Replication_code_section3

September 14, 2024

1 Replication code for Section 3, Song et al. (2024)

This file replicates the output in Section 3 of

"PyTimeVar: A Python Package for Trending Time-Varying Time Series Models."

Authors: Mingxuan Song, Bernhard van der Sluis, and Yicong Lin.

Date current version: September 2024

Section 3 illustrates our package using the Temperature dataset.

1.0.1 Load temperature data and set seed

[13]:
```
# Load data
from PyTimeVar.datasets import temperature
import numpy as np
data = temperature.load(regions=['World'], start_date='1961-01-01',␣
 ↪end_date='2023-01-01')
vY = data.values
X = np.ones_like(vY)

# set seed
np.random.seed(123)
```

1.0.2 Illustation of local linear regression

[14]:
```
from PyTimeVar import LocalLinear
model = LocalLinear(vY, X)
betaHatLLR = model.fit()
```

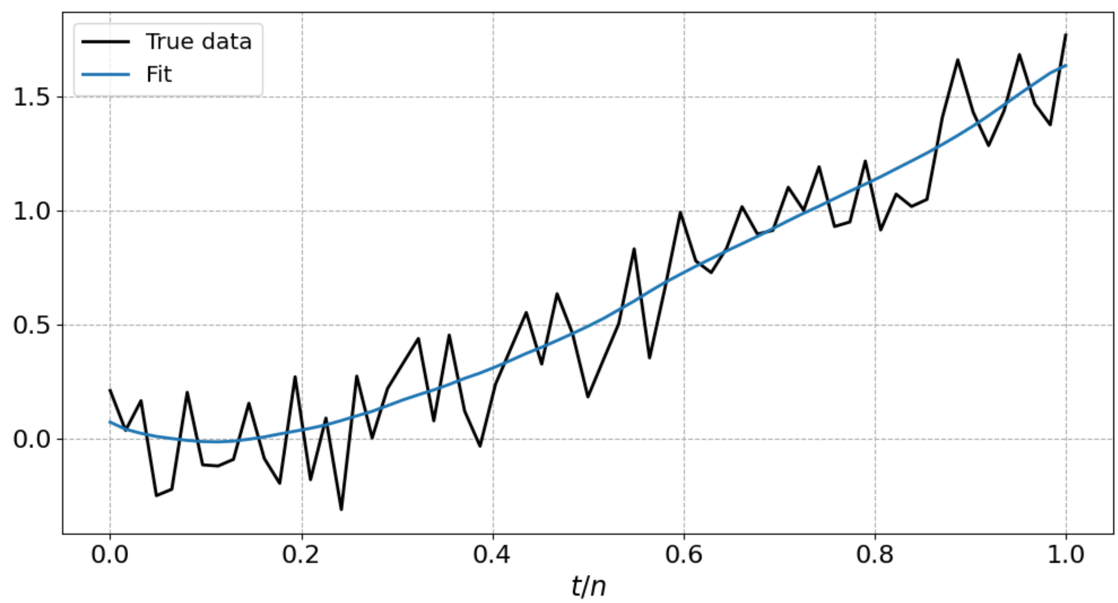
```
No bandwidth or selection method is specified.
------------------------------------------------------------
Optimal bandwidth selected by individual method:
- AIC method: 0.435484
- GCV method:  0.435484
- LMCV-0 method:  0.0600
- LMCV-2 method:  0.1200
- LMCV-4 method:  0.0600
- LMCV-6 method:  0.0600
```

```
------------------------------------------------------------
Optimal bandwidth used is the avg. of all methods:  0.1952

Note: If a residual-based bootstrap method (LBWB, WB, SB, SWB, AWB) is adopted,
the avg. bandwidth  0.1952 is used.
If the MB is implemented, the GCV bandwidth is used.
```

