

USING PATENT BACKWARD CITATION FOR CLASSIFYING STOCK PRICE OF CHINA STOCK MARKET

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Abstract

Based on the company integrated database, more than 2,000 China listed companies of RMB common stocks (A-shares) from 2017 to 2020 were studied. The impact of the backward citation count, which defined as the total number of patent backward citations per A-share, and the average backward citation count, which defined as the average number of patent backward citations per A-share's patent, on the stock price was thoroughly analyzed via ANOVA. With regard to the original stock price, either the backward citation count or the average backward citation count was not a good indicator for classifying China A-share's stock price. When considering the stock price in the natural logarithm form, the backward citation count showed its significant impact on the stock price. The A-shares of higher backward citation counts showed higher stock price means than the A-shares of lower backward citation counts. It worked well even under Covid-19 pandemic.

Keywords: China A-share; patent; ANOVA; stock price; backward citation

JEL Codes: C38, C46, G11, G12

1. Introduction

Innovation is an essential driver of economic progress that benefits consumers, businesses and the economy as a whole. The technological innovation is a key driver of economic growth. The stock market usually reflects the economic conditions of an economy.

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China has been the largest domestic patent application country in the world for many years. China Intellectual Property Administration (CNIPA) is now the world's largest patent office. In 2020, there are more than three millions of patent published and/or granted by CNIPA, including 1,517 thousands of invention publications, 53 thousands of invention grants and 2,377 thousands of utility model grants. Meanwhile, China is now the world No.2 economy to have a stock market with the world No.2 transaction volume. China listed companies lead the development of China patents, which the unlisted companies and individuals follow.

With so huge amount of China patents, CNIPA faced the challenges in trying to process more patent applications in a shorter period of time and made some achievements (Liegsalz & Wagner, 2013). Based on patent information, Motohashi (2008) examined China's development of innovation capabilities from 1985 to 2005 by using more than 679 thousands of China invention patent. Motohashi (2009) proposed to see a substantial trend of Chinese firms catching up with Western counterparts via patent statistics in two high-tech sectors: the pharmaceutical industry and mobile communications technology. He found that these two fields show contrasting trends, the rapid catching up can be found in mobile communications technology, while Chinese companies are still lagging behind Western counterparts in the pharmaceutical industry. Hu & Jefferson (2009) used a firm-level data set that spans the population of China's large and medium-size industrial enterprises to explore the factors that account for China's rising patent activity. They found that China's patent surge is seemingly paradoxical given the country's weak record of protecting intellectual property rights. Lei, Zhao, Zhang, Chen, Huang & Zhao (2011) found that the inventive activities of China have experienced three developmental phases and have been promoted quickly in recent years. The innovation strengths of the three development phases have shifted from government to university and research institute and then industry. Liu & Qiu (2016) used Chinese firm-level patent data from 1998 to 2007 which featuring a drastic input tariff cut in 2002 because of China's WTO accession. They found that input tariff cut results in less innovation undertaken by Chinese firms.

Boeing & Mueller (2019) proposed a patent quality index based on internationally comparable citation data from international search reports to consider foreign, domestic, and self citations. They found that all three citation types may be used as economic indicators if policy distortion is not a concern. They also suggested that the domestic and self citations suffer from an upward bias in China and should be employed with caution if they are to be interpreted as a measure of patent quality.

Dang & Motohashi (2015) proposed that China patent statistics are meaningful indicators because China valid patent count is correlated with R&D input and financial

output. Chen & Zhang (2019) studied China's patent surge and its driving forces on patent applications filed by Chinese firms and found that R&D investment, foreign direct investment, and patent subsidy have different effects on different types of patents. They found that R&D investment has a positive and significant impact on patenting activities for all types of patents; the stimulating effect of foreign direct investment on patent applications is only robust for utility model patents and design patents; the patent subsidy only has a positive impact on design patents.

