Efficient Markets Hypothesis

- If the flow of information is unimpeded
- New information is immediately reflected in the price of a stock
- Tomorrow’s price will only reflect new information
- Since new information is unpredictable – stock prices tomorrow are unpredictable
- Price of a stock reflects all available information

Implication

- Stock prices are a random walk
  - New information unpredictable
  - Best prediction of a price tomorrow is the price today
- Universal nature of information means that you cannot outsmart the market
  - “A blindfolded chimpanzee throwing darts at the Wall Street Journal could select a portfolio that would do as well as the experts”

Three versions

- Weak
  - Cannot predict future prices with current prices
- Semi-strong
  - Current prices reflect all available public information
- Strong form
  - Current prices reflect all information even insider information
Focus on weak form

- Standard test – stock prices are a random walk
  - Best predictor of tomorrow’s price is today’s
  - 1st difference in daily returns is not predictive
- Can test with
  - Single stocks
  - Aggregate indexes
  - At any frequency

Two models

\[ \ln(P_t) = \beta_0 + \ln(P_{t-k}) \beta_1 + \epsilon_t \]

\[ \Delta k \ln(P_t) = \ln(P_t) - \ln(P_{t-k}) \]

\[ \Delta k \ln(P_t) = \alpha_0 + \Delta k \ln(P_{t-k}) \alpha_1 + \xi_t \]

Let \( k = 1, 2, 7, 30 \)

Regress \( \ln(\text{closing price}) \) on 1 day lag

``` stata
* test for random walk  
* run a regression of change in closing price  
* on one period lag  
* reg ln_close ln_close1  
```

```
Source |       SS       df MS              Number of obs =  14361  
--------+------------------------------ F(  1, 14359) =   43.31  
Model |  572.50398     1  572.50398           Prob > F      =  0.0000  
Residual |  1.19637406 14359  .000081702           R-squared     =  0.9996  
--------+------------------------------ Adj R-squared =  0.9996  
Total |  1.19637406 14360  .000081702           Root MSE      =  .00909  

------------------------------------------------------------------------------  
ln_close |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]  
-------------+----------------------------------------------------------------  
ln_close1 |   .9999838   .0000652     15.58   0.000     .9998550     1.000112  
_cons |   .0003805   .0004995     0.76   0.446    -.0005984      .0013593  
------------------------------------------------------------------------------
```

Regress \( \Delta \ln(\text{closing price}) \) on 1 day lag

``` stata
* run a regression of the 1st difference on its lag  
* reg dln_close dln_close1  
```

```
Source |       SS       df MS              Number of obs =  14360  
--------+------------------------------ F(  1, 14358) =  69.43  
Model |  .005716048     1  .005716048           Prob > F      =  0.0000  
Residual |  1.18199835 14358  .000082323           R-squared     =  0.0048  
--------+------------------------------ Adj R-squared =  0.0047  
Total |  1.1877144 14359  .000082716           Root MSE      =  .00907  

------------------------------------------------------------------------------  
dln_close |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]  
-------------+----------------------------------------------------------------  
dln_close1 |   .0693733   .0083254     8.33   0.000     .0530544    .0856921  
_cons |   .0002686   .0000758     3.55   0.000     .0001201    .0004171  
------------------------------------------------------------------------------
```

Regress delta \( \ln(\text{closing price}) \) on 1 day lag

``` stata
* get means of delta daily closing price  
* sum dln_close  
```

```
Variable |    Obs  Mean    Std. Dev.     Min     Max  
------------+-------------------------------  
dln_close |   14361 -.0000428  .4095044  -.0966616  .2563152  

------------------------------------------------------------------------------
```
Regress ln(close) at end of month t on ln(close) at end of previous month:

\[ \text{reg ln_close ln_close1} \]

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>875.654356</td>
<td>1</td>
<td>875.654356</td>
</tr>
<tr>
<td>Residual</td>
<td>1.15990765</td>
<td>683</td>
<td>.001698254</td>
</tr>
<tr>
<td>Total</td>
<td>859.654356</td>
<td>684</td>
<td>.00125680461</td>
</tr>
</tbody>
</table>

\[ R^2 = 0.9987 \]

\[ \text{Adj } R^2 = 0.9986 \]

\[ \text{Root MSE} = .04121 \]

\[ \begin{align*}
\text{ln_close} & : \text{Coef.} = 0.9997576, \text{Std. Err.} = 0.0014061, t = 711.00, p = 0.000 \\\n\text{ln_close1} & : \text{Coef.} = 0.007807, \text{Std. Err.} = 0.0103621, t = 0.75, p = 0.451
\end{align*} \]

Regress Δln(closing price) at end of month t on Δln(closing) at end of previous month:

\[ \text{reg dln_close dln_close1} \]

