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Using Change-Point Detection to Identify Structural Changes in Stock Market: Application to Russell 2000

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ABSTRACT

We term a stock that rises more than 10 times over a short period (less than 3 years) as a ten-bagger stock. Several ten-bagger stocks have existed since the past, and will continue to do so. To identify the characteristics of the ten-bagger stocks that appeared since the early 2000s to the most recent ones, and ultimately, to predict future ten-bagger stocks, we tried to find a connection with the Russell 2000 index. We used Pettitt's test to find the change-point in the Russell 2000 industry index and found a connection with the ten-bagger stocks. This study attempts to predict ten-bagger stocks through case analysis and draws two conclusions. Through this analysis, we could identify new growth sectors and stocks in KOSPI market such as 1st somatic analyzer, 1st lactic acid bacterium in 2012, 1st anode material company, 1st cathode material company, and No. 1 stomach anticancer drugs company in 2017.

Key words : Russell 2000, KOSPI, Ten-bagger, Stock market correlation, Investment

1. Introduction

Recently, the word 'ten-bagger' is frequently mentioned in the domestic stock market. The term was used by Peter Lynch, a legendary fund manager and investor in the United States who managed a 13-year Magellan fund with a return of 2,700%. Many investors invest in their own ways, but making a profit of 1,000% is not easy. In addition, as the stock market grew, many things became more involved in the price of stocks.

The amount of foreign capital investing in the Korean stock market is also increasing, and naturally, they consult the global stock market when investing in the Korean stock market. Besides, the economic policies of major countries not only have a big impact on the stock market of their country, but also affect the Korean stock market. In conjunction with global economic and social flows, the effects of various variables such as exchange rates, interest rates, the environment, and national confrontation make it harder to predict stock markets than ever before. In this situation, much research has been conducted on strategies for maximizing returns in the stock market and reducing risks through hedging. This paper analyzes the patterns and flows that can be used in investment strategies through the case of the stock market in the past decades and studies how to maximize the return on investment.

In the limited period from the late '90s to the present, many ten-bagger stocks appeared worldwide. When categorized by industry, not only in Korea, but also in developed countries, automobiles/parts, construction machinery, IT, refinery/chemistry, renewable energy, shipbuilding, games/entertainment,

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China consumption, and so on. Ten-bagger stocks have emerged in a variety of industries, including new technologies/consumer goods, telecommunications, pharmaceuticals/bios, securities, food, and beverages. The time taken for these stocks to grow more than ten times varies widely from one to five years. This paper studied what features new growth sectors have and how they correlate with stock markets in developed countries.

In this paper, we intend to use a long-term investment strategy for more than two years. There was a previous study on the strategy of maximizing downside risk-adjusted return using the Genetic algorithm [1].

Attempts have been made to maximize returns by applying new algorithms and methodologies in financial markets [2]. But we looked at ways to maximize returns in a more traditional and practical way.

Before this study, there was a study analyzing the effect of the global crisis on the correlation between stock markets [3]. A paper on the time-varying correlation between oil companies that is affected by external factors and the stock market has been published [4].

As a study related to the domestic stock market, a precedent study analyzing the correlation between the stock markets of Korea, Japan, Hong Kong, and Singapore exists [5]. On the other hand, there is little research on the correlation between the US market and the domestic market. There is only research on the transfer of price and volatility from the US market [6].

In this paper, we attempted to find promising sectors that started to show high returns in the United States Stock market. Change point detection was used to find the point at which the sector's index begins to rise. We refer to a study that used change point detection in the financial time series to achieve good results [7]. Also, a study on the volatility of stock returns by industry [8] shows that higher returns can be expected when investing in promising sectors. A study in 2008 also revealed that industry-specific returns in the Korean market were more closely related to the overall Korean market indices than those in the US market, while being increasingly influenced by industry-specific returns in the US market [9].

2. Background

In this study, we conducted research based on Russell 2000's industry index, KOSPI, and individual stocks in KOSPI since 2003.

