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Author	武, 思錚(Wu, Sizheng) 小幡, 績(Obata, Seki)
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慶應義塾大学大学院経営管理研究科修士課程

学位論文（ 2019 年度）

論文題名

Volatility in Stock Market and Investors' Behavior: An Empirical Research
Based on Game Industry

主 査	小幡 績
副 査	林 高樹
副 査	村上 裕太郎
副 査	

氏 名	武 思錚
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論文要旨

所属ゼミ	小幡 研究会	氏名	武 思錚
(論文題名) Volatility in Stock Market and Investors' Behavior: An Empirical Research Based on Game Industry			
(内容の要旨) Game industry, started in the 1970s, is experiencing a great growth in recent years, and more and more investors choose to invest in game related companies. However due to the uniqueness of game industry, the information asymmetry is existing in this industry. It is likely that many investors tend to overact to certain events related to game companies. This paper is going to breakdown the facts and underlying reason of volatility in stock market of game related companies. By using linear regression model with realized volatility, case studies and matching portfolio, two main conclusions are drawn from the analysis: stock prices of game related companies are more volatile comparing to the average in other industries; and a value-weighted portfolio formed by game companies changed more in stock price comparing to a similar portfolio formed by companies in other industries. This is a possible result of investors' overaction towards events related to game industry.			

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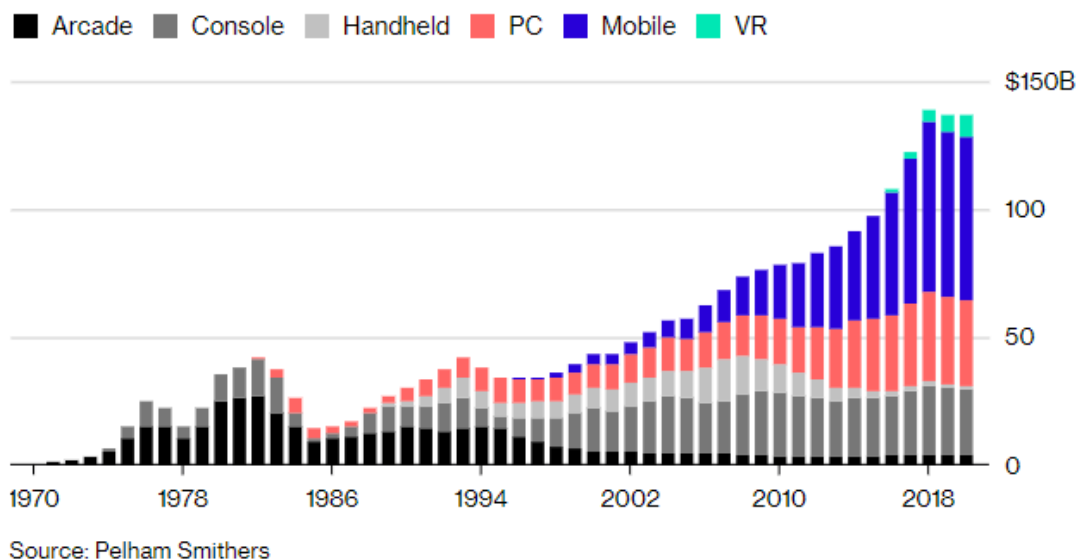
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Chapter 1 Introduction

1.1 Game industry of the world

Game industry, started in the 1970s, took more than 35 years to grow to \$35 billion in 2007, the year that the iPhone was introduced. Since then, the games market has added an extra \$100 billion in revenues to arrive at a total of \$137.9 billion worldwide in 2018. The uptake of smartphones has been a key contributor to the accelerated growth of the games market, in terms of both engagement and revenues (Newzoo, 2018). Game industry has kept a steady growth since year 1995. Analysts from Goldman Sachs Group Inc., Nomura Holdings Inc. and Morgan Stanley estimated game industry is still going to keep growing in year 2019. However, there are some voices indicating that video game revenue is headed for the first decline since 1995 (Nakamura, 2019).

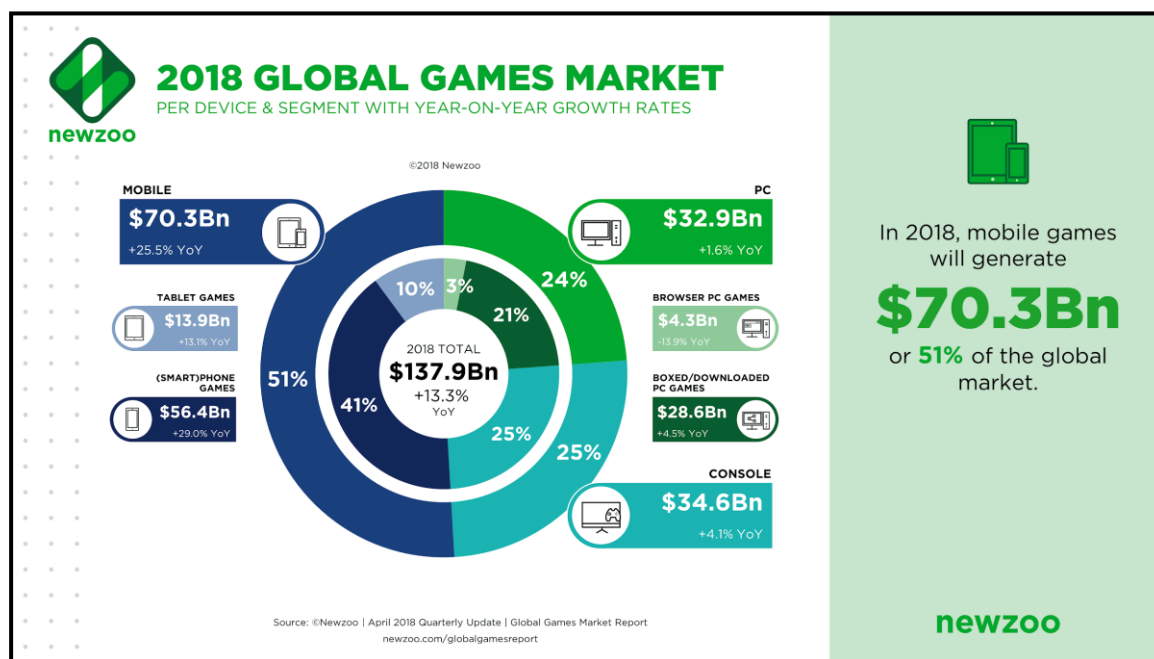
Exhibit 1.1 Past and estimated sales of games market



Games market can be divided into 3 segments based on the devices, which are PC games, console games and mobile games. In some countries like Japan, there is another segment, arcade games, but the share is comparatively low in recent years. Mobile game is the largest segment in 2018, claiming more than half of all global game revenues for the first time. Game industry

is in a healthy state as both console and PC games are also growing. Console is the second-largest segment with revenues of \$34.6 billion in 2018, and the overall PC segment generated \$32.9 billion in 2018. Growth in downloaded/boxed PC games is offset by declining browser PC revenues, as browser gamers have largely transitioned to mobile (Newzoo, 2018).

