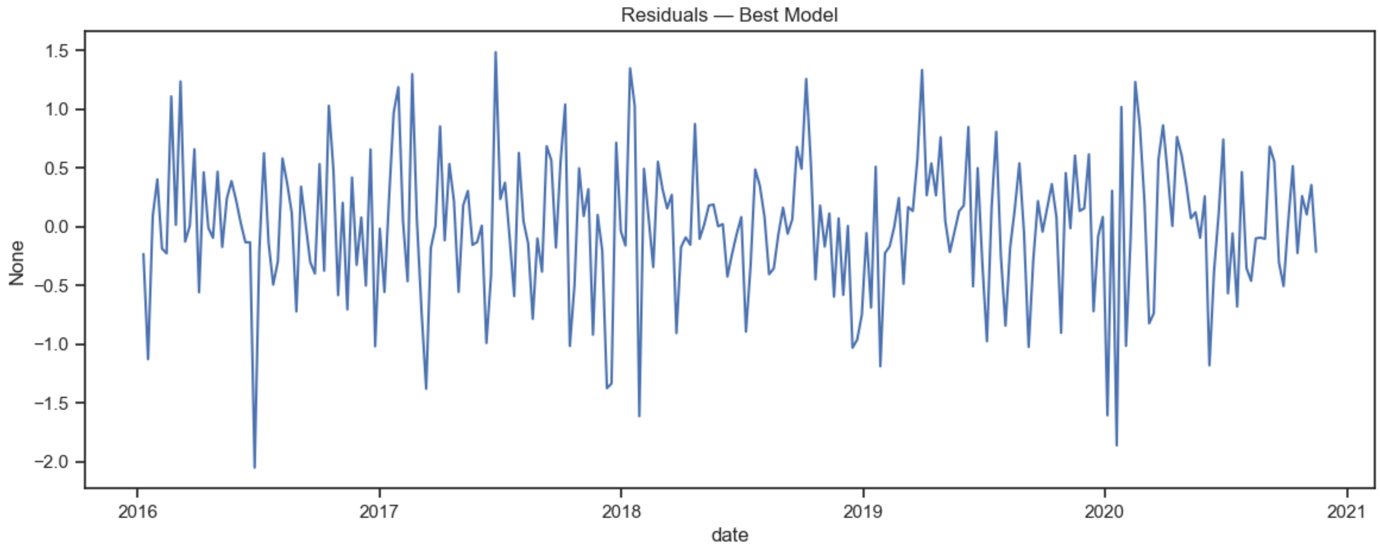
```
# models.append(evaluate_model(ts_final, (0,0,2), (2,0,2,52), "SARIMA(0,0,2)(2,0,2)"))
# models.append(evaluate_model(ts_final, (1,0,1), (2,0,2,52), "SARIMA(1,0,1)(2,0,2)"))
# models.append(evaluate_model(ts_final, (2,0,1), (2,0,2,52), "SARIMA(2,0,1)(2,0,2)"))
# models.append(evaluate_model(ts_final, (1,0,2), (2,0,2,52), "SARIMA(1,0,2)(2,0,2)"))

# models.append(evaluate_model(ts_bc, (1,0,0), (1,1,1,52), "SARIMA(1,0,0)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (2,0,0), (1,1,1,52), "SARIMA(2,0,0)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (0,0,1), (1,1,1,52), "SARIMA(0,0,1)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (0,0,2), (1,1,1,52), "SARIMA(0,0,2)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (1,0,1), (1,1,1,52), "SARIMA(1,0,1)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (2,0,1), (1,1,1,52), "SARIMA(2,0,1)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (1,0,2), (1,1,1,52), "SARIMA(1,0,2)(1,1,1)"))

# models.append(evaluate_model(ts_bc, (1,1,0), (1,1,1,52), "SARIMA(1,1,0)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (2,1,0), (1,1,1,52), "SARIMA(2,1,0)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (0,1,1), (1,1,1,52), "SARIMA(0,1,1)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (0,1,2), (1,1,1,52), "SARIMA(0,1,2)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (1,1,1), (1,1,1,52), "SARIMA(1,1,1)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (2,1,1), (1,1,1,52), "SARIMA(2,1,1)(1,1,1)"))
# models.append(evaluate_model(ts_bc, (1,1,2), (1,1,1,52), "SARIMA(1,1,2)(1,1,1)"))

df_models = pd.DataFrame(models).drop(columns="results").sort_values("aic")

valid_models = [
    m for m in models
    if (m["lb_p"] > 0.05) and (m["shapiro_p"] > 0.01)
]

if len(valid_models) > 0:
    best_model = min(valid_models, key=lambda x: x["aic"])
    print("Best model (passed Ljung-Box):", best_model["name"])
else:
    print("Ningún modelo pasó Ljung-Box — seleccionando por menor AIC")
    best_model = min(models, key=lambda x: x["aic"])
    print("Best model by AIC:", best_model["name"])

best_model = min(valid_models, key=lambda x: x["aic"])

print("Best model:", best_model["name"])

df_models = df_models[
    (df_models['lb_p'] >= 0.05) &
    (df_models['shapiro_p'] >= 0.01)
]

display(df_models.style.format({
    "aic": "{:.2f}",
    "bic": "{:.2f}",
    "lb_p": "{:.4f}",
    "shapiro_p": "{:.4f}"
}))

res = best_model["results"]
resid = res.resid
```

```
Best model (passed Ljung-Box): SARIMA(2,0,0)(1,0,1)
Best model: SARIMA(2,0,0)(1,0,1)
```