2.1 Russell 2000 index

The Russell 2000 Index, published by the US investor advisor Frank Russel since 1982, reflects the stock index of the 2,000 stocks of the top 1,001 to 3,000 by market cap. Although the number of constituent stocks is 2,000, the market cap of all Russell 2000 stocks is only a single digit share of New York markets. In this regard, it can be seen that many small companies with high growth potential belong. Unlike the Nasdaq 100 Index, where large tech stocks account for most of the pie, reflecting the top 100 companies by market cap, the Russell 2000 Index reflects a wide range of industries, with financial,

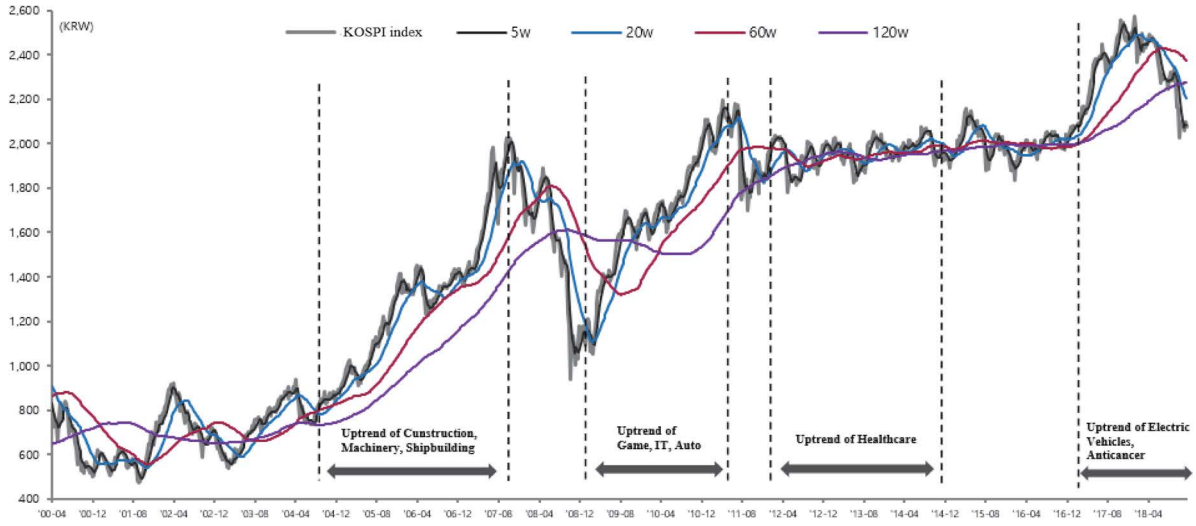

Fig. 1. KOSPI index and boom periods by industry.

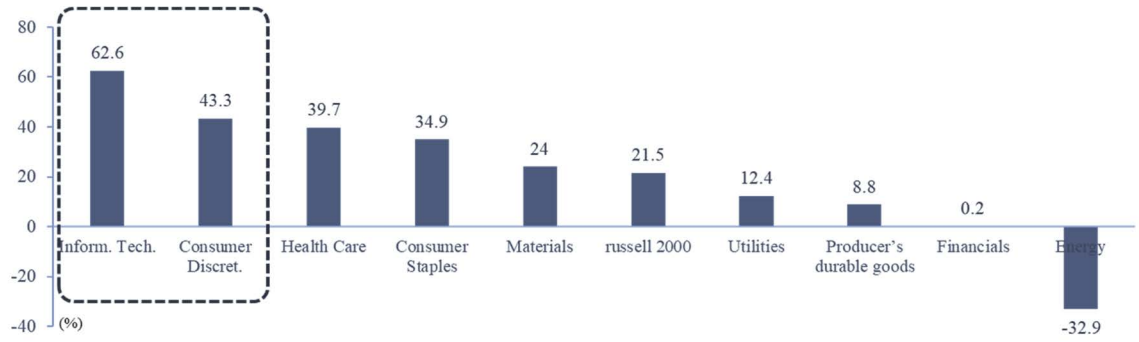

Fig. 2. Russell 2000 index return by industry during the game & IT sector rise (2008.07∼2011.07).

