数据预览：

Y Z X

0 13.857143 33.331832 0.059230

1 23.571429 34.232692 0.047362

2 13.000000 30.742188 0.054712

3 13.000000 30.742188 0.056711

4 13.000000 30.742188 0.065185

数据形状： (612, 3)

数据1（X和Y）的统计信息：

X Y

count 612.000000 612.000000

mean 0.076452 16.449580

std 0.032694 3.857809

min 0.010004 11.000000

25% 0.051438 13.142857

50% 0.074536 15.714286

75% 0.098362 19.857143

max 0.234218 24.857143

数据2（X和Z）的统计信息：

X Z

count 612.000000 612.000000

mean 0.076452 32.260822

std 0.032694 2.752826

min 0.010004 26.619343

25% 0.051438 30.346074

50% 0.074536 31.860885

75% 0.098362 33.876817

max 0.234218 44.697599

格兰杰因果检验结果（X 和 Y）：

C:\Users\zhuxitong\AppData\Local\Programs\Python\Python313\Lib\site-packages\statsmodels\tsa\stattools.py:1556: FutureWarning: verbose is deprecated since functions should not print results

warnings.warn(

Granger Causality

number of lags (no zero) 1

ssr based F test: F=21.1328 , p=0.0000 , df\_denom=608, df\_num=1

ssr based chi2 test: chi2=21.2371 , p=0.0000 , df=1

likelihood ratio test: chi2=20.8763 , p=0.0000 , df=1

parameter F test: F=21.1328 , p=0.0000 , df\_denom=608, df\_num=1

Granger Causality

number of lags (no zero) 2

ssr based F test: F=16.5169 , p=0.0000 , df\_denom=605, df\_num=2

ssr based chi2 test: chi2=33.3068 , p=0.0000 , df=2

likelihood ratio test: chi2=32.4293 , p=0.0000 , df=2

parameter F test: F=16.5169 , p=0.0000 , df\_denom=605, df\_num=2

Granger Causality

number of lags (no zero) 3

ssr based F test: F=9.8617 , p=0.0000 , df\_denom=602, df\_num=3

ssr based chi2 test: chi2=29.9290 , p=0.0000 , df=3

likelihood ratio test: chi2=29.2169 , p=0.0000 , df=3

parameter F test: F=9.8617 , p=0.0000 , df\_denom=602, df\_num=3

Granger Causality

number of lags (no zero) 4

ssr based F test: F=8.0836 , p=0.0000 , df\_denom=599, df\_num=4

ssr based chi2 test: chi2=32.8201 , p=0.0000 , df=4

likelihood ratio test: chi2=31.9649 , p=0.0000 , df=4

parameter F test: F=8.0836 , p=0.0000 , df\_denom=599, df\_num=4

格兰杰因果检验结果（X 和 Z）：

Granger Causality

number of lags (no zero) 1

ssr based F test: F=1.8925 , p=0.1694 , df\_denom=608, df\_num=1

ssr based chi2 test: chi2=1.9018 , p=0.1679 , df=1

likelihood ratio test: chi2=1.8989 , p=0.1682 , df=1

parameter F test: F=1.8925 , p=0.1694 , df\_denom=608, df\_num=1

Granger Causality

number of lags (no zero) 2

ssr based F test: F=1.1564 , p=0.3153 , df\_denom=605, df\_num=2

ssr based chi2 test: chi2=2.3319 , p=0.3116 , df=2

likelihood ratio test: chi2=2.3275 , p=0.3123 , df=2

parameter F test: F=1.1564 , p=0.3153 , df\_denom=605, df\_num=2

Granger Causality

number of lags (no zero) 3

ssr based F test: F=0.8682 , p=0.4573 , df\_denom=602, df\_num=3

ssr based chi2 test: chi2=2.6348 , p=0.4514 , df=3

likelihood ratio test: chi2=2.6291 , p=0.4524 , df=3

parameter F test: F=0.8682 , p=0.4573 , df\_denom=602, df\_num=3

Granger Causality

number of lags (no zero) 4

ssr based F test: F=1.1592 , p=0.3278 , df\_denom=599, df\_num=4

ssr based chi2 test: chi2=4.7064 , p=0.3188 , df=4

likelihood ratio test: chi2=4.6883 , p=0.3208 , df=4

parameter F test: F=1.1592 , p=0.3278 , df\_denom=599, df\_num=4

检验完成，结果已保存到 granger\_test\_results.txt