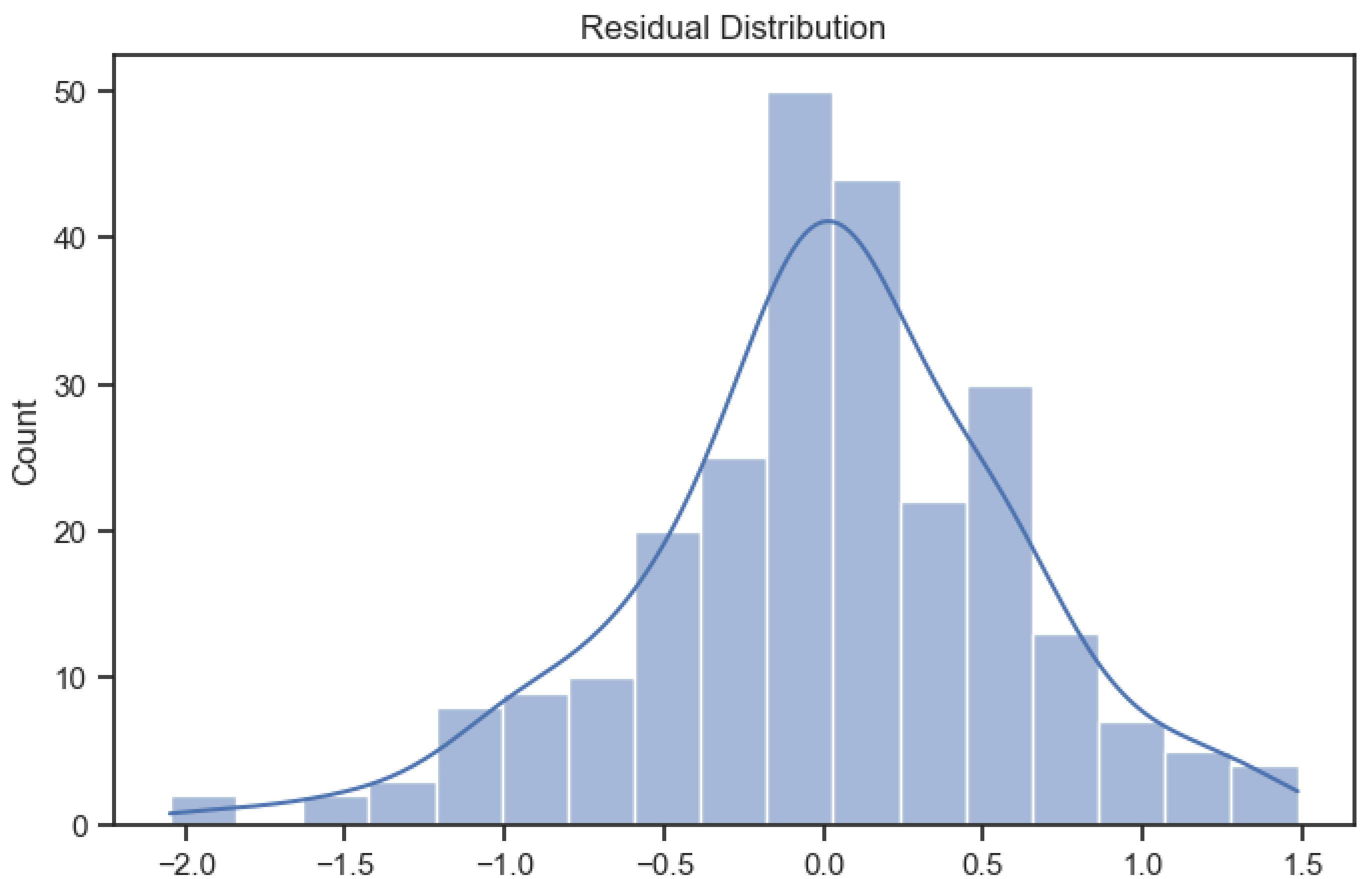
	name	order	seasonal_order	aic	bic	lb_p	shapiro_p
1	SARIMA(2,0,0)(1,0,1)	(2, 0, 0)	(1, 0, 1, 52)	377.49	393.98	0.0618	0.0112

