Testing Weak Form Efficiency on the Toronto Stock Exchange

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Outline

1. Introduction
   - Literature review
   - Motivation

2. Methodology
   - Smoothing
   - Identifying local extrema
   - Chart Pattern Recognition
   - Null Model
   - Compare number of patterns
   - Proportion with high occurrence of reversal patterns
   - Ranking

3. Data

4. Results

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Testing Weak Form Efficiency on the TSX
Market Efficiency
Weak form market efficiency

- Fama (1970): a financial market is (informationally) efficient when market prices reflect all available information about value.

- The more efficient the market, the more random the sequence of price changes generated by such a market; and the most efficient market of all is a market in which price changes are completely random.

- Thus, if the number of patterns identified in the real price series is the same as in simulated price data, then technical analysis cannot be gainfully applied and the weak form of the efficient market hypothesis cannot be rejected.
Existing Literature

- **Brock et al (1992)**
  - Model-based bootstrap
  - 90-year sample period, DJIA (1897-1986)
  - 26 technical trading rules all outperformed the market.

  - Automated mechanical trading systems, chart pattern study.
  - Several chart patterns do provide incremental information and may have some practical value.
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In this study we:

- analyze each security listed on the TSX
- use several null models to simulate the data
- perform sector analysis of the TSX
Methodology outline

1. Smooth price series
2. Find local extrema points
3. Identify chart patterns
4. Use original return series to estimate model parameters
5. Using estimated parameters obtain simulated series
6. Repeat steps 1-3 for each simulated series
7. Compare number of patterns (original vs. simulated data)
8. Find proportion of securities with significantly higher occurrence of reversal patterns
9. Use total ranking techniques
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Smoothing

Smoothing original price series with natural cubic spline

Suppose $P_{it} = f_i(t) + \epsilon_{it}$

$$\hat{f}_i(t) = \arg \min_{f \in C^2[1,T_i]} \left( \sum_{t=1}^{T_i} (P_{it} - f_i(t))^2 + \lambda_i \int_1^{T_i} (f''(x))^2 dx \right)$$

1. The smoothness of $f_i(.)$ is controlled through penalty function, $\lambda_i \geq 0$, acting as a smoothing parameter (or equivalently $df$).
2. Optimal $\lambda_i$ obtained through CV, however, results in highly undersmoothed estimate.
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- Optimal \( \lambda_i \) obtained through CV, however, results in highly undersmoothed estimate.
Local Extrema
Finding optimal smoothing parameter

- Lo et al (2000): used survey approach
- We rely on concavity of a functional relationship between number of patterns identified and a smoothing parameter (df)
Chart Pattern Recognition
Identification conditions based on five consecutive extrema points

- We search for ten reversal patterns
  - e.g. Head-and-Shoulders (HS) reversal pattern

\[
\begin{align*}
E_1 &> E_2 \\
E_3 &> E_1 \\
E_3 &> E_5 \\
\frac{|E_1 - E_5|}{(E_1 + E_5)/2} &\leq C \\
\frac{|E_2 - E_4|}{(E_2 + E_4)/2} &\leq C \\
\frac{E_3 - E_1}{E_3} &\geq S
\end{align*}
\]

- \( E_1 > E_2 \) ensures \( E_1 \) is a local maximum
- \( E_3 > E_1 \) and \( E_5 \) are within \( C \)% of their average
- \( E_3 > E_5 \) head is larger than left shoulder
- \( E_2 \) and \( E_4 \) are within \( C \)% of their average
- \( E_3 \) greater than right shoulder
- \( |E_1 - E_5| \leq C (E_1 + E_5)/2 \)
- \( |E_2 - E_4| \leq C (E_2 + E_4)/2 \)
- \( \frac{E_3 - E_1}{E_3} \geq S \)
  - ensures that the head of the pattern is significantly larger than the shoulders
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\( E_1 \) and \( E_5 \) are within \( C \)% of their average
\( E_2 \) and \( E_4 \) are within \( C \)% of their average

ensures \( E_1 \) is a local maximum
head is larger than left shoulder
head is larger than right shoulder

ensures that the head of the pattern is significantly larger than the shoulders
Null Models
Commonly used models capturing specific data characteristics present in financial returns

