Do Stock Prices in HoSTC Have Unit Root? A Discussion on Power of ADF F Test with Unexpected Initial Value

Presented by: Tran Viet Ha
At GRIP’s Workshop
October 20, 2007
Objectives

- Apply most powerful unit root (UR) tests for Random Walk Hypothesis (RWH) in HoSTC (Ho Chi Minh City Stock Trading Center), Vietnam.
  - Unit root being rejected implies a violation of RWH (and also Efficient Market Hypothesis (EMH), assumed $E(R_t) = R \sim \text{const}: E(R_t|P_{t-1}, P_{t-2},...) = E(R_t)$.
  - Acceptance of null suggests further investigation.
  - Permanent/short-term effect of shocks on the future behavior.
- Show the power superiority of Dickey and Fuller’s F test (ADF-F) as well as Holden and Perman’s test procedure (HP-ADF) when unexpected initial value (IV) exists.
- Recommend for the robustness of UR test.
Outline

- Investigate the power behavior of ADF-F and t test upon the change in IV
- Propose HP-ADF test procedure as an approach improving power
- Apply robust tests for the data of HoSTC and discuss on the results
- Conclusion
Brief introduction to HoSTC

- First trading day: 28th July, 2000
- Total capitalization less than 1% GDP(*)
- Daily trading value: Less than 500,000 USD/day(*).
- Room for foreigner participation: 49% (bank: 30%)
- Operation: Daily since 1st March, 2002
- Mechanism: automated order-matching system (300,000 orders/day), two matches/day(*)
- Minimum order: 10 shares (~7 USD of par value)

(*) Updated information is considerably different.
Brief introduction to HoSTC

- It is believed that the market is inefficient even in the 'weak form':
  - The market is driven by herd behavior
  - Information regulation incompliance and leakage
  - Lack of consulting and rating reports
  - Strict price limit regulation
  - Small scale market which is vulnerable to the manipulation of big traders

*This paper is a first analysis concerning the weak form market efficiency for Vietnamese stock market, using unit root tests as a preliminary step*
The original Dickey and Fuller’s ADF tests (1979 and 1981) and Philips and Perron’s PP tests (1988):

- Size distortion is significant when the moving average component has large negative root (Schwert (1989), Perron and Ng (1996)),
- Low power if the autoregressive coefficient is close to unity (DeJong et al., 1992).

The modified ADF test of Elliot, Rothenberg, and Stock (ERS or GLS-DF test, 1996) and the modified Z test of Perron and Ng (GLS-MZ test, 2001):

- Improve both size and power problem above as long as the lag length is appropriately selected (e.g. by modified AIC)
- Lose power when the nuisance parameter, initial value, is far from the deterministic trend under alternative.
Power and initial value

- The recently modified tests (ERS, 1996/1999 and GLS-MZ, 2001) lose their power for moderately large IV in absolute term.
- ...ADF-t test, contrarily, gains power (Muller and Elliot, 2003, Dejong et al. (1992))
- The choice of appropriate tests depends on the knowledge of initial value.
- Large initial value may occur when studying new market or institution => employ various efficient tests that are most powerful with different magnitude of IV is necessary.
Model

\[ y_t = c + \alpha y_{t-1} + \beta t + \varepsilon_t, \quad t = 1, 2, \ldots, T \]  
(1)

\[ \varepsilon_t \sim \text{IID}(0, \sigma^2); \alpha < 1 \]

\( \alpha, \beta, \) and \( \sigma \) are fixed parameters. \( T \) is finite but big enough to approximate:

\[ \sum_{t=1}^{T} \alpha^{t-1} \approx 1/(1 - \alpha) \]

Unconditional expectation of IV, \( y_0 \):

\[ w_0 = c/(1 - \alpha) - \beta \alpha / (1 - \alpha)^2 \]  
(2)