[15]:
```python
# print summary
model.summary()
```

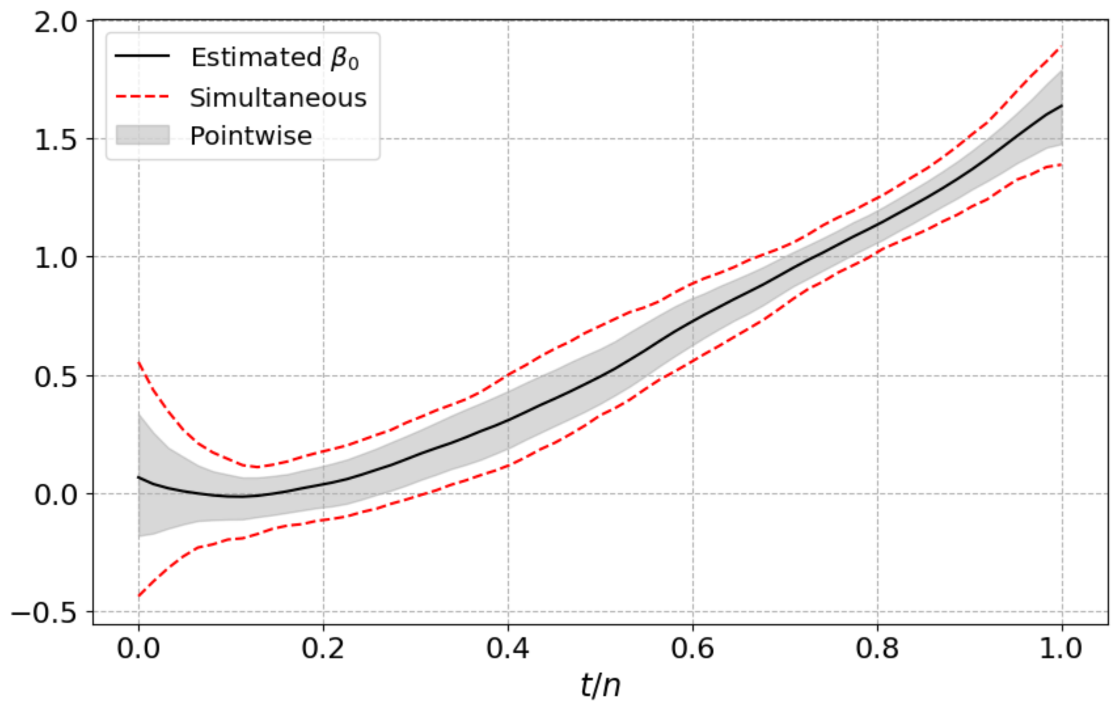
```
Local Linear Regression Results
==============================
Bandwidth:  0.1952
Number of observations: 63
Number of predictors: 1
==============================
Beta coefficients (shape: (1, 63)):
Use the 'plot_betas()' method to plot the beta coefficients.
==============================
Use the 'confidence_bands()' method to obtain the confidence bands and plots.
You can choose out of 6 types of Bootstrap to construct confidence bands:
SB, WB, SWB, MB, LBWB, AWB
==============================
Use the 'plot_residuals()' method to plot the residuals.
```

[16]:
```python
# plot trend and data
model.plot_predicted()
```



[17]:
```
# plot confidence bands using LBWB
cb = model.confidence_bands(bootstrap_type='LBWB', Gsubs=None, plots=True)
```

```
Calculating LBWB Bootstrap Samples

100%|
 | 1299/1299 [00:12<00:00, 106.92it/s]
```