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>.000082068</td>
<td>1</td>
<td>.000082068</td>
</tr>
<tr>
<td>Residual</td>
<td>1.15987162</td>
<td>682</td>
<td>.001700692</td>
</tr>
<tr>
<td>Total</td>
<td>1.15995369</td>
<td>683</td>
<td>.001698322</td>
</tr>
</tbody>
</table>

\[ R^2 = 0.0001 \]

\[ \text{Adj } R^2 = -0.0014 \]

\[ \text{Root MSE} = .04124 \]

\[ \begin{align*}
dln_close & : \text{Coef.} = 0.0084114, \text{Std. Err.} = 0.0382908, t = 0.22, p = 0.826 \\\ndln_close1 & : \text{Coef.} = 0.0059876, \text{Std. Err.} = 0.0015937, t = 3.76, p = 0.000
\end{align*} \]

Stock market anomalies:

- Stock prices show persistent positive and negative returns on certain days: January, Mondays, before holidays, etc.
- Existence of these anomalies demonstrates arbitrage opportunity
- Therefore, there exists some evidence against the EMH
. reg dln_close time dmonth* tue wed thur fri
Number of obs = 14361
---
Source | SS df MS     F( 16, 14344) = 4.04
-------------+------------------------------    Prob > F = 0.0000
Model | 0.00533038 16 .000333144
Residual | 1.18238652 14344 .000082431
Total | 1.18771682 14360 .00008271
-------------+------------------------------    Adj R-squared = 0.0034
                Root MSE = .00908
---

dln_close | Coef. Std. Err. t P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
time | 3.87e-09 1.83e-08 0.21 0.832    -3.20e-08 3.97e-08
dmonth2 | -.0005082 .0003784 -1.34 0.179    -.0012499 .0002334
dmonth3 | -.0001697 .0003656 -0.46 0.643    -.0008863 .0005474
dmonth4 | -.0002654 .0003709 -0.72 0.474    -.0004617 .0009924
dmonth5 | -.000825 .0003684 -1.88 0.061    -.0014373 .0008877
dmonth6 | -.000632 .0003677 -1.72 0.086    -.0013527 .0000887
dmonth7 | -.0001027 .0003692 -0.28 0.781    -.0008264 .0006121
dmonth8 | -.0006352 .0003647 -1.74 0.082    -.0013517 .0000896
dmonth9 | -.0003567 .0003651 -0.98 0.329    -.0004827 .0004694
dmonth10 | -.0002275 .0003743 -0.60 0.547    -.0004019 .0003464
dmonth11 | -.0002412 .0003692 -0.65 0.514    -.0004826 .0004949
tue | .0009457 .000241 3.92 0.000    .0004733 .0014181
tue | .001302 .000241 5.40 0.000    .0007444 .0018636
wed | .0008147 .0002418 3.37 0.001    -.0004057 .0016356
thur | .001219 .0002421 5.03 0.000    .0006444 .0017936
fri | .0003209 .0002395 -0.97 0.330    -.0004687 .0011095
_cons | -.0003209 .0003295 -0.97 0.330
-------------+----------------------------------------------------------------

.test dmonth2 dmonth3 dmonth4 dmonth5 dmonth6 dmonth7 dmonth8 dmonth9 dmonth10 dmonth11 dmonth12
( 1)  dmonth2 = 0
( 2)  dmonth3 = 0
( 3)  dmonth4 = 0
( 4)  dmonth5 = 0
( 5)  dmonth6 = 0
( 6)  dmonth7 = 0
( 7)  dmonth8 = 0
( 8)  dmonth9 = 0
( 9)  dmonth10 = 0
(10)  dmonth11 = 0
(11)  dmonth12 = 0
( 1)  dmonth12 = 0
F( 11, 14344) = 2.67    Prob > F = 0.0020

.test tue wed thur fri
( 1)  tue = 0
( 2)  wed = 0
( 3)  thur = 0
( 4)  fri = 0
F(  4, 14344) = 9.13    Prob > F = 0.0000

---

Exhibit 5
Percentage of Large Capitalization Equity Funds Outperformed by Index Ending 6/30/2002

<table>
<thead>
<tr>
<th></th>
<th>1 year</th>
<th>2 year</th>
<th>3 year</th>
<th>5 year</th>
<th>10 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP500 vs. Large Cap Equity Funds</td>
<td>63%</td>
<td>56%</td>
<td>51%</td>
<td>69%</td>
<td>74%</td>
</tr>
<tr>
<td>Wilshire 5000 vs. Large Cap Equity Funds</td>
<td>72%</td>
<td>64%</td>
<td>69%</td>
<td>74%</td>
<td>74%</td>
</tr>
</tbody>
</table>
Wall Street Journal “Dart Board”

- Starting in Oct of 1988, asked four professional money managers to select a stock
- Compared that portfolio against 4 randomly selected stocks
- Tracked for 6 months
- Ended after 14 years in 2002 – 142 contests

Results

- Average 6 month return
  - Pros 10.2%
  - DJIA 5.6%
  - Darts 3.5%
- Pros beat market 54% of the time
- Pros beat darts 61% of the time
- Does this falsify the EMH?
Nearing the End of the Match

The pros have dominated most contests...

But the margin of victory has varied

<table>
<thead>
<tr>
<th>50 percentage points or more</th>
<th>25 to 49 percentage points</th>
<th>0 to 24 percentage points</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>12%</td>
<td>88%</td>
</tr>
</tbody>
</table>

Day Relative to Announcement

Relative Volume Ratios

Winners

Contenders