CAPTURING ORDER IMBALANCE WITH HIDDEN MARKOV MODEL: A CASE OF SET50 AND KOSPI50

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Motivation

"How long does it take to remove serial dependence over a daily horizon? The pattern of intra-day serial dependence reveals that it takes more than 5 minutes but less than 60 minutes"

Chordia et al (2005)

Motivation

"Prices were closer to random walk benchmarks in the more liquid regime than in others one … these findings indicate that liquidity stimulates arbitrage activity, which, in turn, enhances market efficiency"

Chordia et al(2008)

Objectives of this Study

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(1) Use Hidden Markov Model to capture the states of order imbalance of selected stocks from SET50 and KOSPI50 in a consistent and confident manner

(2) Build and back-test strategies by using the signals generated from proposed models

(3) Compare the result between markets, across different frequencies and with traditional buy-and-hold strategies

Outline

- Scope of data
- Methodology
- Result
- Conclusion and Recommendation

Scope of Data

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- Market: 10 stocks from SET50 (Thailand) and KOSPI50 (Korea)
- Input Data: mid-point closing price, bid size, ask size
- Scope of data: 1st Oct 2016 to 31st Jan 2017
- Frequency of data: Intra-day data
  - Interval: 5 minutes, 10 minutes and 30 minutes

Scope of Data

- Stocks Selection Criteria
  - **Stocks that are consistently listed on SET50 and KOSPI50 Index during the period from 1st January 2012 to 31st July 2016**
  - **Select 10 stocks with highest 250 days average daily volume turnover**
- Data for initial-training and back-testing
  - **Initial Training: 1st Oct 2016 to 31st Oct 2016**
  - **Back testing: 1st Nov 2016 to 31st Jan 2017**

Selected Stocks: SET50

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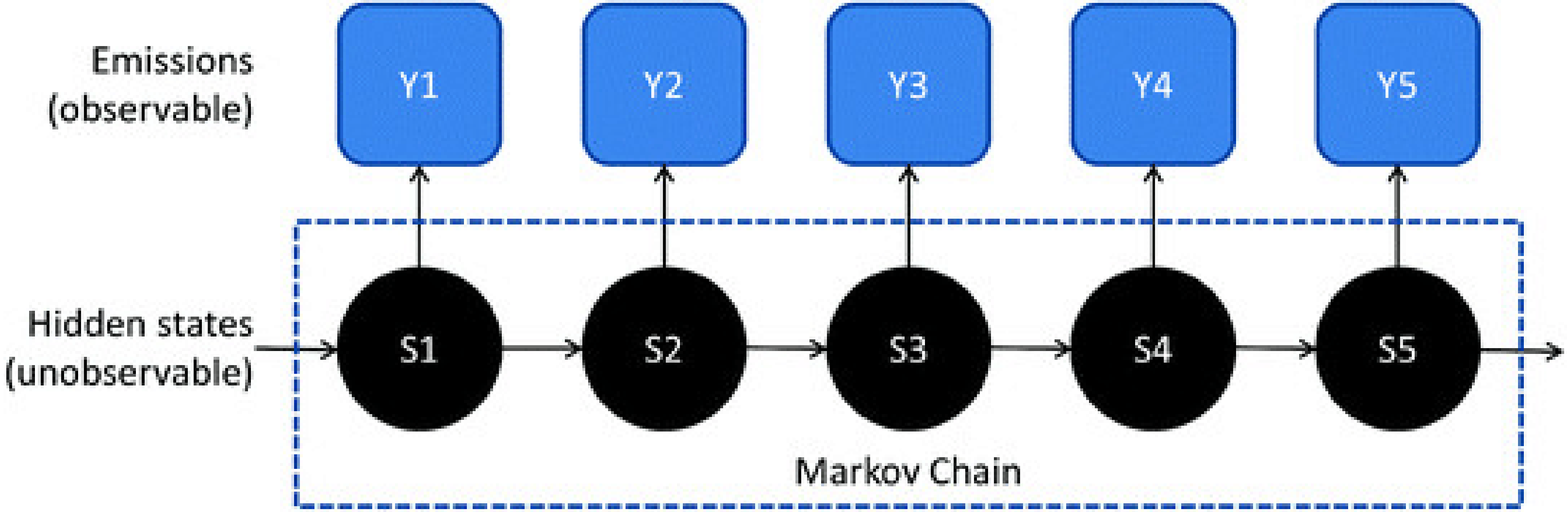
Ticker	Company Name	Sector
ADVANC.BK	Advance Info Service PCL	Information & Communication
BANPU.BK	Banpu PCL	Energy & Utilities
BCP.BK	Bangchak Petroleum PCL	Energy & Utilities
CPF.BK	Charoen Pokphand Foods PCL	Food and Beverage
DTAC.BK	Total Access Communication PCL	Information & Communication
IRPC.BK	IRPC PCL	Energy & Utilities
IVL.BK	Indorama Ventures PCL	Petrochemicals & Chemicals
PTTEP.BK	PTT Exploration and Production PCL	Energy & Utilities
TCAP.BK	Thanachart Capital PCL	Banking
TRUE.BK	True Corporation PCL	Information & Communication