Exhibit 1.2 2018 Global games market



(Source: Newzoo)

Game industry in the Asia-Pacific region will generate \$71.4 billion this year, or 52% of total global game revenues. This represents a +16.8% year-on-year increase. North America remains the second-largest region, taking 23% of the global games market. Total revenues in North America will increase year on year by +10.0% to reach \$32.7 billion. The largest single market will continue to be China, which will reach \$50.7 billion in 2021.

Exhibit 1.3 World game industry ranking

RANK	COUNTRY	POPULATION	ONLINE POPULATION	TOTAL REVENUES
1	CHINA	1,415M	850M	\$37,945M
2	UNITED STATES	327M	265M	\$30,411M
3	JAPAN	127M	121M	\$19,231M
4	SOUTH KOREA	51M	48M	\$5,647M
5	GERMANY	82M	76M	\$4,687M
6	UNITED KINGDOM	67M	64M	\$4,453M
7	FRANCE	65M	58M	\$3,131M
8	CANADA	37M	34M	\$2,303M
9	SPAIN	46M	39M	\$2,032M
10	ITALY	59M	40M	\$2,017M
11	RUSSIA	144M	113M	\$1,669M
12	MEXICO	131M	86M	\$1,606M
13	BRAZIL	211M	142M	\$1,484M
14	AUSTRALIA	25M	23M	\$1,269M
15	TAIWAN, CHINA	24M	20M	\$1,268M
16	INDIA	1,354M	481M	\$1,169M
17	INDONESIA	267M	82M	\$1,130M
18	TURKEY	82M	53M	\$878M
19	SAUDI ARABIA	34M	26M	\$761M
20	THAILAND	69M	38M	\$692M

(Source: Newzoo)

1.2 Game industry in Japan

Game industry is a very important business sector of Japan. Even under the background of declining Japanese economy after 1990, game industry still made a steady growth. For example, the export of office machines including computer shrank from 3,094.2 billion yen (in year 2000) to 1,660 billion yen (in year 2015); semiconductors and other electronic components shrank from 4,575.8 billion yen to 3,914.5 billion yen; communication equipment shrank from 920.3 billion yen to 723 billion yen; television receiver shrank from 358.6 billion yen to 120.9 billion yen; however, game industry had a great growth from 635.5 billion yen to 1,957.2 billion yen (in year 2014) (Koizumi, 2016).

In addition to economic aspect, game industry is closely related to the daily life of Japanese people. Games not only provide pleasure and excitement to people, as the rapid development of information technology nowadays, games are combining different type of arts, including literature, music, movie, etc. to provide people with knowledge and other valuable experience. In Japan, one in each two household owns game consoles, and 13% of the nationals enjoy games

every day (Koizumi, 2016). Despite of the fact of less population, Japan is the third biggest market in the world after China and America. Average consumption on games per person in Japan is 3 times of America, 1.5 times of West Europe (Newzoo, 2018). These facts proved that changes in game industry might have great impact on Japan comparing with other countries.

A uniqueness about game industry in Japan is that its development has been led by few game console manufacturers and supported by many software developers. Two of the three current game console manufacturers are Japanese companies, and Sega used to be a game console manufacturer as well. The console game industry in Japan has repeated a way that hardware companies develop new game consoles with advanced technology every few years and change the market with the addition of popular software (Koizumi, 2016). The market scale of new console games (including sales of new software and hardware) in Japan is 396,352,130,000 yen in year 2017. Including second-hand software and hardware, the total market scale is 488,734,430,000, which is 118.01% of year 2016. Due to the launch of Nintendo Switch, console games market had shown a growth, which had not been seen for 10 years since 2007's decline. Especially for hardware market, the year-on-year was 161.41%. Nintendo Switch gave a boost to the sales of game consoles. On the other hand, the sales of PlayStation 4 stayed at the same level, but the proportion of PlayStation 4 Pro was much more than the previous year (Hosokawa, 2018).

1.3 Game industry value chain

Ben Sawyer of Digitalmill observes that the game industry value chain is made up of six connected and distinctive layers:

- 1) Capital and publishing layer: involved in paying for development of new titles and seeking returns through licensing of the titles.
- 2) Product and talent layer: include developers, designers and artists.
- 3) Production and tools layer: generate content production tools, game development middleware, customizable game engines, and production management tools.
- 4) Distribution layer: involved in generating and marketing catalogs of games for retail and online distribution.

5) Hardware (or Virtual Machine or Software Platform) layer: includes network infrastructure and non-hardware platforms such as virtual machines, or software platforms such as browsers.

6) End-users layer: users or players of the games (Flew & Humphreys, 2005).

1.4 Trends of game industry

Technological changes and changes in people's preference had changed game industry greatly in past decades. Unlike to past decades when PC and console games were the mainstream of games market, mobile games market has been growing with an incredible speed in recent years. The spread of smartphone is a prerequisite of this phenomenon, but it also might be a result of increasing substitutes of entertainment and faster lifestyle of people right now. Games are not considered to be something only for teenagers anymore, and the age range of gamers has become much broader nowadays. More and more people with consuming power have become potential consumers of games market, which contributes to the growth of sales. On the other hand, from game developers' point of view, only fulfilling the needs of hardcore gamers is not enough. They need to consider different market segments to build up their business portfolio under current circumstances.

As an important part of games market in Japan, console games have the value to be discussed separately. In this sector, due to fast increasing computing and graphic power and the spread of high-resolution television, users do not only care about the game process like before. They start to emphasize better graphic and other contents including audio, CG, interactive functions, etc. Some game companies changed their strategy in order to follow this trend. On the other hand, companies like Nintendo which are limited by their technology, are still keeping their former strategy. This increased the polarization of game industry. Console manufactures, especially Sony and Microsoft, are also trying to increase added value of game consoles by developing more non-game functions, such as blue-ray player function of PlayStation 3 and PlayStation 4, while improving their hardware (Hashimoto, 2016). Except for Nintendo with a different strategy, the competence of Sony and Microsoft has already moved into the era of 4K HDR.

Chapter 2 Thesis Statement

2.1 Current problems

Along with the growth of global games market recent years, more and more investors have started to pay attention to this emerging market. As a result, the stock prices of game companies are going up, as well as the volatility of the stocks.

Exhibit 2.1 Market capitalization of 30-largest game publishers



Note: Includes Tencent, Sony, Nintendo, Activision, NetEase, EA, Nexon, Take-Two, Ubisoft, Bandai, NCSoft, Netmarble, Konami, CyberAgent, Perfect World, CD Projekt, Zynga, Square Enix, Sega, Capcom, DeNA, Kingsoft, Youzu, Koei, GungHo, Mixi, Paradox, Gree, Keywords, Codemasters. (Excludes companies whose primary business is not games, like Microsoft.)
Source: Bloomberg

From graphs above, it is easy to observe that despite of the sudden change in the end of year 2018, the stock prices of large game publishers went up since year 2014 and accelerate in year 2016. However, due to the reason of global economic recovery in recent years, it is hard to make a conclusion that game industry has a unique growth comparing with other industries only by referring above data. It is necessary to test whether there were significant differences between moving average and standard deviation of stock prices of game industry and market index, for example Nikkei average or NASDAQ Composite, in the further step of research. Another characteristic of game industry is that it is expected to be more risky comparing to traditional manufacturing industries. Firstly, after the concept of AAA games had been

introduced, publishers tend to take more financial risk in development. AAA game means it is a big project which has high quality and expect high sales, so on the other hand, it has higher cost on both capital and time. The budget for a AAA game in the 7th generation was \$15 million to \$20 million, and it keeps getting higher with the change of platforms and generations (Zackariasson & Wilson, 2012). Secondly, as stated before, consumers' preference changes from time to time, so it is hard to estimate whether a new product (including consoles and games) will be able to win consumers' heart. These two facts lead to a result that game companies might suffer from great loss because of the failure of one single product. For companies, of course, they need to manage their portfolio on different game titles, but on the other hand, in stock market, this nature of game companies might create more frequent and larger changes comparing with traditional industry, like automobile.