In [82]:

```
plt.figure(figsize=(14,5))
sns.lineplot(x=resid.index, y=resid)
plt.title("Residuals — Best Model")
plt.show()
```

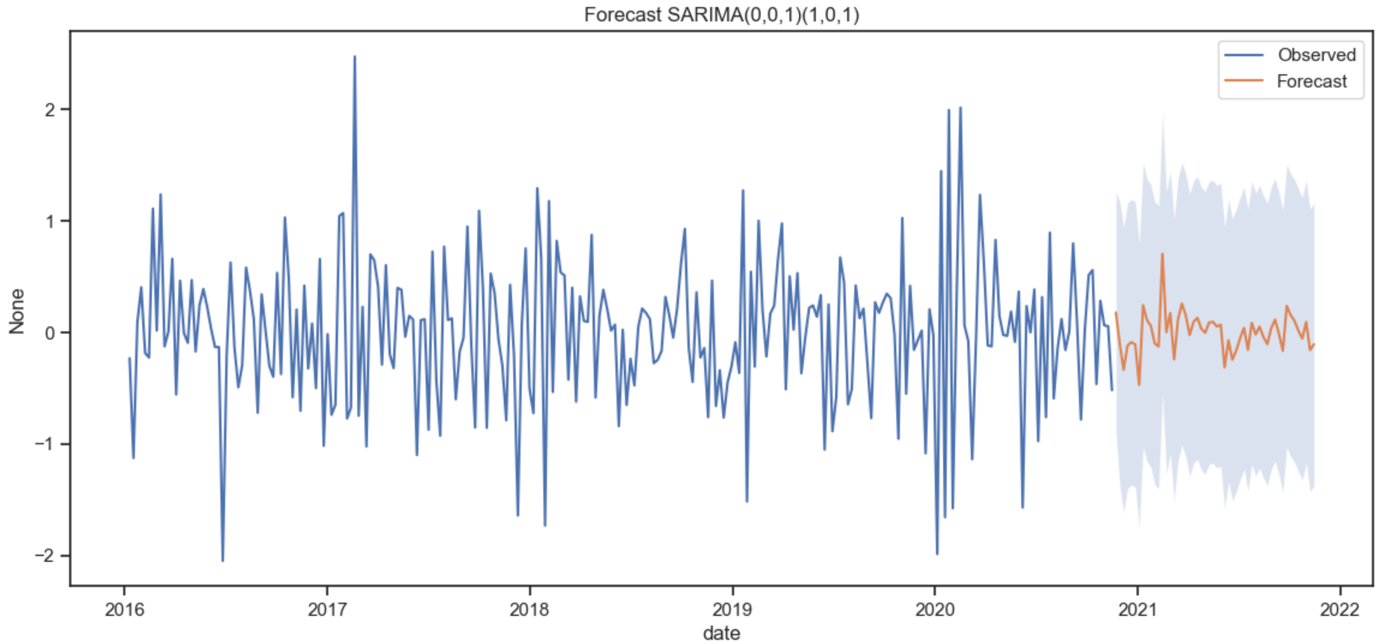


In [83]:
```
plt.figure(figsize=(8,5))
sns.histplot(resid, kde=True)
plt.title("Residual Distribution")
plt.show()
```