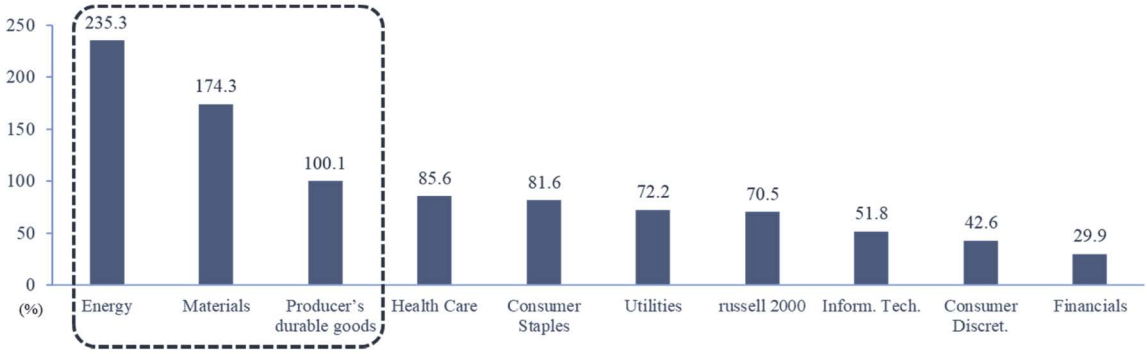

Fig. 3. Russell 2000 index return by industry during the uptrend of the construction/machinery and shipbuilding sectors (2003.07∼2007.12).

IT, healthcare, manufacturing, and consumer discretionary weights accounting for more than 10 percent.

2.2 Boom periods by industry

Although the KOSPI index continues to rise and fall, the sector's stocks generally rise in the uptrend of a sector, regardless of the composite stock index. Leading stocks in the growth sector, which have entered the uptrend, are highly likely to grow into the Ten-bagger stock. Therefore, finding growth sectors that are entering the uptrend is a very important clue to predicting the Ten-bagger stock.

2.2.1 Construction/machinery, shipbuilding

From July 2004 to July 2007, the uptrend of the domestic construction/machinery and shipbuilding sectors began. Earlier, on July 2003, Russell 2000's energy, materials and producers' durable goods sectors saw a sharp increase in yield. The Russell Energy (+235.3%), Materials (+174.3%) and Producer Durables (+100.1%) sectors include construction and shipbuilding.

2.2.2 Game, IT, auto

From the end of 2008 to the end of 2011, the domestic game, IT and auto sectors rose significantly. Russell's technology (+62.6%) and consumer staples (+43.3%) sectors, including the game sector, IT & auto sectors, began to grow the largest among other Russell sector indices since mid-2008. Despite the 2008 Lehman crisis, the sector's growth did not stop, and there was still a correlation between the Russell sector index and the domestic trend.

2.2.3 Cosmetics, healthcare

From the beginning of 2012 to the end of 2014, the domestic cosmetics sector, health functional foods, and healthcare industries centered on health care (Botox, fillers, etc.) surged. Earlier this year, the profitability of the Russell healthcare and consumer staples sectors began to increase. From mid-2011 to the end of 2014, when the cosmetics and healthcare sector boomed, Russell Healthcare and consumer staples rose +100.7% and +81.9%, respectively, showing the highest returns compared to other Russell sector indexes.

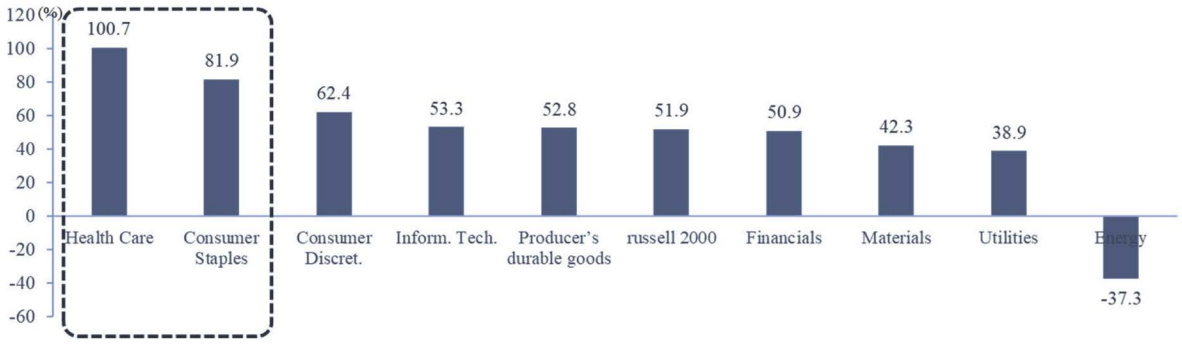

Fig. 4. Russell 2000 index return by industry during the uptrend of the cosmetic and healthcare sectors (2011.08～2014.12).