If the above statements are true, the next question comes with that as an emerging market, many analysts and influential investors only have limited information on game industry. The stock prices of companies in traditional industries are more stable; analyst and investors have more experience related to those industries as well. However, for game industry, it is highly possible that people who make the investment decision (e.g. investment banks) and people who are familiar with the products (e.g. game medias, game reviewers) are two crowds of people. Also, companies usually do not reveal too much information about their products until they are released in order to ensure the sales. Under this circumstance, investment decision-making process highly rely on news, events like game show or trustworthy reviews.

Moreover, since one can only make the judgement on whether a product is successful or not after it is released, it should be delayed that the "correct" information is reflected on the change of stock price. This indicates that changes of stock price in earlier phases are more likely to be unreasonable, so that noise traders are likely leading stock prices away from fundamentals. However, another important issue is that, in the first place, what should be the fundamental of a game company? A unique thing about game companies is that they basically own large amount of intangible assets, including intellectual property, game contents, software, etc. These intangible assets are generally hard to evaluate on a cash base for various reasons. For example, as stated before, people's preference is changing, so very valuable knowhow on making a type of game might be useless if no one play it anymore. The value of IP also changes depending on how much people are interested in it. Different people are very likely to have different evaluation on the same company. These make it even harder to evaluate corporate value of game

companies.

2.2 Hypothesis

Based on facts and inference stated above, two hypotheses can be made.

First, a basic hypothesis is that secondary information has great impact on stock prices of game related companies, and investors tend to overreact to news or events due to information asymmetry. This can be explained by the cases of Nintendo and Capcom. Other main companies in game industry also share similar situation, not only in Japan but in US as well. For example, the slump of Activision Blizzard's stock price after Dec 2018 was estimated to be closely related with its poor presentation on Blizzcon, an annual gaming convention held by Blizzard.

A second hypothesis is that the stock prices of game related companies is more volatile than the average of other industries. One of the reasons is due to the nature of game industry. It is a growing industry with higher risk. However, behavioral factors are also supposed to play an important role, such as the overreaction stated above. Analysts are lack of enough information and knowledge in this industry might also be an important reason, as individual investors do not have a proper benchmark, and thus created more noise in the market.

2.3 Previous Research

Several papers discuss the competition and pricing of game industry. Doi's (2017) paper, "Business Model and Competition in Two-Sided Markets: The Japanese Game Industry", discussed the business nature of game industry as a two-sided (or platform) market. Typically, game business has a vertical layer structure from software suppliers to players, and platform provider acts as an intermediary service provider to connect these two parties. There are mainly two ways of pricing in vertical trading. The first one is match maker's wholesale pricing, which means product or service suppliers sell the goods to platformers with wholesale price and then

platformers set retail price. The second one is match maker's agency pricing, which means product or service suppliers set retail price and then pay fee to platformers. Most of the internet related business, including game business, are using the second pricing model. However, there are cases that platformers set the retail price first, and software suppliers develop their products or services base on that price in game industry especially. Doi's paper indicated that in the game business, along with the freemium, feature competition or differentiation related to quality, brand etc., and technological innovation competition can be regarded as important competitive characteristics. It further pointed out that this phenomenon is related to network externality existing in this industry, which can shift the demand curve to the right. Companies are able to maximize their profit by introducing above business model.

Yamaguchi's (2016) paper, "[Effect Reduction of Network Externality by Time and Spreading Strategy]", focused more on time effect of network externality in game industry. By using linear regression model, he proved that platform product demand model and complement goods input model using discount rate is more accurate than traditional models, so it is able to conclude that the effect of network externality get weaker by time. The discount rate of indirect network externality in platform product demand model is 11%, and the one of direct network externality is 59%. Comparing with number of total users, number of active users who recently purchased has stronger impact on consumer's decision-making process. Using traditional models are likely to overestimate network externality in early phases, and lead to a conclusion that products selling well at the very beginning will have sustainable competitive advantage. Moreover, due to the positive feedback, this effect will become bigger and bigger. However, based on this research, instead of getting bigger, the effect of network externality should discount by time, which means early phase success is not sustainable. Companies need to improve their products and change the price frequently in order to keep the effect of network externality. This conclusion supports the hypothesis that investors tend to overreact to certain news or events, as they infer the impact of the new or events should be long-lasting based on traditional way of thinking, which is not necessarily the truth. This means that the fundamentals of this company might not change as much as they estimated, so their investment decision-making is likely to be unreasonable.

Chapter 3 Difference in Volatility between Markets

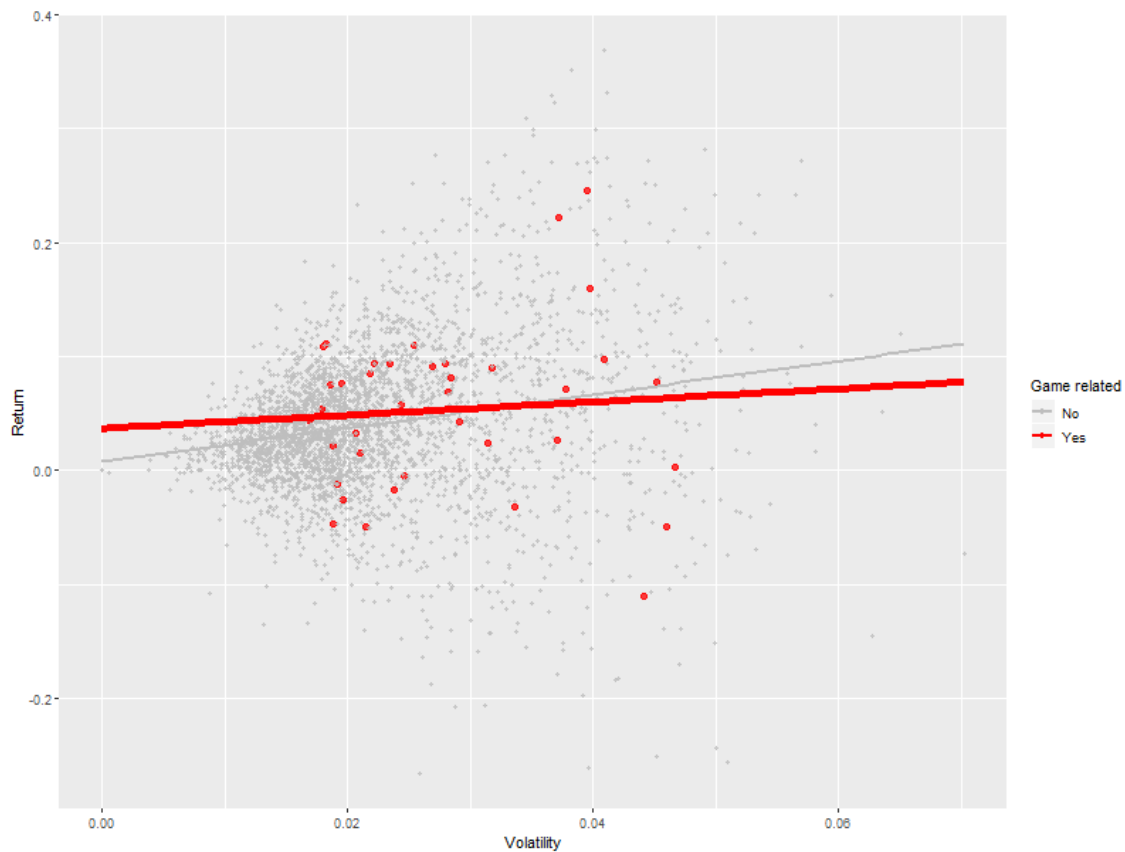
3.1 Volatility and Return in Stock Market