- Data characteristics:
  - leptokurtosis
  - conditional heteroskedasticity
  - moving average and
  - autororrelation

- Sieve bootstrap
  - Random walk with a drift
  - EGARCH(p,q)
  - ARMA(p,q)
    - p,q chosen to minimize BIC and AICc respectively
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Let $M_{ij}$ be a number of patterns identified for security $i$ in simulation $j$

let $M_{i0}$ denote the number of patterns identified in the original price series

The weak form efficient market hypothesis can then be stated as follows:

$H_0 : M_{i0} \leq \overline{M}_i$

$H_1 : M_{i0} > \overline{M}_i$

where $\overline{M}_i = \sum_{j=0}^{n} M_{ij}$. 
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Compare number of patterns
Number of reversal patterns identified in original series vs simulated series

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Occurrence of reversal patterns
Proportion of securities with high occurrence of reversal patterns

- For a given set of securities (e.g. market sectors) find proportion of these securities with significantly higher occurrence of patterns in original data than in simulated data.
Use total ranking techniques to order sectors from highest to lowest in terms of proportion of stocks with significantly higher occurrence of patterns in original data than in simulated data.
Data

- Dividend and split adjusted daily closing prices
- 1336 securities traded on Toronto Stock Exchange (on June 28, 2008)
- Subcategories:
  - 38 market sectors
  - S&P/TSX Composite index
  - 9 iShares ETFs (XEG, XFN, XGP, XTR, XMA, XRE, XIT, XCG, XCV)
- Sample period: 25-year sample, from 1983 (where available) to 2008
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1336 securities traded on Toronto Stock Exchange (on June 28, 2008)
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**EGARCH(p,q)**

Proportions of securities with significantly large number of chart patterns

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<tr>
<th></th>
<th>N</th>
<th>HS</th>
<th>IHS</th>
<th>BT</th>
<th>BB</th>
<th>TT</th>
<th>TB</th>
<th>RW</th>
<th>FW</th>
<th>RT</th>
<th>RB</th>
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<td><strong>All 1336 securities</strong></td>
<td>1336</td>
<td>0.29</td>
<td>0.27</td>
<td>0.03</td>
<td>0.03</td>
<td>0.14</td>
<td>0.15</td>
<td>0.05</td>
<td>0.10</td>
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<tr>
<td><strong>TSX Composite members</strong></td>
<td>251</td>
<td>0.13</td>
<td>0.12</td>
<td>0.02</td>
<td>0.02</td>
<td>0.08</td>
<td>0.09</td>
<td>0.04</td>
<td>0.05</td>
<td>0.35</td>
<td>0.34</td>
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<td>iShares XEG members</td>
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<td>0.13</td>
<td>0.13</td>
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<td>0.00</td>
<td>0.07</td>
<td>0.04</td>
<td>0.00</td>
<td>0.04</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>iShares XFN members</td>
<td>23</td>
<td>0.09</td>
<td>0.04</td>
<td>0.00</td>
<td>0.00</td>
<td>0.09</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.30</td>
<td>0.22</td>
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<tr>
<td>iShares XGP members</td>
<td>15</td>
<td>0.20</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.27</td>
<td>0.33</td>
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<td>iShares XTR members</td>
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<td>0.02</td>
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<td>0.17</td>
<td>0.02</td>
<td>0.02</td>
<td>0.33</td>
<td>0.23</td>
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<td>iShares XMA members</td>
<td>43</td>
<td>0.14</td>
<td>0.09</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.07</td>
<td>0.00</td>
<td>0.00</td>
<td>0.28</td>
<td>0.35</td>
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<td>0.02</td>
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<td>iShares XCV members</td>
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<td>0.00</td>
<td>0.00</td>
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<td>Automobiles &amp; Parts</td>
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<td>Banks</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Chemicals</td>
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<td>0.27</td>
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<td>0.07</td>
<td>0.00</td>
<td>0.07</td>
<td>0.27</td>
<td>0.40</td>
</tr>
</tbody>
</table>
## EGARCH\((p,q)\)