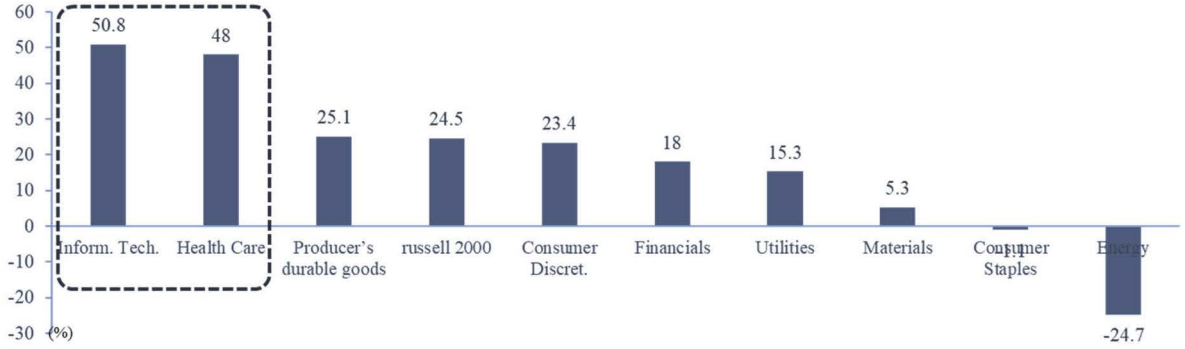

Fig. 5. Russell 2000 index return by industry sector during the trends of electric vehicles, cancer drugs, and entertainment (2016.07～2018.12).

2.2.4 Electric vehicles, anticancer

Since early 2017, the electric car and anticancer sectors have been on the rise. In the Russell industry index, electric vehicles are included in the technology sector and anticancer drugs belong to the healthcare sector. From mid-2016, six months before the rise of the domestic electric car and anti-cancer drugs, returns of Russell's technology and healthcare sectors rose the most increased among all sectors.

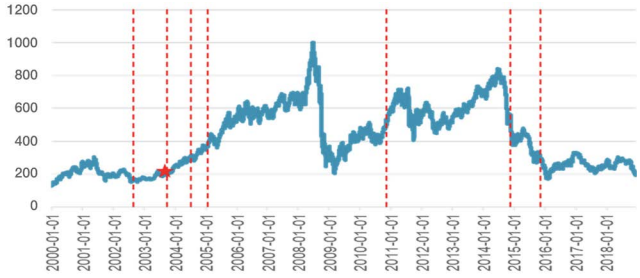

Fig. 6. Detected change-points and estimated uptrend start date in Russell 2000 energy.

2.3 Change-point detection

In the book on classification of change point detection by Csorgo and Horvath [10], three major methods were introduced: the likelihood ratio test for a parametric approach, the Pettitt test for a nonparametric approach, the Chow test for a linear model approach. We used the nonparametric method, the Pettitt test, to find the rise of sector index data.

2.3.1 The Pettitt test

Consider a sequence of random variables $X_1, X_2, \ldots, X_n$. It is defined as change-point at k^* if $\{X_1, X_2, \ldots, X_{k^*})\}$ and $\{X_{k^*+1}, X_{k^*+2}, \ldots, X_n\}$ have distribution functions $F_1(X)$ and $F_2(X)$, respectively, where $F_1(X) \neq F_2(X)$. It tests the null hypothesis of *no-change*, H_0: $k^* = n$, against the alternative hypothesis of *change*, H_1: $1 \leq k^* < n$, using a nonparametric approach.