First, it is necessary to have a brief view on return and volatility of the stock market in Japan. Data from Nikkei NEEDs is collected, including 3645 companies listed in Tokyo Stock Exchange First Section, Second Section, Mothers and JASDAQ. Among these companies, there are 45 companies related to game industry. The list of the companies is:

Fonfun (stock code: 2323), Wedge Holdings Co (2388), Pixel Inc (2743), Restar Holdings (3156), Koei Tecmo Holdings Co (3635), KLab Inc (3656), Poletowin Pitcrew Holdings Inc (3657), Ateam Inc (3662), Digital Hearts Holdings Co (3676), Shift Inc (3697), CRI Middleware Co (3698), Nihon Falcom (3723), Drecom Co (3793), Nippon Ichi Software Inc (3851), Heroz Inc (4382), Imagineer Co (4644), Z Holdings (4689), Tose Co (4728), CyberAgent Inc (4751), Rakuten Inc (4755), Nihon Enterprise Co (4829), Showa Holdings Co (5103), E-guardian Inc (6050), Daikoku Denki Co (6430), Sega Sammy Holdings Inc (6460), Minebea Mitsumi Inc (6479), GameWith Inc (6552), Kyowa (6570), N-links Co (6578), Melco Holdings Inc (6676), Sony (6758), MegaChips (6875), I-O Data Device Inc (6916), And Factory Inc (7035), Happinet (7552), Tay Two Co (7610), Bandai Namco Holdings Inc (7832), Nintendo Co (7974), Bookoff Group (9278), Mti (9438), Kadokawa (9468), Square Enix Holdings Co (9684), Capcom Co (9697), Konami Holdings (9766), SoftBank (9984)

There are two other listed game related companies, Bushiroad (7803) and B&P (7804), but since both of them just went public in July 2019, it is unable to reach their data and they are not included in any further analysis. The graph below shows the average return and standard deviation (volatility) of each company in 3 years until Feb. 19th, 2019.

Exhibit 3.1 Volatility and return of listed companies



(Data retrieved from Nikkei NEEDS)

It is able to find out that although game related companies spread in different areas of this plot, the trend of game industry is still different with other companies. First, standard deviation of game related companies is at least around 0.02, but many low risk companies have standard deviation less than 0.02. Moreover, data of stock prices of 3 years from Feb 2016 to Jan 2019 is collected from Nikkei NEEDS. By conducting F-test with monthly return in above 3 years, true ratio of variances between the return of stocks of game related companies and other companies is significantly greater than 1, $F(1418, 119600) = 1.462, p < .001$. This proves that there is a significant difference in the volatility of game industry and other companies. Second, the slope of the smooth line for game related companies (the red line) is smaller than other companies. This indicates that if forming a portfolio consisted of game related companies, it is likely to have a Shape ratio smaller than an average portfolio from the whole market. For riskier game related companies (companies with higher standard deviation of return), it is likely that their expected return cannot fully payoff the risk investors are bearing.

3.2 Realized Variance and Realized Volatility

In recent research, volatility of a stock is usually considered to be a random quantity changing with probability, so it is more proper to use a stochastic model than a fixed quantity, for example the standard deviation of three-year return. According to continuous-time model of asset pricing, logarithm of the price of an asset, S , should follow such diffusion process:

$$dS = \mu S dt + \sigma S dW_t \quad (1)$$

where μ is percentage drift (expected return in this case), dt is a tiny change in time, σ is percentage volatility and W_t is a Wiener process.

Define the last transaction timing of day $t - 1$ to be $t - 1$ and the last transaction timing of day t to be t , the real daily volatility (variance) of day t should be an integration of the variance $\sigma^2(s)$ in each moment, so it can be defined as Integrated Variance (IV):

$$V = \int_{t-1}^t \sigma^2(s) d(s) \quad (2)$$

For the reason that it is impossible to observe the real volatility, the only way is to estimate it from return data which is able to observe directly. Given n return data in day t as $\{r_{t-1+1/n}, r_{t-1+2/n}, \dots, r_t\}$, it is able to calculate the Realized Variance ($RVar$) of day t by summing up the square of them:

$$RVar_t = \sum_{i=1}^n r_{t-1+i/n}^2 \quad (3)$$

When n is approaching ∞ , $RVar_t$ defined in equation (3) converges in probability towards “the real volatility (variance)” defined in equation (2). If n is large enough, $RVar_t$ could be an accurate estimation of σ_t^2 (Watanabe, 2007). Realized Volatility ($RVol$) is defined as the square root of $RVar$. In other words, it is an estimation of σ_t .

By using these two measures of volatility of stock prices, the goal is to find out relations between volatility and other features of stocks traded in Tokyo Stock Exchange by linear regression analysis. Since only daily data of stock prices can be collected from Nikkei NEEDS,

the method used here is calculating 3-month volatility by using daily stock prices from the beginning of Jan, 2019 to the end of Mar, 2019, which is 3-month period around the update date of governance data, Feb 1st, 2019. Afterwards, the 3-month volatility is normalized to daily volatility by dividing by days of observation, as for some companies, only stock prices of less than 3-month are collected. As a result, in this research, Realized Variance is defined as:

$$RVar = \frac{\sum_{i=1}^n r_i^2}{n} \quad (4)$$

where n is the days of observation and Realized Volatility is defined as:

$$RVol = \sqrt{RVar} \quad (5)$$

However, the accuracy of calculated Realized Volatility might not be high enough in this case. As stated before, n needs to be large enough to converges in probability towards “the real volatility”, so the more frequent the observation is, the more accurate the calculated Realized Volatility would be. However, in this case, n is at most 58, since there were 58 business days in the 3-month period, which is not enough. Hour data of stock price might be necessary for further studies using Realized Volatility.