Recursive equation for \( y_t \), given \( \Delta y_0 = y_0 - w_0 \):

\[ y_t = w_0 + \frac{\beta t}{1 - \alpha} + \Delta y_0 \alpha^t + \sum_{i=0}^{t-1} \alpha^i \varepsilon_{t-i} \]
Deriving $t$ statistic of ADF test

- F statistic is based on the ratio between the restricted sum of squared errors (SSE) and the unrestricted SSE.
- The $t$ statistic squared is a special F statistic with only one restriction.
- When $\Delta y_0$ changes, relative change of the unrestricted SSE is ignorable.
- The restricted errors is the residuals of the regression of the difference series $z_t = y_t - y_{t-1}$:
  
  $$z_t = c + \beta t + e_t$$
Deriving t statistic of ADF test

- Transformations lead to the approximation:

\[
t^2_{stat} \approx \frac{(\Delta y_0)^2 B + \sum_{t=1}^{T} [I_t(\varepsilon)]^2 - SSE_0}{SSE_0} \times (T - k)
\]

- Where B is mainly the difference between the term \(O(T^{-1})\) and \(\{\varepsilon_t\}\) and \(T\).

- \(I_t(\varepsilon)\) is the function of \(\{\varepsilon_t\}\) and \(T\)

- Given \(\{y_t\}\), when IV more deviates from its unconditional expectation, \(t^2\) statistic increases implying the power improvement of ADF t test.
F statistic

- Similarly, we derive the approximation of F statistic

\[
F_{stat} \approx \frac{(\Delta y_0)^2 A + \sum_{t=1}^{T} [H_t(\varepsilon)]^2 - SSE_0}{SSE_0} \times \frac{(T - k)}{2}
\]

- Where \( A = \frac{1 - \alpha}{1 + \alpha} - \frac{1}{T} = q - 1/T \)

- \( H_t(\varepsilon) \) is the function of \( \{ \varepsilon_t \} \) and \( T \)

- Given \( \{ y_t \} \), when IV more deviates from its unconditional expectation, \( F \) statistic increases implying the power improvement of ADF F test.
Comparison of F and t statistic

\[ F_{stat} \approx F_0 + \left( \frac{\Delta y_0}{SSE_0} \right)^2 A \times \frac{(T - k)}{2} \]

\[ t_{stat}^2 \approx t_0^2 + \left( \frac{\Delta y_0}{SSE_0} \right)^2 B \times (T - k) \]

- \( F_0 \) and \( t_0^2 \) are the statistics given \( \Delta y_0 = 0 \)
- If \( T \) is not so large, \( A \) is considerably larger than \( B \), \( F \) statistic grows faster making \( F \) test is potentially gain more power than \( t^2 \) test when \( |\Delta y_0| \) increases.
Comparison of F and t statistic

\[ K = \frac{F - F_0}{t^2 - t_0^2} = \frac{A}{2B} \]

- When \( K \) is big enough, the critical value of F test will ‘move’ to zero before that of t test.
- Numerical example: \( \alpha = 0.98; T = 1,000; \) significance level: 5%.
  - \( F_{\text{crit}} = 6.25 \) and \( t_{\text{crit}} = -3.41 \) or \( t_{\text{crit}}^2 = 11.63 \).
  - \( q = 0.02/1.98 = 0.0101, A = q – 1/T = 0.0091, B = 0.0067 \)
  - \( K = \frac{0.0091}{2 \times 0.0067} = 0.6827 \)
  - When \( F_{\text{crit}} \) ‘moves’ to 0, \( t_{\text{crit}}^2 \) ‘moves’ to \( t^*^2 \):
    \[ t_{\text{crit}}^2 - t^*^2 = F_{\text{crit}} / K = 6.25 / 0.6827 = 9.16 \]
    \[ t^*^2 = 11.63 - 9.16 = 2.47 > 0 \]
Comparison of F and t statistic