The approach devised by Pettitt [11] is applied to detect a change-point in various continuous data. It provides a strong test that detect a change-point. Let

$$U_{k,n} = \sum_{i=1}^{k} \sum_{j=k+1}^{n} D_{ij}$$

where

$$D_{ij} = sgn(X_i - X_j) = \begin{cases} 1, & if\ X_i - X_j > 0, \\ 0, & if\ X_i - X_j = 0, \\ -1, & Otherwise. \end{cases}$$

The statistic $U_{k,n}$ is a test statistic for testing whether the two series $\{X_1, X_2, \ldots, X_{k^*}\}$ and $\{X_{k^*+1}, X_{k^*+2}, \ldots, X_n\}$ are same distribution. For values t, the statistic $U_{k,n}$ with $1 \leq k < n$, the Pettitt test statistic is defined as

$$K_n = \max_{1 \leq k < n} |U_{k,n}|.$$

For the test of H_0: $k^* = n$ against H_1: $1 \leq k^* < n$, consider K_n. The limiting distribution of K_n is approximated to 2 exp $\{-6k^2/(n^2+n^3)\}$ for large n.

3. Proposed Model

This paper focuses on case studies using the Russell 2000 industry index, KOSPI index, and individual stock price data.

3.1 Russell 2000 uptrend sector

Return of the Russell 2000 industry index is likely to be ahead of the domestic industry's returns in the uptrend and is an important indicator for predicting Ten-bagger stock. Therefore, it is important to select promising sectors by synthesizing the industry-specific returns of the Russell 2000 index by period. We also use change-point detection to find the point where the market flow has changed by sector. First, detect one change-point in the entire time series using the Pettitt test, a nonparametric approach among the change-point detection methods. Run the test in each period divided by the change-point to find two change-point detections, and run the test again in the four periods divided here. We find a total of seven change-points by sector and use them as a basis for selecting uptrend sectors compared to detected change-points and when uptrends began.

3.2 KOSPI stock selection

Although there are many stocks in the uptrend sector, the so-called leading stocks in the sector has the highest growth rate. We will select stocks that represent the uptrend sectors selected by Russell 2000.

4. Empirical Study

In order to find Ten-Bagger stocks with a stock return of 1,000% regardless of the trend of the KOSPI market, we attempted to find a correlation between past Ten-Bagger stocks and the sector index of Russell 2000. First, find the uptrend sector of Russell 2000. We found two or three sectors with the highest yields by period and estimated their start date as the Uptrend start date. Then, we used change-point detection to find the point where the flow of the market changed and to check whether the Uptrend start date we found was significant. For example, in Fig. 6, we performed the Pettitt test using the method we presented in 3.1 and indicated seven change points in dotted lines on the energy index chart. Using the period-by-period yield, the Uptrend start date we estimated was marked with a star.

We analyzed the sectors on an uptrend presented in 2.2 above by periods.

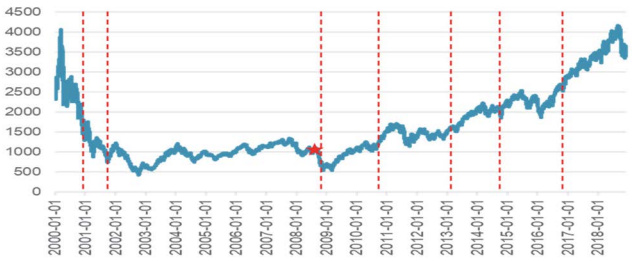

Fig. 7. Detected change-points and estimated uptrend start date in Russell 2000 inform. tech.

Table 1. Detected change-point and uptrend start date by sector in 2003

Sector	Detected change-point	Uptrend start date	Difference (Month)
Energy	2003-10-05	2003-07-01	3
Materials	2003-08-17	2003-07-01	2
Producer's durable goods	2003-08-18	2003-07-01	2

4.1 July 2004~July 2007: construction/machinery, shipbuilding

Since July 2003, Russell 2000's energy, materials and producers' durable goods sectors have seen a sharp increase. Within this, construction and shipbuilding sectors belong to the industry, which was preceded by the Russell sector index before the domestic construction/machinery and shipbuilding sectors entered the uptrend.