3.3 Linear Regression Model

Before getting into details related to game industry, it is important to understand some basic facts that might lead to potential volatility. According to Wang and Deng (2018), stock market volatility is caused by investors’ expectations and behavior. They further argued that market volatility is caused mainly by the difference between expectation consistency and behavior consistency. Even if under an efficient market where all investors have perfect information and only invest rationally (trading based on foundations of the stocks), there will still be volatility in stock price, as foundations might change based on economic environment and the performance of the company. In this research, this kind of volatility will be named as “fundamental volatility”. Apart from this, in the real world, the market is not always efficient. Under this circumstance, there will be noises that makes the stock price deviate from the fundamentals. Unlikely to fundamental volatility that is able to observe from financial data of

the company, noise is random theoretically, so volatility caused by behavioral reasons is hard to predict. This kind of volatility will be named as “behavioral volatility” in the following parts of this paper.

Since Realized Volatility fits the model better than Realized Variance, Realized Volatility in equation (5) will be chosen as the dependent variable. By using corporate governance data from Nikkei NEEDS, explanatory variables are defined as below:

CI_PBR3_0: PBR 3-year average, the average of total market value in recent 3 years / the average of ownership equity (total assets minus total liabilities) in recent 3 years. This variable is expected to have a positive coefficient, as a company with high P/B ratio reflects that investors have strong beliefs on the future growth of this company, but it might bear a greater change in stock price if investors lost their confidence. On the other hand, stocks with high P/B ratio are more likely to be overvalued (usually growth stocks), which are more volatile, and stocks with market value closer to book value seems more stable.

CI_FDIV1: Return to shareholders ratio, (average of dividends paid + buyback in two years) / (cash + marketable securities). This variable is expected to have a negative coefficient, as dividends is expected to stabilize the stock price. This ratio does not include any financial related companies.

CI_INST: Ratio of share hold by domestic institutional investors, ratio of shareholding by trust account + life insurance special account (calculated by NLI Research Institute). This variable is expected to have a negative coefficient, as it shows how much share of this companies is owned by risk-averse institutional investors. If a company is mainly invested by this kind of investors, it is more likely to have a low volatility.

CI_FRFLT: Ratio of share hold by small shareholders. The definition of small shareholders is shareholders with share less than 50 units. This variable is expected to have a positive coefficient, as small shareholders are easier to change their investment decision and more likely to make irrational decision. They are expected to make the stock price more volatile.

CI_ANTEI: Ratio of stable shareholding, ratio of shares hold by domestic companies which belongs to one of the following: (1) owned by companies with reciprocal shareholding

relationship, (2) owned by insurance companies, banks and Shinkin banks (special accounts and trust accounts not included), (3) financial institution shares owned by public companies, (4) owned by public affiliates (parent companies, etc.), (5) owned by board members, (6) owned by employee stock ownership plan, (7) large shares (more than 3%) owned by corporations (including foreign companies, trust banks, etc. not included) (calculated by NLI Research Institute). This variable is expected to have a negative coefficient, for similar reason to CI_INST. The above investors are less likely to change their investing decision, thus decrease the volatility in stock price.

CI_DASS_0: Debt ratio, total debt / total assets multiplied $\times 100$. This variable is expected to have a positive coefficient, as company with high leverage are likely to be riskier, thus having higher volatility in stock price.

CI_ATRM: Financial statement announcement timing, number of days between end of an accounting period and the day of company's financial statement announcement. This variable is expected to have a positive coefficient, as financial statement announcement is one of the most important sources for normal investors to collect latest information about the company. If the time period between end of an accounting period and the announcement is long, it is more difficult for investors to update the information. This information asymmetry might lead to irrational investing decision, thus increase the volatility in stock price.

CI_MISFRC_0: Difference between prediction and performance in the latest term, (final profit and loss in the latest term – prediction for the same term) / performance of sales in the latest term $\times 100$. This variable is expected to have a positive coefficient, as it increases the ambiguity of the company's real performance. The bigger this variable, the harder it is for investors to understand this company's situation and predict the future performance based on prediction. Also, it is possible that a company has higher unsystematic risk or has experience some unexpected changes if it happens to have a big difference between prediction and performance. Both ways will increase the volatility of stock price.

CI_WEBEVL: Adequacy of website, an evaluation based on easiness to understand, easiness to use and amount of information (calculated by Nikko Investor Relations). This variable is expected to have a negative coefficient, as website is another important source for normal investors to collect information about the company, especially for new investors. Adequate

information and easiness of accessing will increase the probability of investors making rational investing decision, thus decrease volatility in stock price.

CI_CGDISCFLG: Able to electronic exercise or not and with or without disclosure materials in English (Boolean variable, in corporate governance report description base). This variable is expected to have a negative coefficient, as it reflects the easiness for foreign investors to get access to this company. Disclosure materials in English is related to how much information foreign investors can collect and for the reasons stated above, more information is expected to decrease volatility in stock price.

CI_L_TKY: Listing information in Tokyo Stock Exchange. The original data is 1 for First Section, 2 for Second Section, 3 for Mothers and 9 for JASDAQ. In this research, this value is adjusted to a Boolean variable with true for First Section and false for the others. This variable is expected to have a negative coefficient, as stocks in First Section are expected to have higher liquidity comparing with other stock. This can reduce the risk of investing in stocks of First Section and reflect as less volatility in stock prices.

CB_MV_0: Market capitalization by the end of the most resent accounting period. In this research, instead of the raw data, logarithms of the market capitalization of each company are used for the purpose of better fitting the linear model. This variable is expected to have a negative coefficient. According to Fama-French three-factor model (Fama & French, 1993):

$$\tilde{R} - R_F = \alpha + \beta_1(\tilde{R}_M - R_F) + \beta_2 SmB + \beta_3 HmL + \tilde{\epsilon} \quad (6)$$

Companies with larger market capitalization are expected to have lower return if holding other variables constant, as their variance SmB is smaller. On the other hand, under an efficient market with no arbitrage, stocks of such companies are supposed to be less risky than companies with smaller market capitalization, thus, their stock prices should be less volatile.

All the data used is the data before the adjustment based on industry and market capitalization. There are basically two types of variables above. PBR, dividend yield, debt ratio and market capitalization are related to fundamentals of a stock, and the other variables are closer to investors' behavior. Listing information is related to liquidity, so it has features of both types

As stated above, these two types of variables can explain fundamental volatility and behavioral volatility separately.

A multiple linear regression was conducted to predict the volatility of a certain stock based on former data. Listwise deletion is used to handle missing data, so all the companies with missing data are excluded from this regression analysis. After removing insignificant variables, it is able to get a model with the lowest AIC, which predict Realized Volatility with 5 variables ($F(5, 3273) = 148, p < .001$), in which R^2 equals .1844 and adjusted R^2 equal .1832. The regression equation is shown as below:

$$RVol = (0.7437 + 0.0211 * CI_PBR3_0 + 0.0003 * CI_DASS_0 - 0.0020 * CI_ANTEI - 0.035 * CI_L_TKY - 0.057 * CB_MV_0) \% \quad (7)$$

Exhibit 3.2 Summary of regression model (7)

term	estimate	std.error	statistic	p.value
Intercept	0.007437	0.000281	26.50958	1.90E-140
CI_PBR3_0	0.000211	1.35E-05	15.63946	3.16E-53
CI_DASS_0	3.14E-06	1.69E-06	1.862671	0.062598
CI_ANTEI	-1.96E-05	1.99E-06	-9.83818	1.58E-22
CB_MV_0	-0.00035	2.59E-05	-13.4171	5.37E-40
CI_L_TKY	-0.00057	9.29E-05	-6.1848	6.99E-10

All the variables are significant under significant level of 0.01, except for CI_DASS_0, debt ratio. The p-value of this variable is slightly above 0.05. All the coefficients prove former prediction to be correct, but the influence of debt ratio and ratio of stable shareholding is rather minor.

The next step is to introduce a dummy variable, game. This is a Boolean variable which is true for the companies in the list of game related companies stated above. After checking the interaction effect between game and other variables and removing insignificant variables, it is able to get a new model ($F(8, 3143) = 88.19, p < .001$) with the lowest AIC, in which R^2 equals .1833 and adjusted R^2 equal .1813. The regression equation is shown as below:

$$RVol = (0.7464 + 0.0207 * CI_PBR3_0 - 0.0000 * CI_INST + 0.0003 * CI_DASS_0 - 0.0020 * CI_ANTEI - 0.035 * CI_L_TKY - 0.055 * CB_MV_0 + 0.1224 * game - 0.72 * CI_INST * game) \% \quad (8)$$

Exhibit 3.3 Summary of regression model (8)

term	estimate	std.error	statistic	p.value
Intercept	0.007464	0.000289	25.78281	3.87E-133
CI_PBR3_0	0.000207	1.38E-05	14.94939	7.23E-49
CI_INST	-4.66E-08	6.66E-06	-0.007	0.994418
CI_DASS_0	3.33E-06	1.72E-06	1.93038	0.05365
CI_ANTEI	-1.99E-05	2.14E-06	-9.29922	2.57E-20
CB_MV_0	-0.00035	2.79E-05	-12.5656	2.28E-35
CI_L_TKY	-0.00055	0.000101	-5.48186	4.54E-08
game	0.001224	0.000618	1.981851	0.047583
CI_INST : game	-7.23E-05	4.72E-05	-1.53165	0.125708

The variance CI_INST, ratio of share hold by domestic institutional investors, is not significant in this model. However, since its coefficient is very small, it is able to ignore this variable. CI_INST has interaction effect with dummy variable game, but the p-value is also higher than 0.05. This might show that institutional investors have some impact on reducing the volatility of stock prices of game related industry, but it barely has any influence on other industries. The p-value of CI_DASS_0, debt ratio, is slightly higher than 0.05, and all the other variance are significant under significant level of 0.05.

This new model indicates that game related companies do have higher volatility due to the nature of this industry, as the dummy variable, game, has a positive coefficient of 0.1224%, which makes the stock price of a game related company more volatile than another company under similar financial situation but in different industries. This proves the hypothesis that stock prices of gaming companies are more volatile than other industries. However, it is hard to define whether this increasing volatility is due to game companies' performance (fundamentals), or due to investors' behavior, such as misunderstanding or overreaction. As explained above, game industry is an industry with high growth and high risk. It also involves more uncertainty

associated with the business environment, so the fundamental volatility of game related companies could also be higher than companies in other industries. Further discussion on underlying reason of this additional volatility will be made in the next chapter.

Chapter 4 Volatility in Stock Prices of Game Related Companies

4.1 Case study of Nintendo

Nintendo is one of the world's largest video game companies. It had market share of Nintendo revealed the information of Nintendo Switch by the end of 2016 and released it on March 3rd, 2017. By then, Nintendo's stock price went through an incredible growth until early 2018. Nintendo's stock price went up by 4% only for the first day of sale. On April 25th, it kept going up, and Morgan Stanley MUFG indicated that Nintendo's stock is one of the best investment options. On Jun 14th, Nintendo announced news about new *Super Mario* game in October, and stock price kept getting higher. On Jul 27th, because of the sales of Nintendo Switch, Nintendo turned to profit, and investors were making decisions of "buy". Nintendo's stock price reached the highest point in past 9 years on Sep 20th. However, things started to change in the next year. On Feb 1st, 2018, due to lack of new contents in conference, Nintendo's stock price started to go down. After Nintendo's poor performance on E3 (Electronic Entertainment Expo) 2018, people started to doubt Nintendo's ability to make anything new in this year and do not expect them to increase the revenue furthermore. This resulted in a slump of the stock price. It then renewed the lowest record in the previous year twice on Jul 4th and Dec 19th. The main reason was concluded to be the disappointment and psychological changes of investors (Nikkei Quick News, 2017-2018).

Exhibit 4.1 Nintendo's stock price from year 2017



(Source: Yahoo! Finance)

From the above graph, it can be observed that the lowest Nintendo's stock price in year 2018, 27,055 yen, was almost only a half of the highest point, 49,880 yen. Stock price made great changes in two years, making it a very risky investment option. These changes were closely related with secondary information related to Nintendo: it is a very common phenomenon that Nintendo's stock price will go up when they launch a new console, for the reason that the new console is likely to become a boom. However, since it is always hard for Nintendo to keep this the boom to a long-lasting competitive advantage, the stock price will eventually fall back. This phenomenon might indicate that investors reacted to the news of Nintendo's new console, but they overreacted, which means they expected Nintendo to achieve a goal out of its capacity by overestimating Nintendo's corporate value. As a result, Nintendo's stock price was overvalued for a long time. Since it took time for investors to realize and understand their problem in the previous investment decision, it was possible for other investors to keep following previous investors by making the same buying decision. This positive feedback would push the stock price higher and thus create a bubble in a short term.

4.2 Case study of Capcom

Capcom is a game software developer based in Osaka. It has grown steadily over the years by leveraging its expertise in developing highly original games and then using the content in many ways through "single content, multiple usage" approach (Capcom, 2019). In other word, Capcom's strategy is fully using its resource of IP, not only limited in the area of games. Capcom decided to develop a new game of one of its most famous series, *Monster Hunter*, with high-resolution and new concepts, such as playing in a more dynamic, living world. In order to achieve this goal, hardware with more capacity is necessary, so Capcom gave up Nintendo's platform of previous games, and brought it back to home consoles, PlayStation 4 and Xbox One (Knezevic, 2017). Capcom announced *Monster Hunter World* at Sony's E3 2017 press conference and released it on Jan 26th, 2018. This game became a great hit, which led to a rise in Capcom's stock price for more than half a year. However, on Aug 13th, when the PC version of *Monster Hunter World* is supposed to be launched in China, it was regulated by Chinese government instead. The license of this game was canceled, so Capcom can no longer sell it in China anymore, and all the previous revenue had to be paid back to the consumers (Hall, 2018). This resulted in an immediate drop of Capcom's stock price. Nikkei Quick News (2018) reported Capcom's low stock price on Aug 31st, and once more on Oct 24th since China regulators announced that they would stop issuing game license. Capcom's stock price reached the lowest of 2018 on Nov 27th, because investors estimated Capcom would be weak in year-end sales season. It did not rebound until Dec 11th, when Capcom announced new DLC (Downloadable Content) of *Monster Hunter World*. Then Capcom's stock price started to rise on Jan 29th, 2019, as Capcom's new title Biohazard RE:2 reached 3 million sales in the first week (Nikkei Quick News, 2019).