Selected Stocks: KOSPI50

TICKER	Company Name	Sector
034220.KS	LG Display Co, Ltd	Electrical & Electronic Equipment
066570.KS	LG Electronics Inc	Electrical & Electronic Equipment
051910.KS	LG Chem Co, Ltd	Chemicals
005490.KS	POSCO	Iron & Metal Products
006400.KS	Samsung SDI Co, Ltd	Electrical & Electronic Equipment
009150.KS	Samsung Electro Mechanics Co Ltd	Electrical & Electronic Equipment
010140.KS	Samsung Heavy Industry Co, Ltd	Transport Equipment
000880.KS	Hanwha Corp	Finance
000720.KS	Hyundai Engineering & Construction Co Ltd	Construction
009540.KS	Hyundai Heavy Industry Co, Ltd	Transport Equipment

Hidden Markov Model

Basic Idea: Hidden Markov Model



Komorowski (2016)

Possible states of risky assets

- Three fundamental states:
  - Asset is not adjusted to positive information
  - Asset is not adjusted to negative information
  - Asset price is in equilibrium
  - Other possible states

- This study considers models from 3 states to 5 states

Order Imbalance

- **3 indicators from previous literature (Chordia et al, 2005)**
  1. **Number of buy order less number of sell order**
  2. **Number of buy-initiated shares purchased less number of seller-initiated shares sold**
  3. **Dollars paid by buy initiators less dollars received by sell initiators**

Order Imbalance

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- In this study, we define the order imbalance indicator as:

$$\text{OIR} = \frac{V_t^B}{V_t^A + V_t^B}$$

$$V_t^B = size\ of\ bid\ order\ at\ best\ price\ at\ time\ t$$
$$V_t^A = size\ of\ ask\ order\ at\ best\ price\ at\ time\ t$$

Generating trading signal

- We plan to generate trading signal by 2 approaches:
  - Discrete Case
  - Continuous Case