We confirmed that during this period, the difference between

Table 2. Over 1,000% return on the construction/machinery sector from July 2004 to July 2007

Stock	Yield (%)
Hyundai E & C	1,114
Doosan E & C	1,124
Doosan Heavy Industries & Construction	1,582
Samsung Engineering	1,024

Table 3. Over 1,000% return on the shipbuilding sector from July 2004 to October 2007

Stock	Yield (%)
STX	1,080
Hyundai Heavy Industries	1,297
Sungkwang Bend	4,454
Hy-Lok Korea	1,765

Table 4. Detected change-point and uptrend start date by sector in 2008

Sector	Detected change-point	Uptrend start date	Difference (Month)
Inform. Tech	2008-09-28	2008-07-01	3
Consumer Discret.	2008-01-03	2008-07-01	6

the detected change-point and the uptrend start date of the three sectors we determined to enter the uptrend was within 3 months.

4.1.1 Construction/machinery

Between July 2004 and July 2007, the construction/machinery sector entered a big upcycle. Hyundai E & C (1,114%), Doosan E & C (1,124%), Doosan Heavy Industries & Construction (1,582%), and Samsung Engineering (1,024%) showed a sharp increase with a return of more than 1,000% over the period. Construction companies went through a long restructuring period after undergoing the 1997 IMF and restructured their workforce structure and financial structure. The construction boom can be attributed to the boom in the domestic housing sector and the increase in overseas plant orders.

4.1.2 Shipbuilding industry

The shipbuilding industry's supercycles lasted for three years and three months, from July 2004 to October 2007. The period was a time when the new paradigm of ocean, along with traditional merchant ship orders, drove up the share price. STX (1,080%), Hyundai Heavy Industries (1,297%), Sungkwang Bend (4,454%), and Hy-Lok Korea (1,765%) rose more than 10 times during the period.

Table 5. Over 1,000% return on the game sector from late 2008 to the end of 2011

Stock	Yield (%)
NCsoft	1,062
Neowiz Games	1,027
Joy City	1,277

Table 6. Over 1,000% return on the IT sector from 2008 to 2011

Stock	Yield (%)
Duksan Hi-Metal	1,140
Interplex	1,221
Inox	1,140
Eugene Tech	1,189

4.2 Late 2008~2011: games, IT, automotive

Since mid-2008, Russell's technology and consumer discretionary sectors, which include the game, IT and automotive sectors, have grown the most in the Russell index. Despite the Lehman Brothers crisis in 2008, the rising trend showed good returns. We can see that Russell 2000's industry index precedes KOSPI's industry index.

The difference between the detected change-point and the uptrend start date of the two sectors is within 6 months and we consider it to be significant.

4.2.1 Game industry

From late 2008 to the end of 2011, there will be a long rally in the game sector. NCsoft (1,062%), Neowiz Games (1,027%) and Joy City (1,277%) led the game industry's boom based on solid new titles, and each yielded more than 10 times.

4.2.2 IT industry

The IT industry is warming up the domestic IT industry with smartphones in 2008~2011. The importance of parts makers that can support Samsung Electronics has also grown, and Duksan Hi-Metal (1,140%), the only OLED producer capable of producing OLED, was selected as the OLED material. Besides,

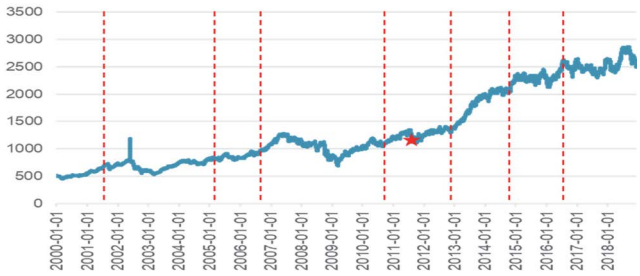

Fig. 8. Detected change-points and estimated uptrend start date in Russell 2000 consumer staples.

Table 7. Over 1,000% return on the automotive/ auto Parts sector from 2009 to 2011

Stock	Yield (%)
Duksan Hi-Metal	1,140
Interplex	1,221
Inox	1,140
Eugene Tech	1,189

due to the rapid growth of smartphones, the demand for FPCB is soaring, and related companies are starting to attract attention. Among them, Interplex (1,221%) and Inox (1,140%) are expanding MS with high yield and quality. Also, when semiconductors are becoming smaller and smaller, Eugene Tech (1,189%), who had previously prepared 30-nm process equipment in the semiconductor microfabrication process, exclusively supplied SK Hynix, and returned more than 10 times.