Total ranking report

<table>
<thead>
<tr>
<th>Rank</th>
<th>Objects</th>
<th>Desirability</th>
<th>Utility</th>
<th>Dominance</th>
<th>Abs. Ref.</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>iShares XFN</td>
<td>0.87</td>
<td>0.877</td>
<td>0.784</td>
<td>1</td>
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<tr>
<td>2</td>
<td>iShares XEG</td>
<td>0.86</td>
<td>0.863</td>
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<td>3</td>
<td>iShares XM4</td>
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<td>4</td>
<td>iShares XCV</td>
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<tr>
<td>5</td>
<td>Banks</td>
<td>0.863</td>
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<td>0.684</td>
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<tr>
<td>6</td>
<td>iShares XCG</td>
<td>0.8</td>
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<td>7</td>
<td>iShares XTI</td>
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<tr>
<td>8</td>
<td><strong>TSX Composite</strong></td>
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<td><strong>0.813</strong></td>
<td><strong>0.646</strong></td>
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<tr>
<td>9</td>
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<td>0.854</td>
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<td>iShares XGP</td>
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<tr>
<td>12</td>
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<td>0.817</td>
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<td>0.903</td>
</tr>
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<td>13</td>
<td>Life Insurance</td>
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<td>0.833</td>
<td>0.596</td>
<td>0.92</td>
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<tr>
<td>14</td>
<td>Forestry &amp; Paper</td>
<td>0.822</td>
<td>0.833</td>
<td>0.589</td>
<td>0.835</td>
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<td>15</td>
<td>Oil &amp; Gas Producers</td>
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<td>16</td>
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<tr>
<td>21</td>
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<td>22</td>
<td>Leisure Goods</td>
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<td>Mining</td>
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<td>24</td>
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<tr>
<td>25</td>
<td>Household Goods &amp; Home Constru</td>
<td>0.696</td>
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<td>0.366</td>
<td>0.793</td>
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</table>
## EGARCH\((p,q)\)

Total ranking report

<table>
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<tr>
<th>Rank</th>
<th>Objects</th>
<th>Desirability</th>
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<th>Dominance</th>
<th>Abs. Ref.</th>
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<tr>
<td>26</td>
<td>General Retailers</td>
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<td>0.688</td>
<td>0.33</td>
<td>0.752</td>
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<tr>
<td>27</td>
<td>Industrial Metals &amp; Mining</td>
<td>0.719</td>
<td>0.727</td>
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<tr>
<td>28</td>
<td>Construction &amp; Materials</td>
<td>0.702</td>
<td>0.72</td>
<td>0.325</td>
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<tr>
<td>29</td>
<td><strong>All 1336</strong></td>
<td><strong>0.702</strong></td>
<td><strong>0.712</strong></td>
<td><strong>0.323</strong></td>
<td><strong>0.824</strong></td>
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<td>30</td>
<td>General Industrials</td>
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<td>0.675</td>
<td>0.299</td>
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<tr>
<td>31</td>
<td>Software &amp; Computer Services</td>
<td>0.677</td>
<td>0.696</td>
<td>0.296</td>
<td>0.791</td>
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<tr>
<td>32</td>
<td>iShares XRE</td>
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<td>0.697</td>
<td>0.283</td>
<td>0.776</td>
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<tr>
<td>33</td>
<td>Electronic &amp; Electrical Equipm</td>
<td>0.708</td>
<td>0.716</td>
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<tr>
<td>34</td>
<td>Support Services</td>
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<tr>
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<td>Automobiles &amp; Parts</td>
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<table>
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<td>13.64</td>
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</table>
Summary

- Some sectors appear to be more efficient than others
- Top ranked categories are comprised of largest and most frequently traded securities.
- Technical analysis will be potentially gainful in lower ranked sectors

Outlook
- $ARMA(p,q)$ presented controversial results
- Analysis of 5-year subsamples
C. Park and S. Irwin  
*The profitability of technical analysis: A review.*  

W. Brock and J. Lakonishok and B. LeBaron  
Simple technical trading rules and the stochastic properties of stock returns.  

A. Lo and H. Mamaysky and J. Wang.  
Foundations of technical analysis: Computational algorithms, statistical inference, and empirical implementation.  