1.0.3 Illustration of parameter specifications for local linear regression

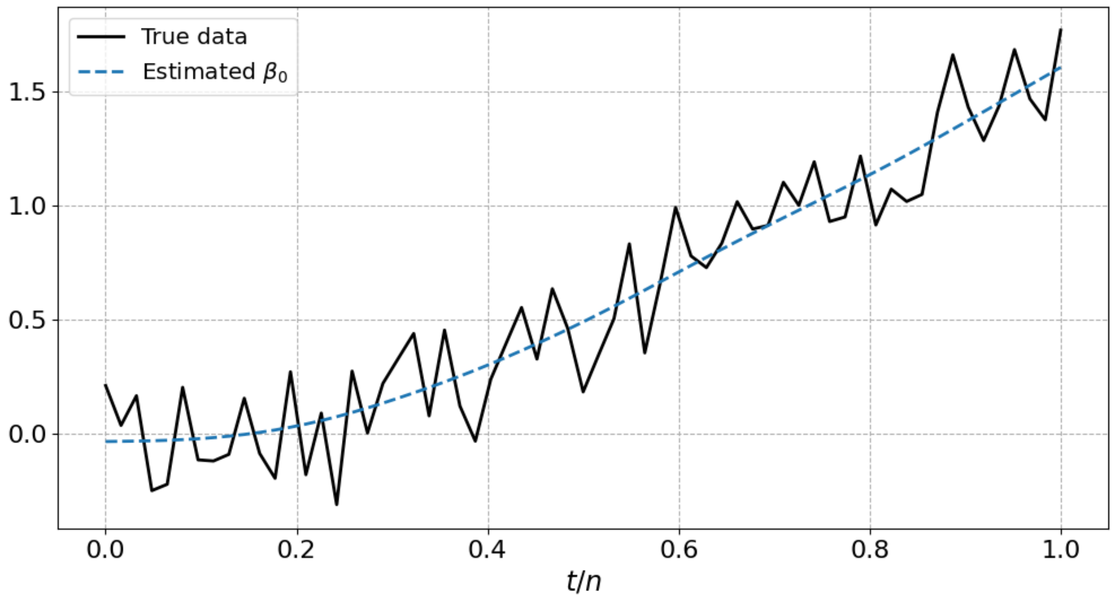
[18]:
```
# auxiliary LLR model to illustrate kernel, bandwidth selection, and tau
tau = np.linspace(0, 0.5, len(vY))
model2LLR = LocalLinear(vY, X, kernel='Gaussian', bw_selection='lmcv_8',␣
↪tau=tau)
beta_hat_model2 = model2LLR.fit()
```

```
------------------------------------------------------------
Optimal bandwidth used is LMCV-8:  0.0750

---------------------------------------------------------
Note: If a residual-based bootstrap method (LBWB, WB, SB, SWB, AWB) is adopted,
the LMCV-8 bandwidth  0.0750 is used.
If the MB is implemented, the GCV bandwidth is used.
```

1.0.4 Illustation of boosted HP filter

[19]:
```
from PyTimeVar import BoostedHP
bHPmodel = BoostedHP(vY, dLambda=1600, iMaxIter=100)
bHPtrend, bHPresiduals = bHPmodel.fit(
    boost=True, stop="adf", dAlpha=0.05, verbose=False)
bHPmodel.summary()
bHPmodel.plot()
```

```
Boosted HP Filter Results:
Stopping Criterion: adf
Max Iterations: 100
Iterations Run: 1
Lambda: 1600
Alpha: 0.05

Information Criteria Values:
[3.54412124e-12]
```



1.0.5 Illustration of power-law model

[20]:
```
from PyTimeVar import PowerLaw
PwrLaw = PowerLaw(vY, n_powers=1)
pwrTrend, pwrGamma = PwrLaw.fit()
PwrLaw.summary()
```

```
PwrLaw.plot()
```

```
yhat= 0.001 t^1.848
```

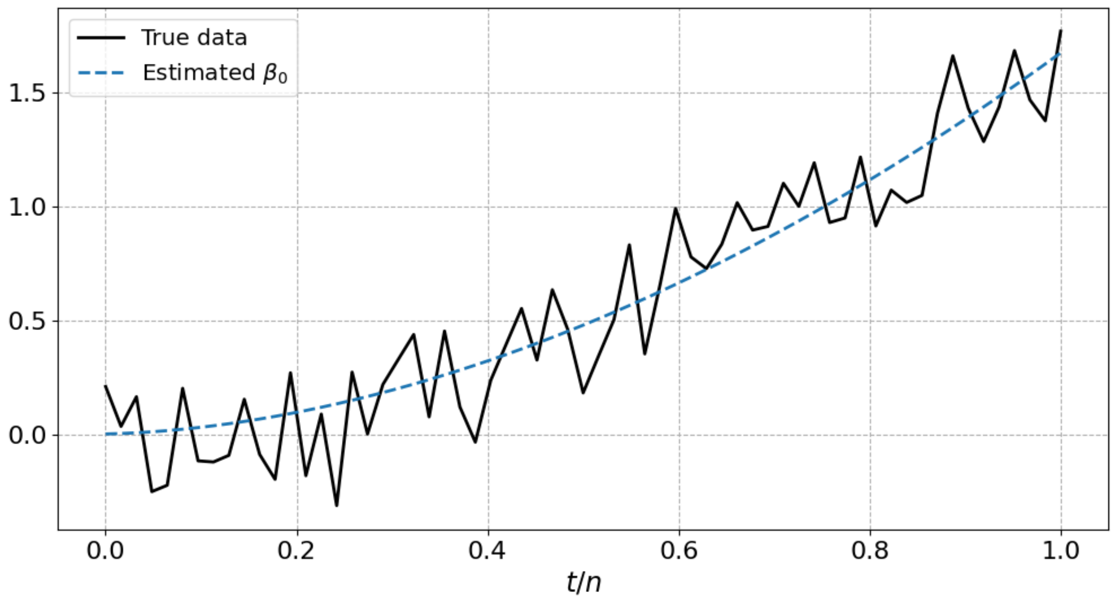


Illustration of parameter specifications for power-law model

[21]:
```
# auxiliary power-law model to illustrate options
vgamma0 = np.arange(0, 0.1, 0.1)
options = {'maxiter': 5E5, 'disp': False}
auxPwr = PowerLaw(vY, n_powers=1, vgamma0=vgamma0, options=options)
auxPwrTrend, auxPwrGamma = auxPwr.fit()
auxPwr.summary()
```

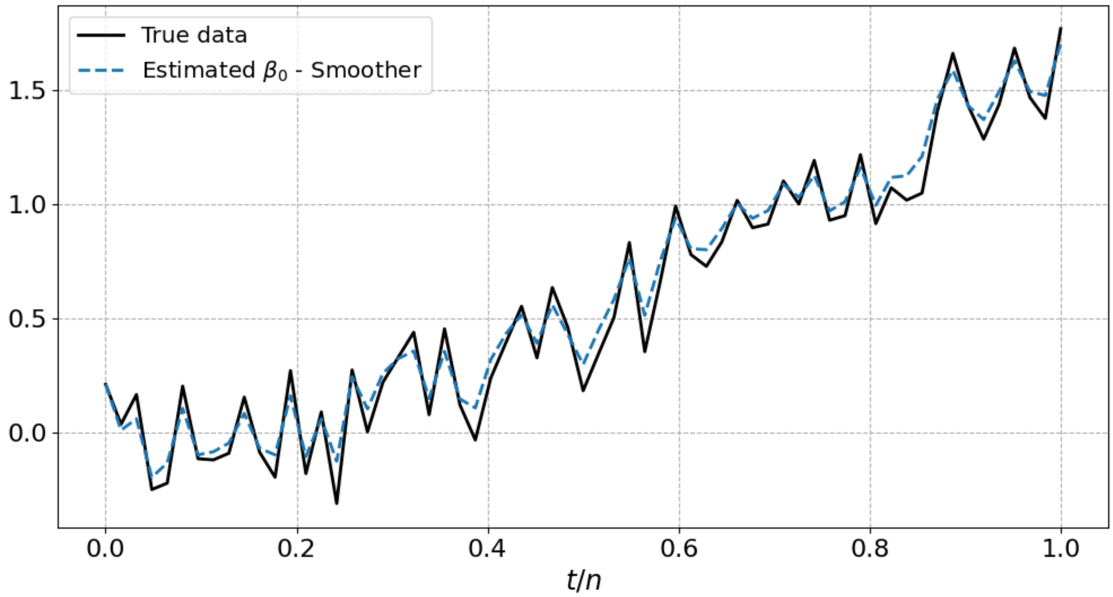
```
yhat= 0.001 t^1.848
```

1.0.6 Illustration of state-space model

[22]:
```
from PyTimeVar import Kalman
kalmanmodel = Kalman(vY=vY)
smooth_trend = kalmanmodel.fit('smoother')
kalmanmodel.summary()
kalmanmodel.plot()
```

```
C:\Users\bpvan\anaconda3\lib\site-packages\scipy\optimize\_optimize.py:284:
RuntimeWarning: Values in x were outside bounds during a minimize step, clipping
to bounds
  warnings.warn("Values in x were outside bounds during a "
```

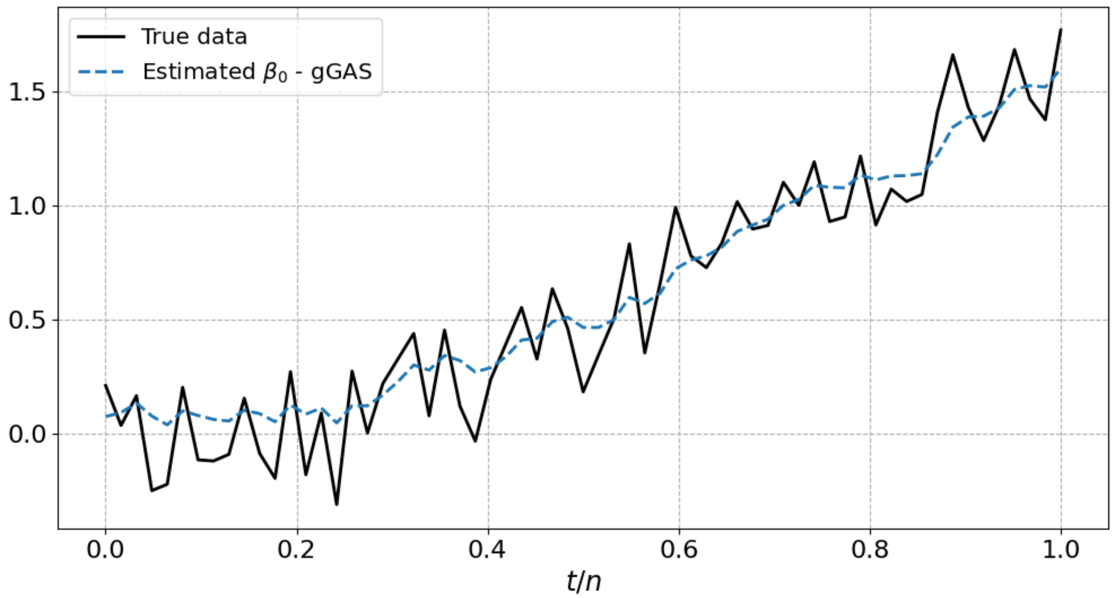
```
Optimization success
Kalman Filter specification:
H: [[[[0.12777861]]]]
Q: [[[[0.03454909]]]]
R: [[1.]]
T: [[1]]
```



1.0.7 Illustration of score-driven (GAS) models

[23]:
```
from PyTimeVar import GAS
N_gasmodel = GAS(vY=vY, mX=X, method='gaussian')      # Gaussian GAS
N_GAStrend, N_GASparams = N_gasmodel.fit()
N_gasmodel.plot()
```

```
Time taken: 0.60 seconds
```



True data
Estimated β_0 - gGAS
1.5
1.0
0.5
0.0
0.0
0.2
0.4
0.6
0.8
1.0
t/n