4.2.3 Automotive/auto parts industry

At the end of 2008, the auto/auto parts industry, which led Hyundai/Kia, is on an upswing. Auto goods, which are directly related to safety, maintain a conservative purchasing tendency. The financial crisis, which began in earnest due to the bankruptcy of Lehman Brothers in 2008, gave late-comers a chance to take the lead. In a severe economic crisis, price sensitivity increases, and customers who purchase Hyundai Motors, which put a reasonable price and good quality on the front, quickly increase. Before the financial crisis, 5% of US market share enters 10%.

As a result, the sales performance of auto parts makers, whose sales exposure was high, also improved rapidly.

Kia Motors (1,174%), Sungwoo Hitech (1,077%), Hanil Ewha (1,023%), SL (1,259%), Pyung Hwa Jung (1,152%) and Hwashin (1,506%) rose during the period.

Table 8. Detected change-point and uptrend start date by sector in 2010

Sector	Detected change-point	Uptrend start date	Difference (Month)
Health Care	2010-09-27	2011-08-01	10
Consumer Staples	2010-09-23	2011-08-01	10

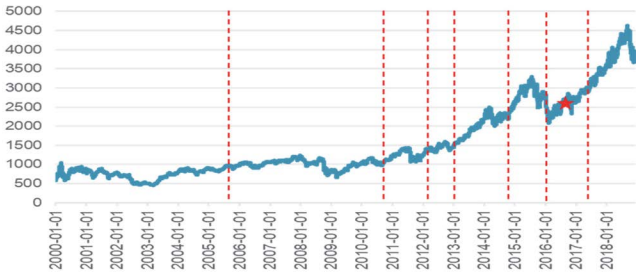

Fig. 9. Detected change-points and estimated uptrend start date in Russell 2000 health care.

4.3 Early 2012~2014: Healthcare sector centered on the domestic cosmetics industry, dietary supplements, and medical care (Botox, fillers, etc.)

The cosmetics and healthcare sectors of Russell 2000, which started to rise in the middle of 2011, showed the highest growth rate among the Russell 2000's sector indexes in the same period. Since the beginning of 2012, the domestic cosmetics and healthcare sectors have entered an upswing.

The change-points detected in the health care and consumer staples sectors differed by about 10 months from the date we estimated, suggesting that the uptrend has already begun.

Due to growing interest in industries related to improving quality of life, such as anti-aging and well-being. The demand for anti-aging and wellness silver services has expanded. The health care sector (cosmetics, functional foods, medical, etc.) has emerged as a small and medium-sized stock and the most promising new growth item. Examples include Kolmar Holdings (+3,518%), Nature (+3,015%), Koseon (+2,537%), Koreana (+2,293%), Korean cosmetics (+2,253%), and Amore G (+1,007%). This showed a high growth.

According to the United Nations, the world's 100-year-old population is expected to reach 322 million by 2020. The importance of prolonging life has also increased with the global aging, and the pharmaceutical and medical device sectors are

Table 9. Over 1,000% return on the healthcare (cosmetics, medical) sector from 2012 to 2014

Stock	Yield (%)
Kolmar Holdings	3,518
Nature	3,015
Koseon	2,537
Koreana	2,293
Korean cosmetics	2,253
Amore G	1,007

Table 10. Over 1,000% return on the healthcare (pharmaceutical) sector from 2012 to 2014

Stock	Yield (%)
Meditox	3,670
Hanmi Science	1,960
Chong Kun Dang Holdings	1,653
Kolon Life Sciences	1,442
Hanmi Pharm	1,228

Table 11. Detected change-point and uptrend start date by sector in 2016

Sector	Detected change-point	Uptrend start date	Difference (Month)
Inform. Tech.	2016-11-15	2016-07-01	4
Health Care	2016-01-05	2016-07-01	6

attracting global attention and growing. Pharmaceutical stocks such as Meditox (+3,670%), Hanmi Science (+1,960%), Chong Kun Dang Holdings (+1,653%), Kolon Life Sciences (+1,442%), and Hanmi Pharm (+1,228%) returned more than 10 times.