Data Discretization

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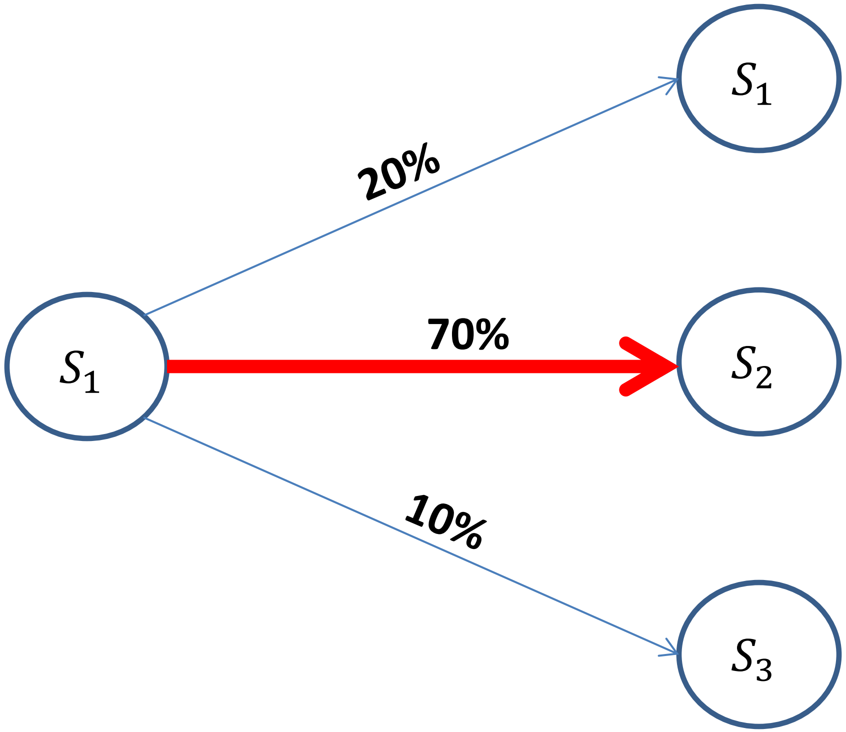
- **Before the model training, data needs to be discretized:**

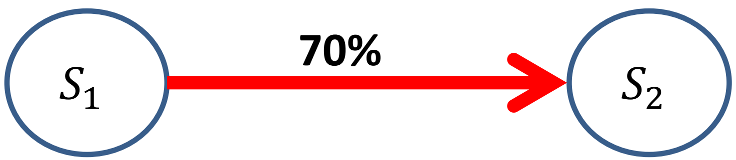
Symbol	Price movement	Order Imbalance Ratio
1	$0\% <$	$< 25\%\ \boldsymbol{percentile}$
2	$0\% <$	$25\%\ \boldsymbol{percetile} \leq \mathbf{OIR} \leq \mathbf{0.75}\%\ \boldsymbol{percentile}$
3	$0\% <$	$\mathbf{OIR} > 75\%\ \mathbf{percentile}$
4	$\geq 0\%$	$< 25\%\ \mathbf{percentile}$
5	$\geq 0\%$	$25\%\ \mathbf{quantile} \leq \mathbf{OIR} \leq \mathbf{0.75}\%\ \mathbf{quantile}$
6	$\geq 0\%$	$\mathbf{OIR} > 75\%\ \mathbf{quantile}$

Be noted: the percentile is computed by averaging the percentile of each selected stocks during the initial training period

Generating trading signal



Case1 :Discrete Trading signal



Probability of emission:

Symbol	Return	Probability
1	$0\% <$	5%
2	$0\% <$	5%
3	$0\% <$	5%
4	$\geq 0\%$	30%
5	$\geq 0\%$	30%
6	$\geq 0\%$	25%

$$P(q_{t+1} = S_2 | q_t = S_1) P(r \geq 0 | S_2)$$

If $P \geq 80\%\ threshold$, then signal is generated

Intuition behind threshold

- This study aims to capture the price movement in a confident manner:
  - **Confidence in transition: 90%**
  - **Confidence in observing the desire movement: 90%**

- The joint-probability gives us an approximate number of 80% for our threshold value

Trading strategy

1. **Generate a list of signals that we should enter long position**
2. **Liquidate any stocks that are not in the list**
3. **If there is any remaining wealth, allocate wealth equally to all stocks in the list**
4. **If current interval is the end of the day, then re-train the models**
5. **Proceed to next period**

The study will consider bi-directional transaction cost at 0.05%

Performance evaluation

- Hit ratio: how well the signal is able to predict positive return for each individual stock

$$\boldsymbol{Hit\ Ratio = \frac{\#\ correct\ positive\ movement\ signals}{\#signals\ results\ in\ non-zero\ movement}}$$