- Both F- and t-tests are not affected by the nuisance parameters $\beta$ and $c$ but depend on $|\Delta y_0|$, $T$, and $\alpha$.
- The power of (one-side) t test is higher than F test given small $|\Delta y_0|$.
- The power of both tests increase as $|\Delta y_0|$ grows from certain large value.
- F test becomes superior to t test when $|\Delta y_0|$ is large enough due to its higher sensitivity to $|\Delta y_0|$, not from join-test nature by itself.
- Closer is $\alpha$ to unity, more distinguishable is F test to t test.
- When the sample size increases, both tests have the power approaching unity and the difference between them gradually reduces.
ADAPTED HOLDEN AND PERMAN’S PROCEDURE (1994)

- Step 1: Estimate the equation:

\[ y_t = \alpha + \beta t + \rho y_{t-1} + \sum_{i=1}^{l-1} \zeta_i \Delta y_{t-i} + \epsilon_t \]

- Step 2: Use \( z_3 \) statistic to test: \( H_0: (\beta, \rho, \zeta) = (0, 0, 1) \) versus \( H_1: (\beta, \rho, \zeta) \neq (0, 0, 1) \). If null is rejected, go to step 3, otherwise, go to step 5.

- Step 3: Test \( \beta = 1 \) using the t-statistic from step 1, with critical values from the standard normal tables.
  - If the null is not rejected, conclude: process has unit root with time trend (rare).
  - Otherwise, the process is stationary with/without time trend.
ADAPTED HOLDEN AND PERMAN’S PROCEDURE (1994) - continued

- Step 5: Use a t statistic to test for $\phi = 1$, assuming $\theta$ is zero – non-standard critical values are required (t test is expected to consistent with F test, $\phi_3$)

- The further steps (4, 6, and 7) are not used because:
  - $\phi_1$ and $\phi_2$ are proved to be redundant (John Elder and Peter E. Kennedy, 2001).
  - Drift and existence of trend are not of primary concerns.
Holden and Perman’s approach

- HP-ADF basically has similar size to t and F tests in relevant cases.
- HP-ADF is more powerful than ADF t test when $|\Delta y_0|$ is large enough.
- Following the additional rule that: if F test cannot reject null while t test can, we reject the null, HP-ADF would be more powerful than F test when $|\Delta y_0|$ is moderate.
- HP-ADF avoid over rejection of F test when the model is unit root with time trend.
- In sum, HP-ADF is superior to both F and t test alone in the appropriate situation, especially, in the case of large $|\Delta y_0|$, HP-ADF is more powerful than t test.
Simulation model

\[ y_t = \alpha y_{t-1} + \beta t + \varepsilon_t \]

\[ \varepsilon_t \sim \text{i.i.d. } N(0,0.01), \quad t = 1, 2, \ldots, T \]

\( T = 500 \) or \( T = 1,000 \)

\( y_0 = w_0 + \Delta y_0 \)

\( w_0 = -\beta \alpha / (1-\alpha)^2 \)

\[ |\Delta y_0| = (0, 10, 20, \ldots, 50) \sigma \]

\( \alpha = 0.98; \beta = 0.00005 \)

Replications number: 5,000 for each value of \( \Delta y_0 \)

Tests used: HP-ADF/F, ADF test, GLS-DF
Table 1 – Power of HP-ADF, t, and GLS-DF tests with different IV