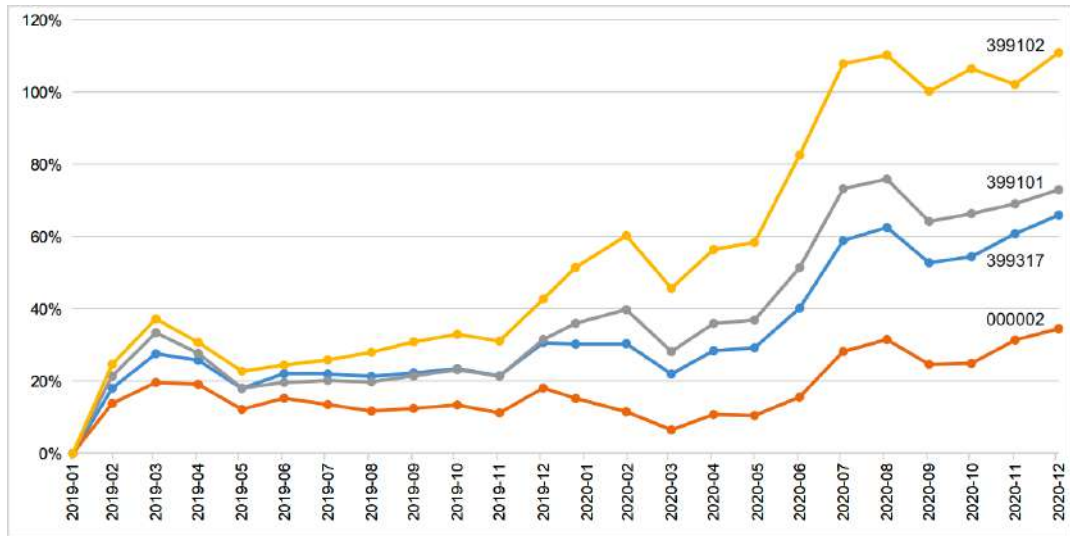
He, Tong, Zhang & He (2016) found that it was difficult in integrating Chinese patent data with company data, so they constructed a China patent database of all China listed companies and their subsidiaries from 1990 to 2010. Chen, wei & Che (2018) used the patent data and stock data of China listed companies of RMB common stocks (A-shares) in Shanghai main board (SH main board) from 2011 to 2017 and found the patent indicators have leading effect on A-share's stock price. Chiu, Chen & Che (2020a, 2020b) focused on the whole China A-shares without distinguishing the stock boards from 2016Q4 to 2018Q3. They found that the patent indicators also have leading effect on the financial indicators including the stock price, return-on-asset (ROA), return-on-equity (ROE), book-value-per-share (BPS), earnings-per-share (EPS), price-to-book (PB) and price-to-earnings (PE). The patent prediction equations for quantitatively giving the predictive values of the aforementioned financial indicators are proposed.

The China A-shares are listed on four stock boards including SH main board, Shenzhen main board (SZ main board), Growing-Enterprises board (GE board) and Small-and-Medium Enterprises board (SME board). The majority of A-shares in SH main board, SZ main board are state-owned companies and big companies; most A-shares in GE board and SME board are small and medium companies. Chiu, Chen & Che (2020c, 2020d, 2020e, 2020f, 2021), Li, Deng & Che (2020a, 2020b, 2021) further studied the patent leading effect on each stock board, proposed each stock board's patent prediction equations on the stock price, ROA, ROE, BPS, EPS, PB and PE, finally proposed patent based stock selection criteria to have stock the performance surpassing the market trend.

COVID-19 is an impact to everything including technology and finance. The World Health Organization (WHO) on March 11, 2020, has declared COVID-19 outbreak a global pandemic. The stock markets around the world including China stock market fluctuated dramatically in 2020. Figure 1 shows the principal China stock indexes performance from Jan. 2019 to Dec. 2020, wherein, 300317 is the stock index consisting of all China A-shares, 000002 is the stock index consisting of all A-shares in SH main board, 399101 is the stock index consisting of all A-shares in SME board, 399102 is the

stock index consisting of all A-shares in GE board. Apparently, stock indexes in 2020 are more volatile though they are in upgoing trend.

Figure 1: Performance of Principal China Stock Indexes from Jan 2019 to Dec 2020



Source: Shanghai Stock Exchange and Shenzhen Stock Exchange in China

In addition, the fluctuation modes of stock indexes are far beyond any patent indicator’s varying trend. Is it possible to correlate China stock market with patent? Tsai, Che & Bai (2021a, 2021b, 2021c, 2021d) discussed the relationship between China patents and China A-shares’ stock performance in 2020. It is found that the A-shares with the higher innovation continuity (Tsai et al., 2021a), the higher patent count (Tsai et al., 2021b), the higher technology variety (Tsai et al., 2021c), or the longer examination duration (Tsai et al., 2021d) have the higher stock return rates.

With regard to the backward citation count of patents, it is usually regarded to be important for evaluating patent’s novelty and non-obviousness. Lai & Che (2009a, 2009b, 2009c) focused on US patents and applied the backward citation count as an indicator for quantitatively modeling US patent values. Though the backward citation count of China patents has been applied for quantitatively giving the predictive values of A-share’s financial indicators (Chiu et al., 2020a~2020f, 2021; Li et al., 2020a, 2020b, 2021), however, the detailed relationship between the backward citation count and A-share’s stock price is not yet discussed. It is therefore the objective of this research to find out, and more particularly, to see whether it is different before and under the COVID-19 pandemic.

2. Methodology

2.1 Company Integrated Patent Database

It is a common phenomenon that a listed company has lots subsidiaries. When a subsidiary's revenue is merged to its parent company as showed in the formal financial report, the subsidiary's patents are inferred to contribute to parent company's financial performance. Therefore, a company integrated patent database is built in this research, wherein, all subsidiaries' patents are merged together with parent company's patents. Furthermore, if a patent is co-owned by parent company and any of the subsidiaries, it is regarded as a single one patent of the parent company for avoiding duplicated calculation. However, if a patent is co-owned by two or more parent A-shares, it is inferred to contribute equivalently to each parent A-share's financial performance, so the patent is duplicated and specified to each of the co-owners for counting.