Exhibit 4.2 Capcom's stock price from May 2017



(Source: Yahoo! Finance)

From the above graph, it can be observed that the game regulation of China had a strong impact on Capcom's stock price. However, under the environment of current games market, consumers have multiple ways to approach to a certain game title. Even if the publication of PC version of *Monster Hunter World* is regulated in China, Chinese consumers are still able to buy this title from other platforms. Of course, there must be some influence on the sales of this game, but the Capcom's fundamentals should not change by that degree. The volatility was too big, which was likely a result of investor's overreaction. Different from Nintendo's case, this time it had minus influence on the stock price. However, there is a second possibility, which is investors overestimated the value of *Monster Hunter World* and overreacted in early 2018. The slump afterwards meant returning to fundamentals instead.

4.3 Matching Portfolio

Due to the reason that it is hard to observe the fundamentals of companies, the benchmark of defining whether a change in stock price is overaction or not is very ambiguous. Greenwood, Shleifer and You (2019) suggest a methodology of observing average returns after price run-ups in different industries and checking whether there are crashes in price. The general logic of this methodology is that since the benchmark is ambiguous, the only way to define a bubble (similar to overaction) is observing crashes after price run-ups. This is a reasonable argument, but the methodology is hard to imply in case of this research. The main reason is that game related companies are small samples. There are only 45 companies according to the definition of game related companies in this paper, and many of them just went public in recent years. It is unable to get same size of data like Greenwood's research, as he collected data of returns from January 1926 to March 2014. As a result, it is difficult to define how much return can be identify as a price run-up. If the return is set too high, there will be only few samples and thus become insignificant. On the other hand, if the return is set too low, it is impossible to show the difference between game industry and other industries.

Former case studies have shown that cases of crashes right after price run-ups do exist in game industry. In order to deal with more data, a methodology of matching portfolio will be used in further analysis. The benefit of this methodology is that it is able to reach an intuitive comparison even using small-data. First, consider forming a value-weighted portfolio consisted of each game-related company. The next step is searching for companies under similar financial situation but in different industry with each company in former portfolio, to form a matching portfolio. The objective is to observe the change of stock price in both portfolios after the announcement of financial result. If a stock has greater change in this case, investors are more likely to overact to a certain event (like announcement of financial result). This is because that rational investors should have certain belief on a stock and act before the announcement. On the other hand, the rest of the investors do not have enough information about this company, thus very much relying on the announcement, but they are not prepared and tend to overact to the announcement. This will increase the change of the stock price after the announcement.

As this research is focusing on volatility of stock prices, the most critical financial data should be market capitalization and sales growth rate, so companies under similar financial situation means companies with similar market capitalization and sales growth rate. The matching companies of each game related company are chosen by program according to the above principle. The algorithm is designed to pick the company which has the closest sales growth

rate in a certain range of market capitalization of the benchmarking company. In other word,

$$\text{Min}|G_m - G_g| \quad \text{s.t.} \quad |V_m - V_g| \leq k \quad (9)$$

where G_m is the sales growth rate of matching company, G_g is the sales growth rate of game company, V_m is the market value of matching company, V_g is the market value of game company, and k is the range set for the difference in market value. The result of matching portfolio is shown as below:

Exhibit 4.3 Company list of matching portfolio

Name	V_g	G_g	Name	V_m	G_m
Fonfun	1161	5.36%	ChiikiShinbunsha Co	992	5.58%
Wedge Holdings Co	7701	4.79%	Arbeit-Times Co	7672	4.69%
Pixel Inc	3931	-47.14%	Nagaoka International	3907	-10.05%
Restar Holdings	34760	2.41%	Japan Cash Machine Co	34498	2.27%
Koei Tecmo Holdings Co	223849	0.98%	Nagase & Co	229972	1.05%
Klab Inc	31215	16.04%	Vitec Holdings Co	31455	16.13%
Poletowin Pitcrew Holdings Inc	43739	14.71%	Sala	43653	17.01%
Ateam Inc	46303	33.52%	Es-con Japan	46274	25.16%
Digital Hearts Holdings Co	41570	9.31%	Yutaka Giken Co	41540	7.71%
Shift Inc	70965	57.28%	Open Door Inc	72054	26.34%
CRI Middleware Co	14291	11.15%	DVx Inc	14247	10.14%
Nihon Falcom	13364	14.38%	Softbrain Co	13373	14.52%
Drecom Co	33571	21.82%	FRONTEO Inc	33348	24.87%
Nippon Ichi Software Inc	9180	8.86%	System Research Co	9204	8.27%
Heroz Inc	88680		Nishimatsuya Chain Co	88656	2.23%
Imagineer Co	11437	8.28%	Artner Co	11441	10.38%
Z Holdings	2814248	27.93%	Tokyo Electron	3306696	22.63%
Tose Co	7864	-6.80%	Village Vanguard Co	7837	-9.44%

CyberAgent Inc	764881	18.15%	Tsuruha Holdings Inc	794728	15.19%
Rakuten Inc	1055846	15.57%	Ryohin Keikaku Co	1029059	13.40%
Nihon Enterprise Co	8772	-8.71%	HAPiNS Co	8670	-8.03%
Showa Holdings Co	6459	7.08%	Japan Asia Investment Co	6403	6.18%
E-guardian Inc	29469	25.05%	FJ Next Co	29796	18.62%
Daikoku Denki Co	26034	-14.24%	Hiroshima Gas Co	25907	-6.03%
Sega Sammy Holdings Inc	448597	-3.03%	Casio Computer Co	410807	-2.38%
Minebea Mitsumi Inc	970327	20.64%	Ryohin Keikaku Co	1029059	13.40%
GameWith Inc	28691	69.32%	IBJ Inc	28564	42.05%
Kyowa	5985		Actcall Inc	5986	18.73%
Melco Holdings Inc	80279	-4.32%	Yamagata Bank	80036	-2.59%
Sony	6516754	1.31%	Mizuho Financial Inc	4859578	1.09%
MegaChips	88237	11.49%	Funai Soken Holdings Inc	87026	13.81%
I-O Data Device Inc	17792	10.42%	Business Brain Showa-Ota Inc	17768	8.64%
Happinet	36869	-3.11%	Aeon Kyushu Co	36711	-1.41%
Tay Two Co	2670	-1.48%	Musashino Kogyo Co	2703	-1.34%
Bandai Namco Holdings Inc	775890	6.25%	Acom Co	756638	6.31%
Nintendo Co	6638609	24.29%	Nidec	4886551	13.11%
Mti	38337	-4.58%	PC Depot	37941	-5.27%
Kadokawa	78619	27.16%	Rakus Co	77696	23.37%
Square Enix Holdings Co	596063	14.25%	McDonald's Holdings Japan	619594	12.84%
Capcom Co	311391	13.71%	Nabtesco	299821	16.36%
Konami Holdings	802165	3.16%	Hino Motors	786601	2.93%
SoftBank	8750250	1.84%	Nippon Telegraph And Telephone	10272333	2.07%