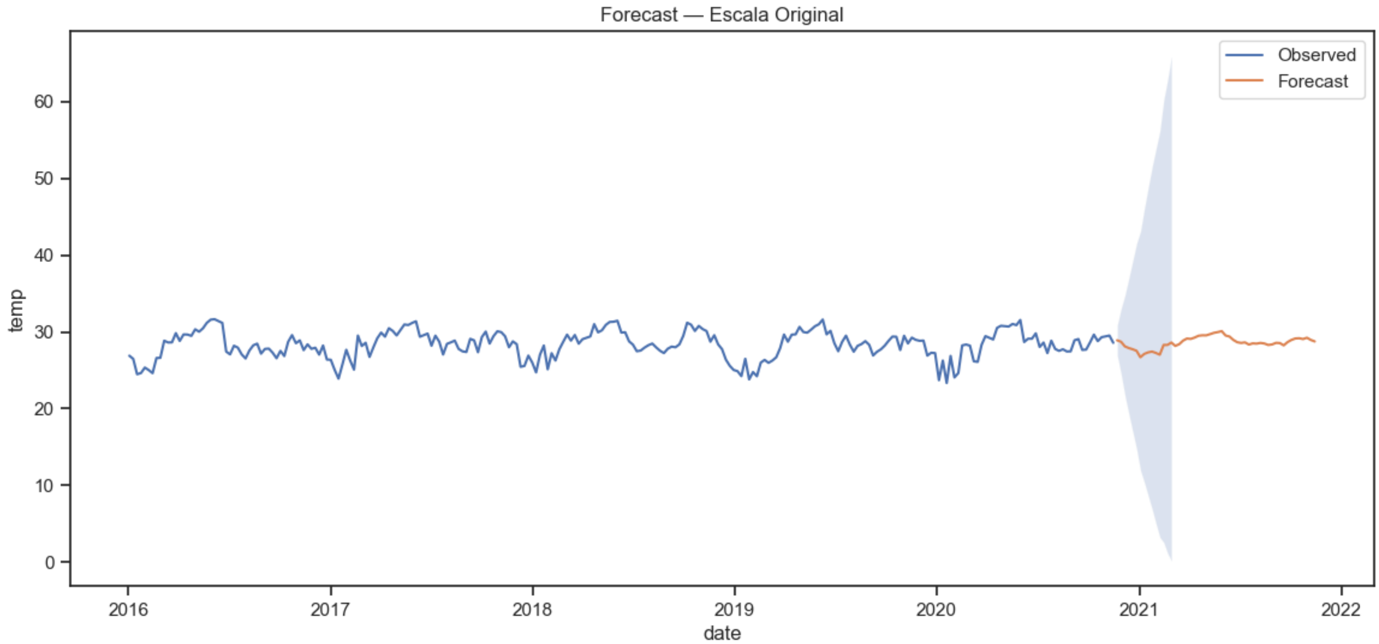
In [84]:
```
forecast = res.get_forecast(steps=52)

pred_mean = forecast.predicted_mean
conf_int = forecast.conf_int()

plt.figure(figsize=(14,6))

sns.lineplot(x=ts_final.index, y=ts_final, label="Observed")
sns.lineplot(x=pred_mean.index, y=pred_mean, label="Forecast")

plt.fill_between(conf_int.index,
                 conf_int.iloc[:,0],
```

```
                 conf_int.iloc[:,1],
                 alpha=0.2)

plt.title("Forecast " + best_model["name"])
plt.legend()
plt.show()
```



In [85]:
```
def invert_differencing(forecast_diff, original_bc, d=0, D=0, s=52):

    forecast_level = forecast_diff.copy()

    if d > 0:
        last_vals = original_bc.iloc[-d:]
        forecast_level = forecast_level.cumsum() + last_vals.iloc[-1]

    if D > 0:
        seasonal_vals = original_bc.iloc[-s:]
        for i in range(len(forecast_level)):
            forecast_level.iloc[i] += seasonal_vals.iloc[i % s]

    return forecast_level

pred_bc = invert_differencing(pred_mean, ts_bc, d=best_d, D=best_D, s=52)
lower_bc = invert_differencing(conf_int.iloc[:,0], ts_bc, d=best_d, D=best_D, s=52)
upper_bc = invert_differencing(conf_int.iloc[:,1], ts_bc, d=best_d, D=best_D, s=52)

pred_original = inv_boxcox(pred_bc, lam)
lower = inv_boxcox(lower_bc, lam)
upper = inv_boxcox(upper_bc, lam)
```

In [86]:
```
plt.figure(figsize=(14,6))

sns.lineplot(x=ts.index, y=ts, label="Observed")
sns.lineplot(x=pred_original.index, y=pred_original, label="Forecast")

# plt.fill_between(pred_original.index, lower, upper, alpha=0.2)
plt.fill_between(conf_int.index,
                 lower,
                 upper,
                 alpha=0.2)

plt.title("Forecast – Escala Original")
plt.legend()
plt.show()
```


Forecast — Escala Original
Observed
Forecast
temp
date
0
10
20
30
40
50
60
2016
2017
2018
2019
2020
2021
2022

In [ ]:

In [ ]: