

Replication_code_section4

September 13, 2024

```
[1]: from PyTimeVar import BoostedHP
from PyTimeVar import LocalLinear
from PyTimeVar import GAS
from PyTimeVar import Kalman
from PyTimeVar.datasets import herding
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
```

0.1 Replication code for Figure 7 in Section 4.1

```
[2]: ##### Importing data for replicating the results in Section 4.1
np.random.seed(123)
herd_data = herding.load(start_date='2015-01-05', end_date='2022-04-29')
vY = herd_data[['CSAD_AVG']].values
mX = np.ones_like(vY)
```

```
[3]: ##### Local linear estimation
# LLr_model = LocalLinear(vY=vY, mX=mX, bw_selection='lmcv6') ##### this
    ↳function will cost around 48 mins.
##### We use the
    ↳resulted bandwidth directly in the next line
LLr_model = LocalLinear(vY=vY, mX=mX, h=0.140)
LLr_trend = LLr_model.fit()
```

Bandwidth specified by user: 0.1400

Note: this bandwidth will be used for any bootstrap implementation.

```
[12]: ##### Boosted HP filter
bHPmodel = BoostedHP(vY=vY, dLambda=1600, iMaxIter=100)
bHPtrend, bHPresiduals = bHPmodel.fit(boost=True, stop="bic", dAlpha=0.05,
    ↳verbose=False)
```

```
[5]: ##### t-GAS model
gasmodel = GAS(vY=vY, mX=mX, method='student')
```

```
tGAStrend, tGASparams = gasmodel.fit()
```

Time taken: 86.74 seconds

```
[6]: ##### Kalman smoother
kalmanmodel = Kalman(vY=vY, mX=mX)
smooth_trend = kalmanmodel.fit('smoother')
```

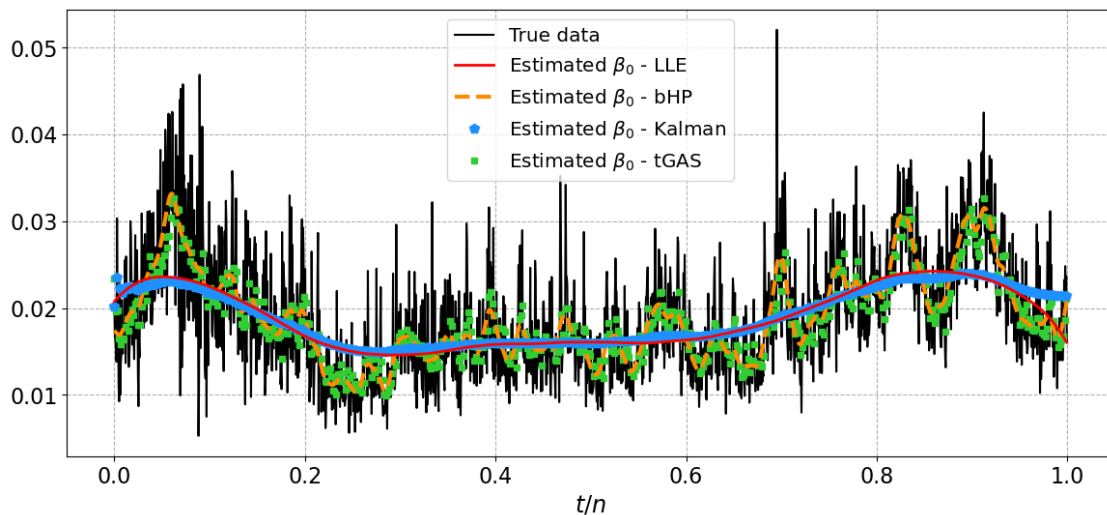
Optimization success

```
[13]: ##### Replication code for Figure 7
x_axis_trend = np.arange(0,1,1/len(vY))
plt.figure(figsize=(14, 6))

line2, = plt.plot(x_axis_trend, vY, label='True data',color='black')
line4, = plt.plot(x_axis_trend, tGAStrend, label='Estimated  $\beta_0$  - tGAS',color='limegreen',linestyle='',marker='s',markersize=5,markevery=3)
line5, = plt.plot(x_axis_trend, bHPtrend, label='Estimated  $\beta_0$  - bHP',color='darkorange',linestyle='--',linewidth=3)
line1, = plt.plot(x_axis_trend, smooth_trend, label='Estimated  $\beta_0$  - Kalman',color='dodgerblue',linestyle='',marker='p',markersize=7,markevery=5)
line3, = plt.plot(x_axis_trend, LLr_trend[0], label='Estimated  $\beta_0$  - LLE',color='red',linewidth=2)

# Customize the plot
plt.legend(handles=[line2, line3, line5, line1, line4],fontsize="x-large")
plt.xlabel('$t/n$',fontsize="xx-large")
plt.tick_params(axis='both', labels=16)
plt.grid(linestyle='dashed')

plt.show()
```



0.2 Replication code for Figure 8 in Section 4.2

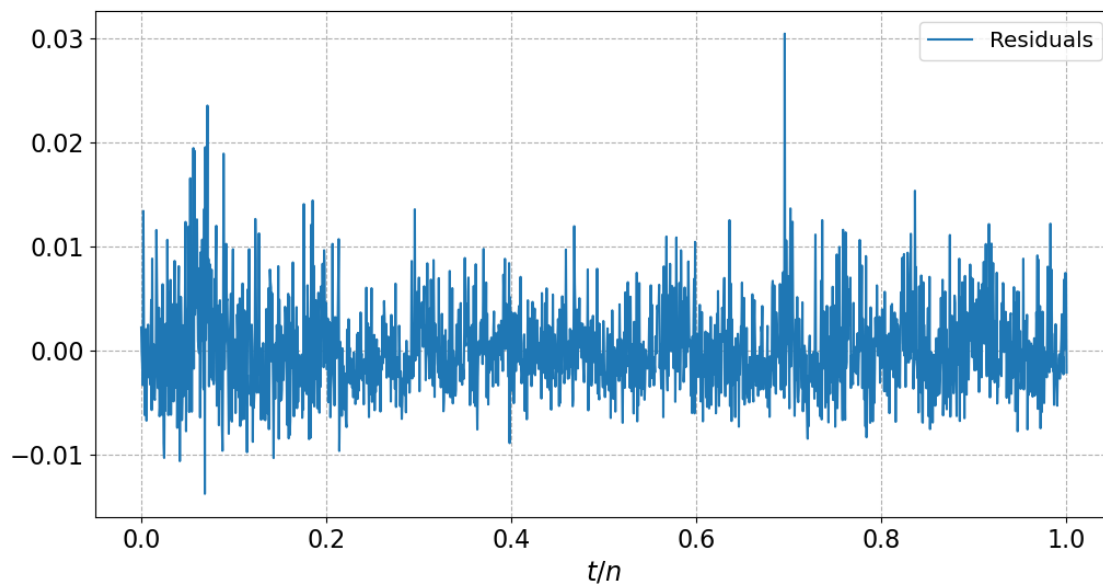
```
[12]: ##### Importing data for replicating the results in Section 4.2 and
      ↳ Appendix A.5
vY,mX = herding.load(data_replication=True)
breakindex_1 = 284
breakindex_5 = 1459
np.random.seed(123)

##### Local linear estimation
LLr_model = LocalLinear(vY=vY, mX=mX, h=0.0975)
LLr_betahat = LLr_model.fit()
```

Bandwidth specified by user: 0.0975

Note: this bandwidth will be used for any bootstrap implementation.

```
[13]: ##### The code below replicates Figure 8 in Section 4.2
      ##### plot residuals, replication of 8a
residuals = LLr_model.plot_residuals()
```

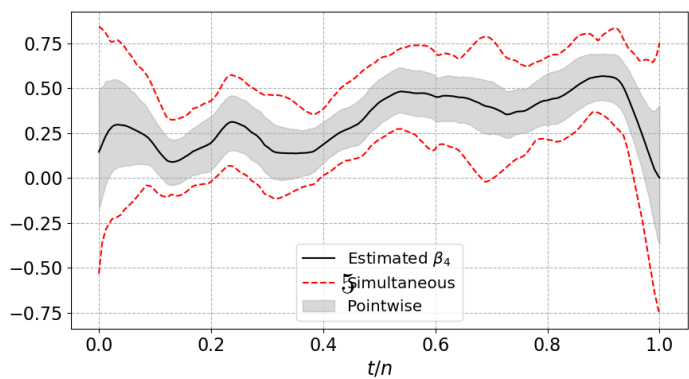
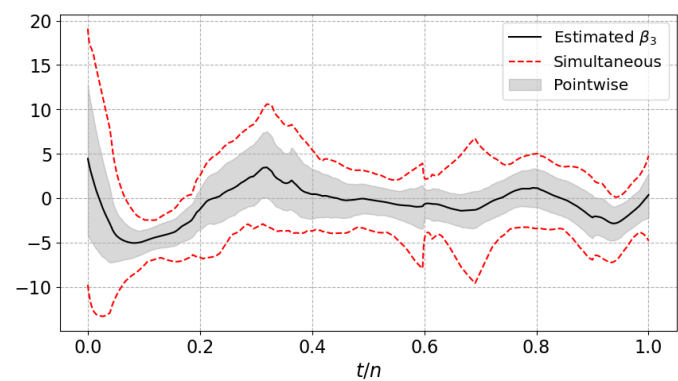
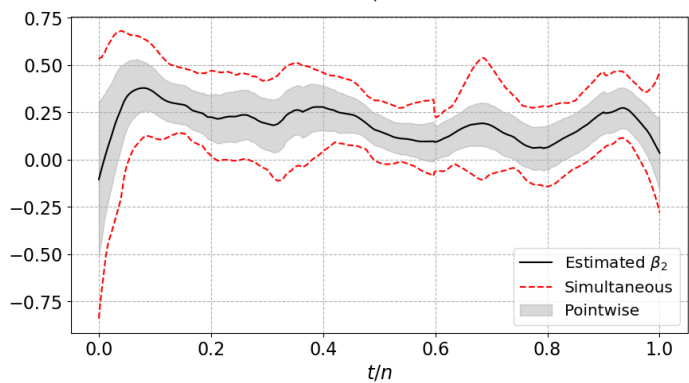
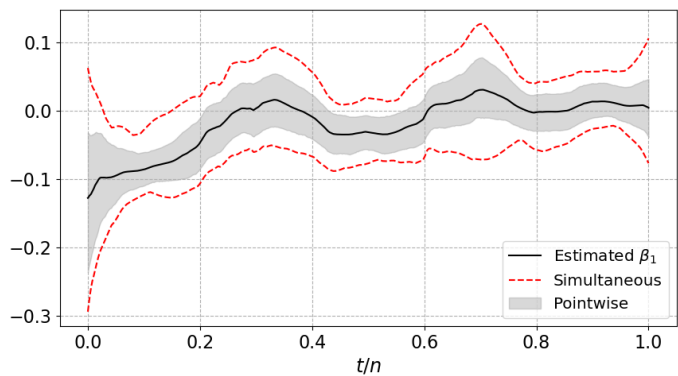
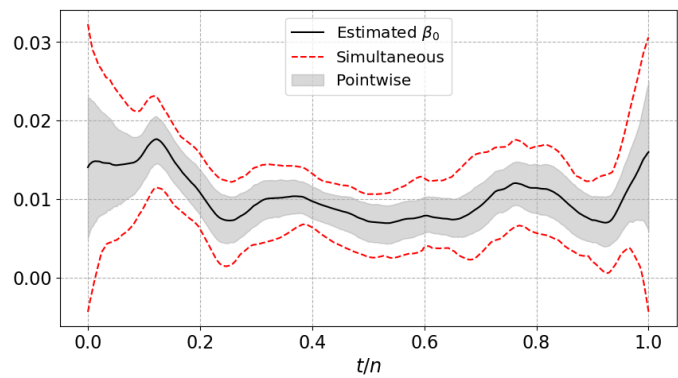


```
[10]: ##### plot LBWB full sample bands, replication of 8b.
      ##### Only the plot of beta_3 is reported in the paper (takes about
      ↳ 27 mins).
```

```
S_LB_full, S_UB_full, P_LB_full, P_UB_full = LLr_model.  
↳ confidence_bands(plots=True)
```

Calculating LBWB Bootstrap Samples

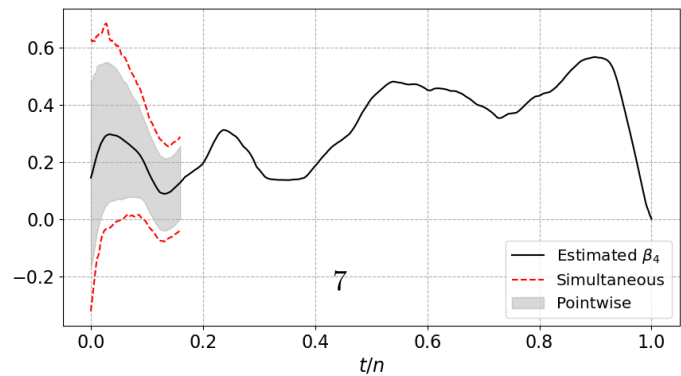
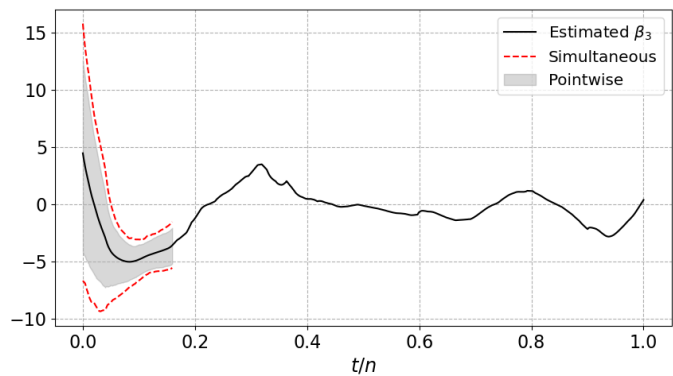
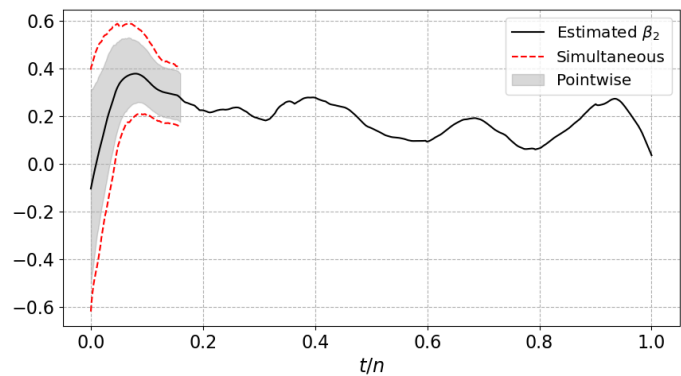
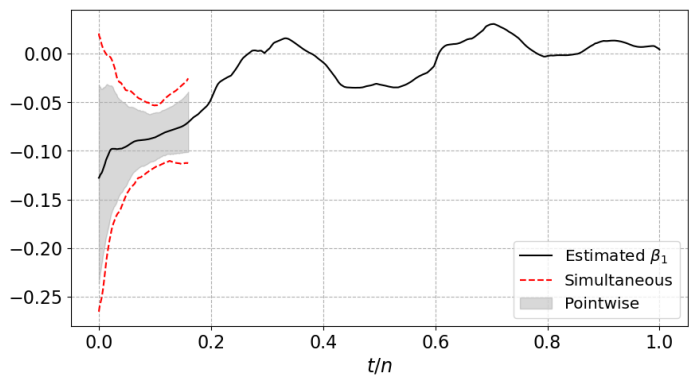
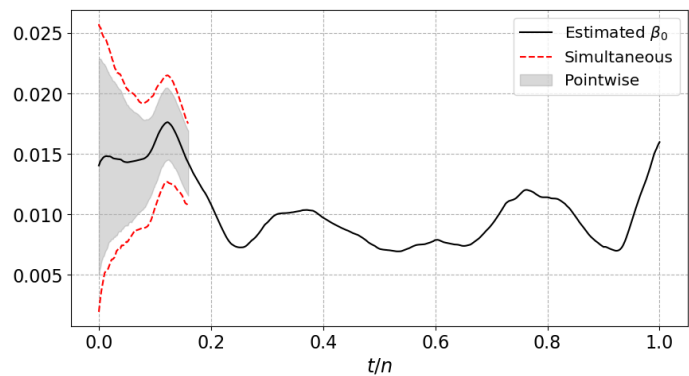
100%| | 1299/1299 [27:11<00:00, 1.26s/it]



```
[15]: ##### plot LBWB G1 bands, replication of 8c.
##### Only the plot of beta_3 is reported in the paper (takes about 6
↳mins).
S_LB_G1, S_UB_G1, P_LB_G1, P_UB_G1 = LLr_model.confidence_bands(plots=True,
↳Gsubs=[(0, breakindex_1)])
```

Calculating LBWB Bootstrap Samples

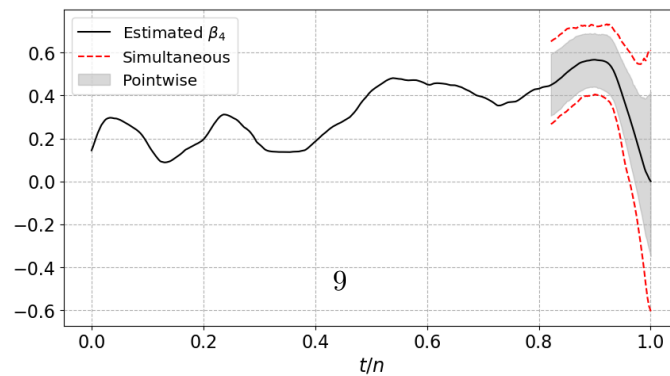
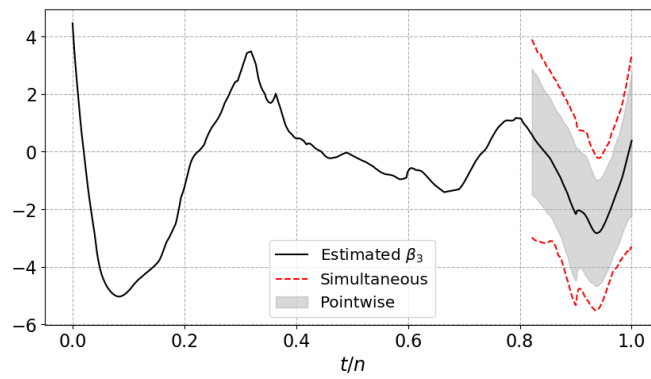
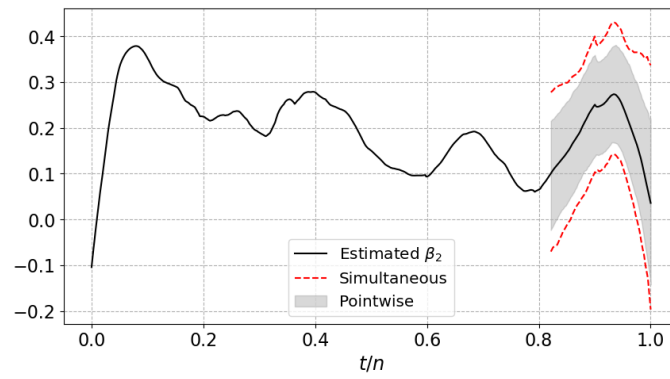
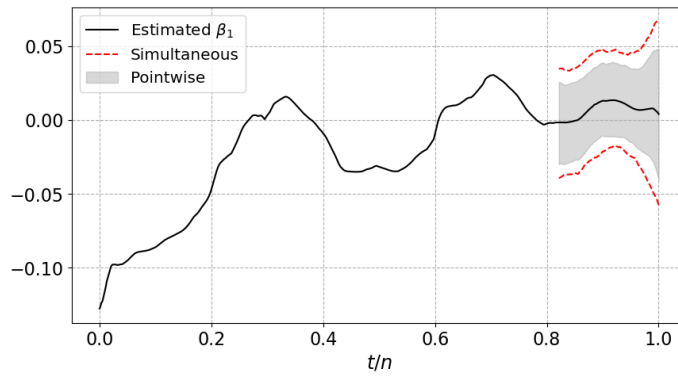
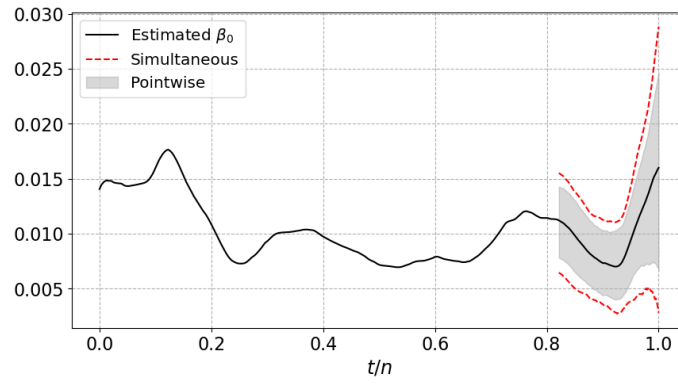
100%| | 1299/1299 [06:49<00:00, 3.17it/s]



```
[16]: ##### plot LBWB G6 bands, replication of 8d.
##### Only the plot of beta_3 is reported in the paper (takes about 7
↳mins).
S_LB_G6, S_UB_G6, P_LB_G6, P_UB_G6 = LLr_model.confidence_bands(plots=True,
↳Gsubs=[(breakindex_5, len(vY))])
```

Calculating LBWB Bootstrap Samples

100%| | 1299/1299 [07:14<00:00, 2.99it/s]



0.3 Replication code for Figure 9 in Appendix A.5

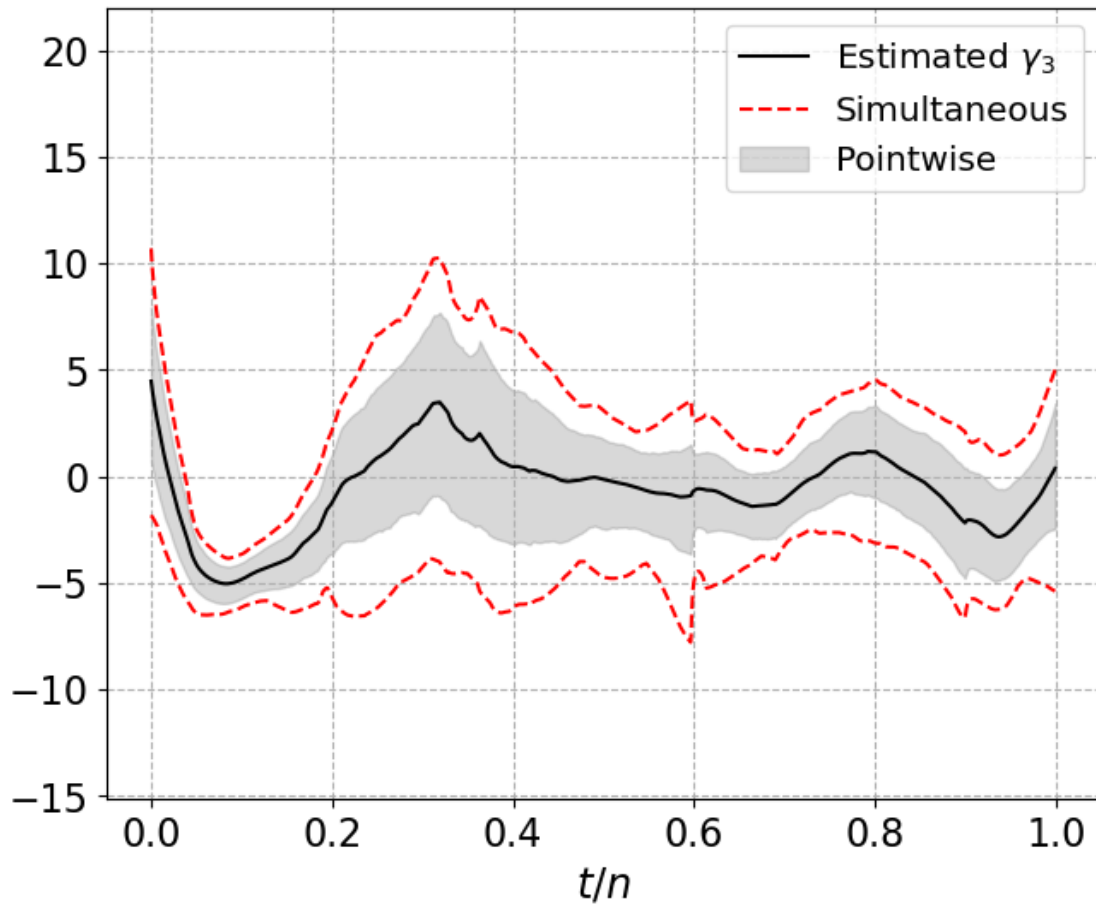
```
[29]: ##### Define the function to unify the format of plots as in Figure 9
def plot_figure9(LLr_betahat, S_LB_full, S_UB_full, P_LB_full, P_UB_full):
    x_axis=np.arange(0,1,1/len(vY))
    plt.figure(figsize=(7.5, 6))
    plt.plot(x_axis, LLr_betahat[3], color='black', label='Estimated_
    ↳ $\gamma_3$')
    plt.plot(x_axis, S_LB_full[3], color='red', linestyle='dashed')
    plt.plot(x_axis, S_UB_full[3], color='red', linestyle='dashed',
    ↳ label='Simultaneous')
    plt.fill_between(x_axis, P_LB_full[3], P_UB_full[3], color='grey', alpha=0.
    ↳ 3, label='Pointwise')
    plt.grid(linestyle='dashed')
    plt.xlabel('$t/n$', fontsize="xx-large")
    plt.ylim(-15.1, 22)
    plt.tick_params(axis='both', labels=16)
    plt.legend(fontsize="x-large")
    plt.show()
```

```
[25]: ##### Sieve bootstrap (SB) bands, Figure 9a (takes about 31 mins)
S_LB_full_SB, S_UB_full_SB, P_LB_full_SB, P_UB_full_SB = LLr_model.
    ↳ confidence_bands(plots=False, bootstrap_type="SB")
```

Calculating SB Bootstrap Samples

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```
[30]: ##### replication code for Figure 9a
plot_figure9(LLr_betahat, S_LB_full_SB, S_UB_full_SB, P_LB_full_SB,
    ↳ P_UB_full_SB)
```

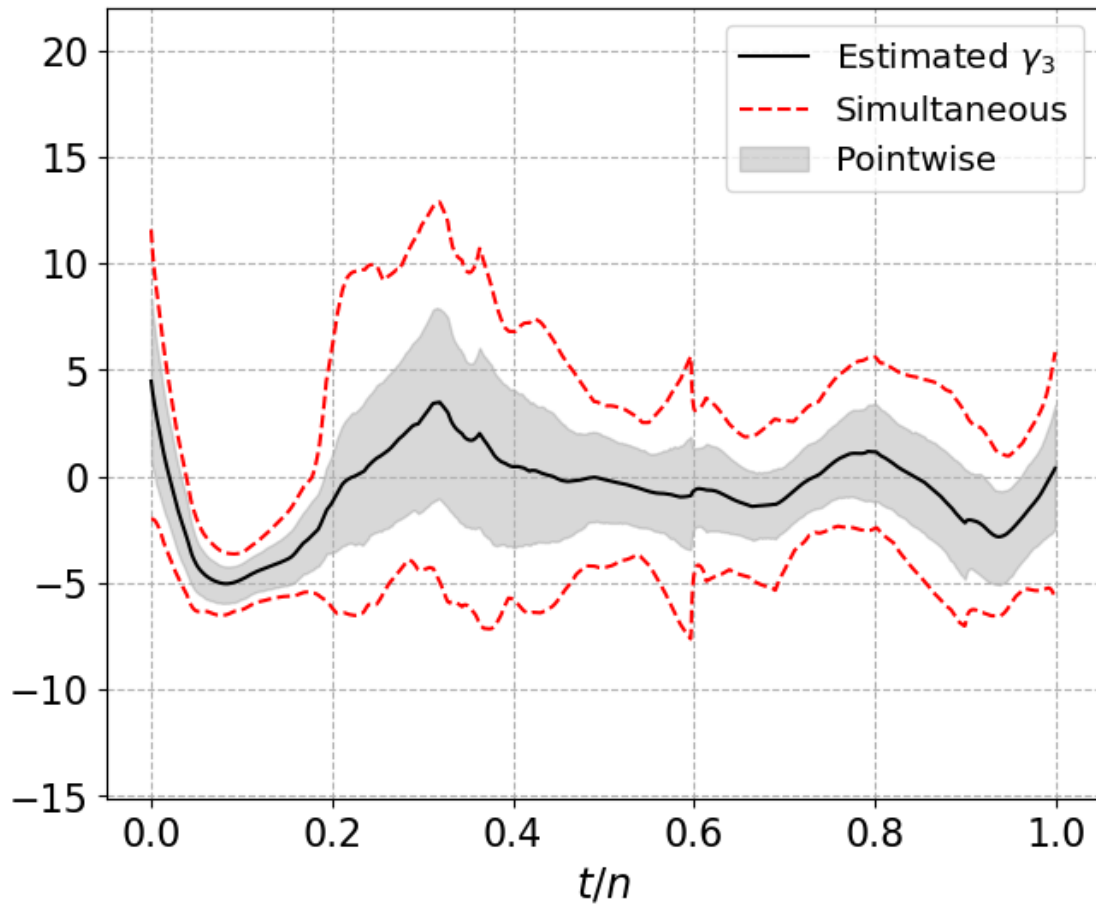


```
[26]: ##### Sieve wild bootstrap (SWB) bands, Figure 9b (takes about 36
      ↪mins)
      S_LB_full_SWB, S_UB_full_SWB, P_LB_full_SWB, P_UB_full_SWB = LLr_model.
      ↪confidence_bands(plots=False, bootstrap_type="SWB")
```

Calculating SWB Bootstrap Samples

100%| | 1299/1299 [36:11<00:00, 1.67s/it]

```
[31]: ##### replication code for Figure 9b
      plot_figure9(LLr_betahat, S_LB_full_SWB, S_UB_full_SWB, P_LB_full_SWB,
      ↪P_UB_full_SWB)
```

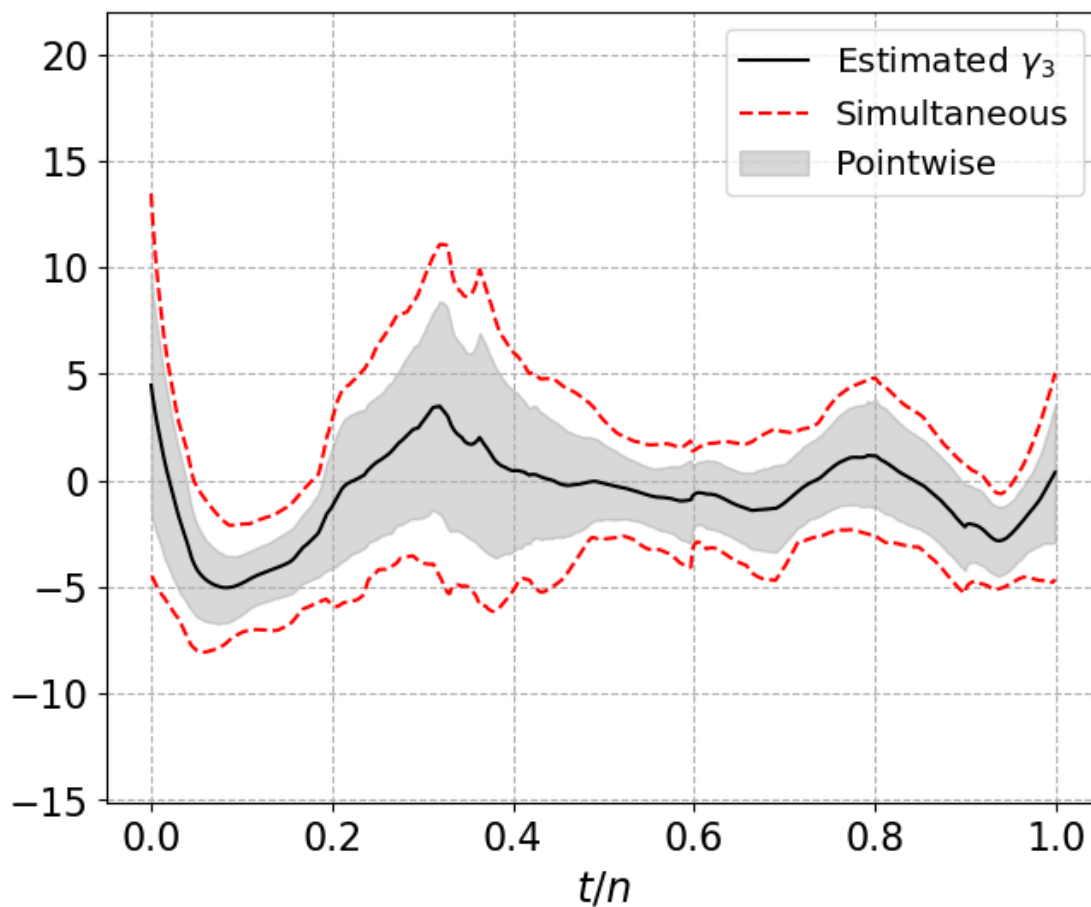


```
[27]: ##### Wild bootstrap (WB) bands, Figure 9c (takes about 28 mins)
S_LB_full_WB, S_UB_full_WB, P_LB_full_WB, P_UB_full_WB = LLr_model.
↳ confidence_bands(plots=False, bootstrap_type="WB")
```

Calculating WB Bootstrap Samples

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```
[32]: ##### replication code for Figure 9c
plot_figure9(LLr_betahat, S_LB_full_WB, S_UB_full_WB, P_LB_full_WB,
↳ P_UB_full_WB)
```



```
[28]: ##### Autoregressive wild bootstrap (AWB) bands, Figure 9d (takes
      ↪ about 27 mins)
      S_LB_full_AWB, S_UB_full_AWB, P_LB_full_AWB, P_UB_full_AWB = LLr_model.
      ↪ confidence_bands(plots=False, bootstrap_type="AWB")
```

Calculating AWB Bootstrap Samples

100%| | 1299/1299 [27:33<00:00, 1.27s/it]

```
[33]: ##### replication code for Figure 9d
      plot_figure9(LLr_betahat, S_LB_full_AWB, S_UB_full_AWB, P_LB_full_AWB,
      ↪ P_UB_full_AWB)
```