<table>
<thead>
<tr>
<th>$y_{0b}$</th>
<th>HP-ADF</th>
<th>ADF t</th>
<th>GLS-DF</th>
<th>HP-ADF</th>
<th>ADF t</th>
<th>GLS-DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 500</td>
<td></td>
<td></td>
<td></td>
<td>T = 1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.6225</td>
<td>0.979</td>
<td>0.853</td>
<td>0.000</td>
<td>0.999</td>
<td>0.997</td>
<td>0.000</td>
</tr>
<tr>
<td>-0.5225</td>
<td>0.929</td>
<td>0.667</td>
<td>0.000</td>
<td>0.995</td>
<td>0.986</td>
<td>0.000</td>
</tr>
<tr>
<td>-0.4225</td>
<td>0.682</td>
<td>0.449</td>
<td>0.000</td>
<td>0.955</td>
<td>0.921</td>
<td>0.000</td>
</tr>
<tr>
<td>-0.3225</td>
<td>0.349</td>
<td>0.282</td>
<td>0.001</td>
<td>0.784</td>
<td>0.769</td>
<td>0.000</td>
</tr>
<tr>
<td>-0.2225</td>
<td>0.162</td>
<td>0.181</td>
<td>0.074</td>
<td>0.571</td>
<td>0.624</td>
<td>0.194</td>
</tr>
<tr>
<td>-0.1225</td>
<td>0.129</td>
<td>0.163</td>
<td>0.244</td>
<td>0.489</td>
<td>0.563</td>
<td>0.778</td>
</tr>
<tr>
<td>-0.0225</td>
<td>0.177</td>
<td>0.189</td>
<td>0.064</td>
<td>0.575</td>
<td>0.632</td>
<td>0.194</td>
</tr>
<tr>
<td>0.0775</td>
<td>0.337</td>
<td>0.273</td>
<td>0.002</td>
<td>0.790</td>
<td>0.782</td>
<td>0.001</td>
</tr>
<tr>
<td>0.1775</td>
<td>0.680</td>
<td>0.444</td>
<td>0.000</td>
<td>0.959</td>
<td>0.934</td>
<td>0.000</td>
</tr>
<tr>
<td>0.2775</td>
<td>0.925</td>
<td>0.662</td>
<td>0.000</td>
<td>0.992</td>
<td>0.983</td>
<td>0.000</td>
</tr>
<tr>
<td>0.3775</td>
<td>0.976</td>
<td>0.848</td>
<td>0.000</td>
<td>0.998</td>
<td>0.996</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* The unconditional expectation of IV

GLS-DF is used with MAIC for lag selection in the OLS framework for the PSSD for HP-ADF and t tests.
Results

- The results are consistent with the theoretical inferences
- Both t test and F/ADF-HP test have minimum power at zero $\Delta y_0$ (Figure on the right)
- At zero $\Delta y_0$ (for both sample sizes):
  - GLS-DF $\gg$ t $>$ F/HP-ADF tests
    - 24% $>>$ 16% $>$ 13%, $T = 500$
    - 78% $>>$ 56% $>$ 49%, $T = 1,000$
- At non-zero, e.g. $\Delta y_0 = 30\sigma$:
  - GLS-DF $<<$ t $<$ F/HP-ADF
    - 0% $<<$ 45% $<$ 68%, $T = 500$
    - 0% $<<$ 92% $<$ 96%, $T = 1,000$
- The difference between HP-ADF/F and t tests diminishes when $T$ increases
- GLS-DF loses its power very fast when IV more deviates from expected value
A remark when the errors are serial correlated

- HP-ADF test is still more powerful than ADF-t tests for small or moderate sample sizes.
- Positive large AR(1) and MA(1) coefficients may diminish the superiority of HP-ADF/F test over ADF t test.
- Size distortion of both tests are similar:
  - Considerable size distortion when MA(1) coefficient is negative.
  - Acceptable size distortion for the remaining cases except when the sample size is small, e.g. T = 100.
Robust UR for stock prices series in HoSTC and data

- Stock prices in HoSTC:
  - The most early-quoted stocks experienced the first peak in 2001 when VNINDEX achieve 571 points from the starting value of 100 points.
  - Many stocks have the ‘outlier’ (high) opening prices following by adjusted periods.

- Selected tests:
  - GLS-DF would improve size and power for the case of expected IV.
  - HP-ADF and ADF t tests would improve power when IV deviates far from the deterministic trend.
  - KPSS testing for the null of stationary would provide a good complimentary view.