N-links Co (6578), And Factory Inc (7035) and Bookoff Group (9278) are removed from the

game portfolio as they do not have available market value. It is impossible to complete the matching. The result of price change is the weighted-average of the change in stock price of each company:

$$d = \frac{\sum_{i=1}^n d_i V_i}{\sum_{i=1}^n V_i} \quad (10)$$

where d_i is the change in stock price of company i . In order to get rid of the influence of the timing of announcement, d_i is calculated by the absolute value of the difference between the day before and the day after the announcement of financial result.

$$d_i = \left| \frac{p_{t+1} - p_{t-1}}{p_{t-1}} \right| \quad (11)$$

d_g results to be 0.0421 and d_m results to be 0.0306. This proved that the portfolio formed by game companies changed more than the matching portfolio formed by companies in other industries. It is likely that investors overact to events related to game companies.

Chapter 5 Conclusion

This paper identifies the issue of volatility in stock market and investors' behavior by analyzing the phenomenon in game industry. Former hypotheses are proved by using linear regression model with Realized Volatility, case study and matching portfolio. It is able to make two conclusions. First, stock prices of game related companies are more volatile comparing to the average in other industries. The reason for such volatility might also be different from other industry: some factors show stronger impact on game related companies. Second, there are several cases of crashes right after price-ups proving investors are overacting to certain events. The matching portfolio analysis further indicates that a value-weighted portfolio formed by game companies changed more in stock price comparing to a similar portfolio formed by companies in other industries. This is a possible result of investors' overreaction towards events related to game industry. The above conclusion imply that investors' behavior plays a very important role in influencing the stock prices of game related companies.

Further research could try to increase the accuracy of data, for example, calculating the Realized Volatility with hour return instead of daily return, or involving time series data in the linear regression model and matching portfolio. Another considerable method is conducting events study on game related industry, but the bottleneck is that it is difficult to compare such events with events in other industries due to the differ in time. One interesting topic beyond the discussion of this research is that, will the games market become the next bubble? As mentioned above, there were analysts that were pessimist towards game industry. Main arguments included Mobile games revenue (49 percent of industry total) would fall as China, the world's biggest smartphone market sees a 10 percent contraction due to Beijing's tighter grip on game approvals; consoles (19 percent) would struggle but depend on whether PlayStation 5 will come at the end

of 2020; PCs gaming (25 percent) will slump as players start to lose interest in current popular game titles. Investors had already lost their confidence in giants of this industry, such as Nintendo, EA games and Activision Blizzard (Nakamura, 2019). Although this statement needs to be argued, for example, PC gamers tired of current titles may simply move to new popular ones, which is just a common cycle in past decades. However, cloud gaming, as a new concept, is possible to bring new vitality to game industry. Which way will this growing industry goes? This question is still remaining to be answered.

Appendix 1 Linear Regression Model Using Standard Deviation of 3-year Return

If using standard deviation of 3-year return (x-axis in Exhibit 3.1), it is able to get a model which predict volatility with 6 variables ($F(6, 3153) = 141.7, p < .001$), in which R^2 equals .2124 and adjusted R^2 equal .2109. The regression equation is shown as below:

$$\text{Volatility} = 3.2938 + 0.1067 * CI_PBR3_0 + 0.0131 * CI_INST - 0.0056 * CI_ANTEI + 0.0089 * CI_ATRM - 0.3258 * CI_L_TKY - 0.1268 * CB_MV_0 \quad (12)$$

Exhibit 6.1 Summary of regression model (12)

term	estimate	std.error	statistic	p.value
Intercept	3.29375	0.159315	20.6744	3.74E-89
CI_PBR3_0	0.106676	0.00549	19.4321	1.55E-79
CI_INST	0.013118	0.002634	4.980068	6.70E-07
CI_ANTEI	-0.00562	0.000853	-6.59122	5.09E-11
CI_ATRM	0.00892	0.002294	3.889226	0.000103
CI_L_TKY	-0.32575	0.040027	-8.13824	5.71E-16
CB_MV_0	-0.12681	0.011222	-11.3005	4.69E-29

All the variables are significant under significant level of 0.01. Most of the coefficients prove former prediction to be correct, except for CI_INST, ratio of share hold by domestic institutional investors, has a positive coefficient. It might prove that former assumption on institutional investors' impact to be wrong, but one single partial regression coefficient can barely tell anything. It is important to take the whole model into consideration.

After introducing dummy variable, game, it is able to get a new model ($F(8, 3151) = 109, p < .001$), in which R^2 equals .2167 and adjusted R^2 equal .2147. The regression equation is shown as below:

$$\begin{aligned}
\text{Volatility} = & 3.3012 + 0.1055 * CI_PBR3_0 + 0.1230 * CI_INST - 0.0056 * CI_ANTEI + 0.0089 \\
& * CI_ATRM - 0.3205 * CI_L_TKY - 0.1279 * CB_MV_0 + 0.9944 * \text{game} - 0.6343 * CI_L_TKY \\
& * \text{game}
\end{aligned}
\tag{13}$$

Exhibit 6.2 Summary of regression model (13)

term	estimate	std.error	statistic	p.value
Intercept	3.301168	0.158972	20.76578	7.09E-90
CI_PBR3_0	0.105491	0.005484	19.23567	4.70E-78
CI_INST	0.012998	0.002629	4.944492	8.03E-07
CI_ANTEI	-0.00561	0.000851	-6.58722	5.23E-11
CI_ATRM	0.008871	0.002289	3.876023	0.000108
CI_L_TKY	-0.32047	0.039989	-8.0138	1.55E-15
CB_MV_0	-0.12793	0.011213	-11.4099	1.41E-29
game	0.994435	0.283614	3.506302	0.000461
CI_L_TKY : game	-0.63425	0.326073	-1.94513	0.051848

All the variables are significant under significant level of 0.01, except for the interaction effect between CI_L_TKY, listing information and dummy variable game. The p-value of this variable is slightly above 0.05. The negative coefficient in this interaction variable shows that the difference between companies listed in Tokyo Stock Exchange First Section and other sections are bigger for game related companies. Among 45 game related companies, 29 are listed in First Section. A possible explanation of this phenomenon is that stocks of game related companies not listed in First Section are more illiquid comparing to other industries. These companies might be considered to be riskier, thus become a less favorable choice for most investors. Another possible reason is that as stated above, game companies are taking high financial risk. Companies not listed in First Section generally have smaller market capitalization, so their ability of bearing such financial risk is less than companies listed in First Section. As a result, their performance is more unstable, and reflect on stock price with higher volatility.

Taking the external environment of game industry into consideration, many independent game developers are either unlisted company or being subsidiary of a bigger corporation. Few of them, like Nihon Falcom, are listed in sections other than First Section in Tokyo Stock

Exchange. If the game related companies keep growing in the future and the above companies plan to go public, they might face the same situation with the 16 game related companies not listed in First Section right now.

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