4.4 2017~Present: Electric vehicle, anticancer industry

From July 2016, the Russell 2000 index's technology and healthcare sectors' yields were significantly higher than those of other sectors. Here, we can confirm that the Russell sector index can be an important indicator in predicting the domestic bull market.

The Pettitt test results support the uptrend of Inform. Tech and the Health care sectors in 2016.

4.4.1 Growth of the electric vehicle market

Electric car-related stocks (POSCO Chemtech, L & F, PNE Solution, SangA Front Tech, etc.) have surged since 2017.

4.4.2 Anticancer drug market

The largest and fastest-growing segment of the global pharmaceutical market is by far anticancer drugs. According to EvaluatePharma, the global anticancer market is expected to more than double from $ 93.7bn in 2016 to $ 192.2bn over six years from 2022. As such, anti-cancer drug stocks are likely to become Ten-Bagger stocks in Korea.

5. Conclusion

Although the cases of stocks with more than 1,000% returns in the past are not all the same, we can find common features in different momentum. These characteristics suggest that we can find stocks that can achieve a 1,000% yield in the future.

The common characteristics of stocks that have previously yielded more than 1,000% can be summarized into two categories.

First, shares related to the uptrend sector of Russell 2000, which has a lot of new growth stocks, are likely to become Ten-Bagger stocks. In addition, the sector is in an uptrend, and domestic stocks are in an uptrend six months later. To find these uptrend sectors, we found sectors with the best yields by period, and used the Pettitt test to detect the change point where the uptrend began.

Second, first-tier stocks are more likely to grow within the big-cycle sector. When a industry demands that stage of the growth cycle, buying a top-ranking company in the industry increases the likelihood of achieving significant returns. For example, the stock price of Meditox, the No. 1 Botox company, rose +3,670%, far higher than other Botox companies. In the case of electric vehicles, the stock prices of POSCO Camtech, the No. 1 anode material company, and L & F, the No. 1 cathode material company, tend to rise further.

This past case suggests that sectors and companies with these two characteristics are likely to receive attention from the market, and that companies with all three characteristics will have a strong share price. Therefore, it is necessary to pay attention to new growth industries and companies with these characteristics in the future.

In this study, due to the methodological limitation of change point detection, at least three months of data is required to

determine which sector has entered an uptrend, and the time to review to determine investment in the domestic market is short. In future studies, machine learning methods such as Hidden Markov Model are expected to determine whether they are uptrend with shorter data.

References

1. Park CH, Lee HJ, Oh KJ. An investment strategy using genetic algorithm to maximize downside risk-adjusted returns for long-term investors. QBS 2017;36:111-117.
2. Lee SY, Yang JH, Jeong BJ, Oh KJ. A study of the convertible bond index and the investment performance using rough set. QBS 2019;38:23-31.
3. Sonali D, Riza D, Rangan G, Siphumlile M. The effect of global crises on stock market correlations: Evidence from scalar regressions via functional data analysis. Struct Change Econ Dynam 2019;50:132-147.
4. Xue L, Chen F, Guo S, Fu G, Li T, Yang Y. Time varying correlation structure of Chinese stock market of crude oil related companies greatly influenced by external factors. Physica A 2019; 530.
5. Choi WS. Dynamic nature of conditional correlation in east-Asian equity markets. Asian Rev Financ Res 2006;19:155-187.
6. Jeong JH, Lim JO, Jei SY. Comparative study of the spill-over in the conditional volatility and dynamic conditional correlation of various stock markets. Korean J Financ Eng 2012;11:1-16.
7. Oh KJ, Roh TH, Moon MS. Developing time-based clustering neural networks to use change-point detection: Application to financial time series. Asia Pac J Oper Res 2005;22:51-70.
8. Kim SW, Hwang YK, Kim GR. Is asymmetric volatility different between industries? New evidence from seven Korean industries. Sogang Econ Pap 2018;47:151-176.
9. Kim YB. Comovement of industry returns in the Korean and US stock market. Korean J Bus Admin 2008;21:169-188.
10. Csorgo M, Horvath L. Limit theorems in change-point analysis. New York: John Wiley & Sons; 1997.
11. Pettitt A. A non-parametric approach to the change-point problem. J Roy Stat Soc C-app 1979;28:126-135.