- Data: All available stock prices series of HoSTC from June 25, 2001 (the first peak of VNINDEX) to November 14, 2005:
  - 31 series (including VNINDEX) with lengths vary from 83-899.
  - The series starting before March 1st, 2002 are the alternative-day series.
  - The prices series are adjusted for dividend payments and splits and then transformed into natural logarithm form.
Examples of UR tests for stock prices series

Supporting evidences include:
- Panagiotidis (2004) testing for three indices of Athens Stock Exchange
- Chan et al. (1997) testing for monthly price indices of 18 developed countries

Rejection evidences include:
- Abeysekera (2001) testing for SSI and FSI of Sri Lanka’s indices
- Li et al. (2002) testing for NZSE’s indices (New Zealand)
Table 2 – Unit root tests for HoSTC

<table>
<thead>
<tr>
<th>Stock</th>
<th>Size</th>
<th>DF-GLS (MAIC)</th>
<th>KPSS</th>
<th>HP-ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>t_stat.</td>
<td>T_crit. 5%</td>
<td>t_stat.</td>
</tr>
<tr>
<td>AGF</td>
<td>887</td>
<td>-1.35</td>
<td>-2.89</td>
<td>0.30**</td>
</tr>
<tr>
<td>BBC</td>
<td>583</td>
<td>-0.56</td>
<td>-2.89</td>
<td>0.61**</td>
</tr>
<tr>
<td>BBT</td>
<td>423</td>
<td>-0.43</td>
<td>-2.92</td>
<td>0.59**</td>
</tr>
<tr>
<td>BPC</td>
<td>899</td>
<td>-1.42</td>
<td>-2.89</td>
<td>0.30**</td>
</tr>
<tr>
<td>BT6</td>
<td>894</td>
<td>-0.96</td>
<td>-2.89</td>
<td>0.35**</td>
</tr>
<tr>
<td>BTC</td>
<td>569</td>
<td>-1.59</td>
<td>-2.89</td>
<td>0.37**</td>
</tr>
<tr>
<td>CAN</td>
<td>608</td>
<td>-1.29</td>
<td>-2.89</td>
<td>0.58**</td>
</tr>
<tr>
<td>DHA</td>
<td>401</td>
<td>-0.31</td>
<td>-2.89</td>
<td>0.46**</td>
</tr>
<tr>
<td>DPC</td>
<td>592</td>
<td>0.13</td>
<td>-2.89</td>
<td>0.55**</td>
</tr>
<tr>
<td>GIL</td>
<td>577</td>
<td>-1.42</td>
<td>-2.89</td>
<td>0.26**</td>
</tr>
<tr>
<td>GMD</td>
<td>892</td>
<td>-0.77</td>
<td>-2.89</td>
<td>0.38**</td>
</tr>
<tr>
<td>HAP</td>
<td>658</td>
<td>-0.62</td>
<td>-2.89</td>
<td>0.61**</td>
</tr>
<tr>
<td>HAS</td>
<td>723</td>
<td>-1.56</td>
<td>-2.89</td>
<td>0.39**</td>
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<tr>
<td>KHA</td>
<td>810</td>
<td>-1.45</td>
<td>-2.89</td>
<td>0.44**</td>
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<tr>
<td>LAF</td>
<td>658</td>
<td>-0.50</td>
<td>-2.89</td>
<td>0.64**</td>
</tr>
<tr>
<td>MHC</td>
<td>168</td>
<td>-1.78</td>
<td>-2.96</td>
<td>0.09</td>
</tr>
<tr>
<td>NKD</td>
<td>230</td>
<td>-0.98</td>
<td>-2.93</td>
<td>0.41**</td>
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<tr>
<td>PMS</td>
<td>509</td>
<td>-1.47</td>
<td>-2.89</td>
<td>0.17*</td>
</tr>
<tr>
<td>PNC</td>
<td>90</td>
<td>-2.63</td>
<td>-3.07</td>
<td>0.23**</td>
</tr>
<tr>
<td>REE</td>
<td>658</td>
<td>-0.47</td>
<td>-2.89</td>
<td>0.53**</td>
</tr>
<tr>
<td>SAM</td>
<td>658</td>
<td>-0.78</td>
<td>-2.89</td>
<td>0.46**</td>
</tr>
<tr>
<td>SAV</td>
<td>882</td>
<td>-1.17</td>
<td>-2.89</td>
<td>0.32**</td>
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</tbody>
</table>
Table 2 – Unit root tests for HoSTC (continued)