- t-test: $\boldsymbol{H_0\!: Hit\ ratio = 0.5, H_a\!: Hit\ rato > 0.5}$

Performance evaluation

- Benchmark: SET and KOSPI total return Index
- Sharpe's ratio
- Jenson's Alpha

Result

Predictability

Hit ratio: SET50, Discrete case

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	3 states	4 states	5 states
5 min	78.61%	80.60%	83.38%
10 min	72.21%	72.41%	67.15%
30 min	71.81%	62.89%	62.20%

Observations

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- As frequency decreases, the predictability of the signals decreases.

- At highest frequency, model with higher number of states achieve higher hit ratio.

Hit ratio: KOSPI50, Discrete case

	3 states	4 states	5 states
5 min	72.71%	58.93%	71.57%
10 min	66.16%	69.61%	59.41%
30 min	60.00%	43.04%	45.04%

Observations

- Similar pattern is obersved, as frequency decreases, the hit ratio decreases

- Compare to Thai market:
  - hit ratio is lower across all frequency and models
  - Though having longer trading hours, number of signals is significantly lower

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Profitability

Jenson’s Alpha SET50, Discrete case

	3 states	4 states	5 states
5 min	2.87%*** (0.00538)	3.57%*** (0.00493)	4.73%*** (0.00399)
10 min	1.06%*** (0.00233)	0.14% (0.00175)	0.41% (0.00343)
30 min	0.77%*** (0.00157)	0.05% (0.00137)	0.06% (0.00134)

Be noted: 0.05% bi-directional transaction cost assumed. Number of stars represent the level of significance, with *** represents 0.01 significance, ** represents 0.05 significance and * represents 0.1 significance. The HAC standard errors are presented below the estimators.

Observation

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- Outperform the market in the highest frequency due to high predictability

- Lower predictability in lower frequency cases result in insignificant alpha

Jenson's Alpha
KOSPI50, Discrete case

	3 states	4 states	5 states
5 min	-0.09% (0.00062)	0.05% (0.00082)	0.03% (0.00154)
10 min	-0.10% (0.00101)	-0.28%*** (0.00089)	-0.17%** (0.00077)
30 min	-0.04% (0.00035)	-0.08% (0.00083)	-0.17%* (0.00095)

Be noted: 0.05% bi-directional transaction cost assumed. Number of stars represent the level of significance, with *** represents 0.01 significance, ** represents 0.05 significance and * represents 0.1 significance. The HAC standard errors are presented below the estimators.

Observation

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- Strategy could not outperform the market or generate significant alpha due to lower predictability

- Strategy make a loss in most cases due to transaction cost and incorrect predictions

Conclusion

Performance of models

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- Appropriate number of states should be further investigated.
  - At 5 minute frequency, the 5 states model achieves decent hit-ratio
  - As frequency decreases, the 3 states model seems to outperform

Effect of frequency on performance of models

- Observed from both market, the higher the frequency, the higher the predictability. The same goes for profitability.

- Consistent with the literature by Chordia et al (2005): Price adjustment to information occurs on the intra-day level and predictability tends to dispear when frequency decreases.

Effect of market liquidity on performance of models

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- In market with higher liquidity, the model is less consistent and confident:
  - Generate less signals
  - Achieve lower hit ratio

- Consistent with previous literature (Chordia et al, 2008): In a high liquidity environment, the cost of trading is lower (ex. bid-ask spread). Hence, investors have more incentives to exploit the deviation of asset price from equilibrium. This enhances the speed of price adjustment to new information.

Limitation

- Short period of study
- Only consider stocks that satisfied the defined criteria
- For trading strategy:
  - No short selling
  - Assume we can trade at mid-price.
  - Assume we can trade at interval closing price
  - Assume no limitation on number of shares we can buy.

Recommendation

- Focus on data of higher frequency
- Re-consider the data discretization method
- Re-consider the method of constructing order imbalance indicator