<table>
<thead>
<tr>
<th>Stock</th>
<th>Size</th>
<th>DF-GLS (MAIC)</th>
<th>KPSS</th>
<th>HP-ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$t_{\text{stat.}}$</td>
<td>$T_{\text{crit. 5%}}$</td>
<td>$t_{\text{stat.}}$</td>
</tr>
<tr>
<td>SFC</td>
<td>291</td>
<td>-0.74</td>
<td>-2.91</td>
<td>0.35**</td>
</tr>
<tr>
<td>SGH</td>
<td>649</td>
<td>-2.12</td>
<td>-2.89</td>
<td>0.62**</td>
</tr>
<tr>
<td>SSC</td>
<td>182</td>
<td>-1.67</td>
<td>-2.95</td>
<td>0.36**</td>
</tr>
<tr>
<td>TMS</td>
<td>658</td>
<td>-0.71</td>
<td>-2.89</td>
<td>0.56**</td>
</tr>
<tr>
<td>TNA</td>
<td>83</td>
<td>-1.02</td>
<td>-3.11</td>
<td>0.30**</td>
</tr>
<tr>
<td>TRI</td>
<td>579</td>
<td>-0.93</td>
<td>-2.89</td>
<td>0.38**</td>
</tr>
<tr>
<td>TS4</td>
<td>817</td>
<td>-0.97</td>
<td>-2.89</td>
<td>0.30**</td>
</tr>
<tr>
<td>VNIa</td>
<td>658</td>
<td>-0.61</td>
<td>-2.89</td>
<td>0.55**</td>
</tr>
<tr>
<td>VTC</td>
<td>693</td>
<td>-1.31</td>
<td>-2.89</td>
<td>0.51**</td>
</tr>
</tbody>
</table>

Note:
- For KPSS tests, critical values are 0.216 (1%), 0.146 (5%), and 0.119 (10%).
- All the tests are specified with time trend. GLS-DF is used with MAIC for lag selection. KPSS is used with Newey-West using Bartlett kernel method for selection of bandwidth. HP-ADF is used with OLS F-test and t-test for lag selections (GTS approach).
- (*) or (**) mean the tests reject null at 5% or 1% respectively.
- For HP-ADF tests shown in this table based on non-standard distribution assuming that $\beta$ (time trend coefficient) is zero. If $\beta$ is non-zero, t statistic would follow standard normal distribution (-1.65 at 5%, one-side).
- a: Stands for VNINDEX
SOME REJECTED SERIES QUOTING DURING THE TESTED PERIOD

DPC

DHA

VNINDEX

MHC
Table 3 – ARMA(1,1) estimates of difference series rejected by ADF t or HP-ADF tests

<table>
<thead>
<tr>
<th>Stock</th>
<th>Const</th>
<th>AR(1)</th>
<th>MA(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBT</td>
<td>0.0010</td>
<td>0.98</td>
<td>-0.99</td>
</tr>
<tr>
<td>DHA</td>
<td>0.0009</td>
<td>-0.33</td>
<td>0.36</td>
</tr>
<tr>
<td>DPC</td>
<td>-0.0014</td>
<td>-0.34</td>
<td>0.42</td>
</tr>
<tr>
<td>MHC</td>
<td>0.0040</td>
<td>0.47</td>
<td>-0.62</td>
</tr>
<tr>
<td>PMS</td>
<td>0.0012</td>
<td>0.03</td>
<td>-0.23</td>
</tr>
<tr>
<td>SAM</td>
<td>0.0005</td>
<td>0.20</td>
<td>0.06</td>
</tr>
<tr>
<td>SFC</td>
<td>0.0037</td>
<td>0.89</td>
<td>-1.00</td>
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<tr>
<td>TMS</td>
<td>0.0016</td>
<td>0.97</td>
<td>-0.96</td>
</tr>
<tr>
<td>TNA</td>
<td>0.0021</td>
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<td>0.47</td>
</tr>
<tr>
<td>VNINDEX</td>
<td>-0.0008</td>
<td>0.10</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Results and discussions

- GLS-DF and KPSS support the existence of UR for all of the series (except KPSS cannot reject null of stationarity of one series)
- All of the series which seem to have extreme IVs are rejected by HP-ADF. The rejections seem not to be caused by size distortions.
- ADF t test also rejects the series with large IVs but less powerful than HP-ADF.

The series is likely to follow AR(1) process with the root very close to unity
THE CASE OF DHA

- MA coefficient: 0.36; AR coefficient: -0.33

- ERS and KPSS are in favor of unit root.

- ADF t test cannot reject null of UR: $t_{\text{statistic}} = -1.93 > t_{\text{critical}} = -3.42$

- HP-ADF reject null of UR:
  - $\Delta_3 \text{ reject (0,0)}: F_{\text{statistic}} = 8.24 > F_{\text{Critical}} = 6.31$
  - $t_{\text{statistic}} = -1.93 < -1.65 = t_{\text{critical}} - \text{reject} \Delta = 0$

- DHA maybe a stationary process with unexpected initial value and time trend
A SIMULATION OF DHA

\[ y_t = 0.0624 + 0.00005t + 0.98y_{t-1} + u_t \]

\[ u_t = -0.33u_{t-1} + \epsilon_t + 0.36\epsilon_{t-1} \]

- \[ \epsilon_t \sim \text{IIN}(0,0.01), \quad t=1,2,\ldots,401. \]
- \( y_0 = 3.4 \) (real value of 3.46)
A SIMULATION OF DHA

- HP-ADF rejects 86.4\% in 250 simulated series
- ADF t test rejects 43.2\%
- DF-GLS (ERS-MAIC) rejects 0\%
- KPSS accept null of stationarity at rate of \( \frac{2}{250} = 0.8\% \)
- DHA seem to be a particular case that HP-ADF test is more powerful than DF-GLS as well as KPSS tests
CHARTS OF SIMULATED AND REAL SERIES OF DHA

A simulated series

Real series of DHA
An interpretation

- In ‘normal’ condition, stocks prices follow a process very close to random walk (or at least, UR) process, swinging about a trend.

- Whenever there is a large shock, mean-reversion behavior appears; the series gradually converge to the deterministic trend. Possible causes:
  - Over-reaction and correction of the market
  - The effect of price limit regulation which does not allow the daily price change being more than 5% (the limit varied among 2%, 3%, and 7% depending on each period before set at 5% recently)
The robust unit root tests surprisingly cannot decisively reject the random walk hypothesis:

- VNINDEX seems to be more close to RW process than some indices as the ones of New Zealand and Sri Lanka markets.

The consistent rejections of HP-ADF test for the series seemingly having unexpected initial values reflect mean-reversion behavior (including VNINDEX). This support the view that the market is inefficient even in weak-form.

HP-ADF is strongly recommended when unexpected IV is highly possible, e.g. the case of stock prices in emerging market, besides other efficient tests like DF-GLS (Elliot et al., 1996/1999) and GLS-MZ (Ng, S., 2001)
Thank you very much for your attention!

Your questions and comments are very welcomed!