2.2 Patent Backward Citation

There are four major patent species in China including the invention publication, the invention grant, the utility model grant and the design grant. The design grant is a design application of a product which granted by overcoming the preliminary examination by having a distinct configuration, distinct surface ornamentation or both. The utility model grant is a utility model application of a product which granted by overcoming the preliminary examination. The invention publication is an invention application of a product or a process which published by overcoming the preliminary examination. The invention grant is an invention application which granted by overcoming not only the preliminary examination but also the substantial examination by having novel and distinct technical features of non-obvious effects.

The backward citations in China patent system are the prior arts which examiners officially used in the substantial examination of the invention grant. A patent with more backward citations usually implies to have a stronger patentability of non-obviousness. A company having patents with lots of backward citations usually implies to have good R&D capability and innovation outcome. Therefore the backward citation count (hereinafter, BW citation count) and the average backward citation count (hereinafter, ABW citation count) of an A-share in this research are therefore defined as the number of total backward citations and the average number of backward citations per invention grant respectively.

In order to derive the BW citation counts and ABW citation counts of all A-shares, the patent retrieval interval of one year is applied. For each quarter from 2017 to 2020,

the invention grants are retrieved from the company integrated patent database by the grant date over previous one year, the backward citations corresponding to all derived invention grants are extracted, then the BW citation counts and ABW citation counts for all A-share corresponding to said quarter is calculated. More specifically, for 2017Q1, patents are retrieved by the grant date from 2016/04/01 to 2017/03/31; for 2018Q2, patents are retrieved by the grant date from 2017/07/01 to 2018/06/30; for 2019Q3, patents are retrieved by the grant date from 2018/10/01 to 2019/09/30; and so forth.

By setting the stock price as the dependent variable and either BW citation count or ABW citation count as the independent variable, the R^2 of a linear regression equation is less than 0.1. The linear modeling is inappropriate because of the poor explanatory ability.

The discrete data analysis model is therefore applied. Before dividing the effective samples into different groups, the Kolmogorov-Smirnov test of BW citation counts and ABW citation counts is applied. The result shows that the original data distributions of BW citation counts and ABW citation counts are both seriously skewed, so BW citation counts and ABW citation counts are reformed by the percentile rank (PR) corresponding to each quarter from 2017 to 2020. Two H-groups and two L-groups are generated and discussed in this research as below.

BW citation H-group: A-shares of BW citation count above PR 50;

BW citation L-group: A-shares of BW citation count below PR 50;

ABW citation H-group: A-shares of ABW citation count above PR 50;

ABW citation L-group: A-shares of ABW citation count below PR 50;

2.3 Population and Sample

The population comprises all China A-shares listed in Shanghai exchange and Shenzhen exchange. An effective sample for each specified quarter must meet two conditions:

(1) It was listed to have a definite stock closing price in the last trading day of the specified quarter; and

(2) It must have at least one new invention granted for calculating BW citation count and ABW citation count by the patent retrieval interval as described in sub-section 2.2.

Table 1 shows the effective samples statistics by quarter from 2017 to 2020. Based on the world's No. two stock transaction volume of China, The number of effective samples in each quarter is around 2,000. The sampling rate for effective samples ranges from 50.8% to 64.1%. The analysis in this research should be free of survivorship bias.

Table 1: Effective Samples Statistics in Each Quarter from 2017 to 2020

Year		Effective Samples			
		Q1	Q2	Q3	Q4
2017	A-shares	3,164	3,276	3,380	3,467
	Effective Samples	2,029	1,988	1,718	1,844
	Sampling Rate for Effective Samples	64.1%	60.7%	50.8%	53.2%
2018	A-shares	3,466	3,463	3,463	3,442
	Effective Samples	1,914	1,958	2,018	2,024
	Sampling Rate for Effective Samples	55.2%	56.5%	58.3%	58.8%
2019	A-shares	3,595	3,628	3,648	3,653
	Effective Samples	2,073	2,063	2,064	2,049
	Sampling Rate for Effective Samples	57.7%	56.9%	56.6%	56.1%
2020	A-shares	3,653	3,653	3,641	3,638
	Effective Samples	1,940	1,932	1,930	1,931
	Sampling Rate for Effective Samples	53.1%	52.9%	53.0%	53.1%

Source: This Research

2.4 Analysis of Variance

Analysis of Variance (ANOVA) is applied in this research for discovering:

(1) Whether BW citation count and ABW citation count significantly different between different years?

(2) Whether the stock price between different BW citation groups significantly different or not?

(3) Whether the stock price between different ABW citation groups significantly different or not?

(4) Whether BW citation count and/or ABW citation count good for classifying China A-share's stock price?

ANOVA is a statistical approach used to compare variances across the means of different data groups. The outcome of ANOVA is the "F-Ratio".

$$F = \frac{MST}{MSE} = \frac{\sum n_j (\bar{x}_j - \bar{x})^2 / (k-1)}{\sum \sum (x - \bar{x}_j)^2 / (N-k)}$$

This ratio shows the difference between the within group variance and the between group variance, which ultimately produces a result which allowing a conclusion that the null hypothesis $H_0: \mu_1 = \mu_2 = \dots = \mu_k$ is supported or rejected. If there is a significant difference between the groups, the null hypothesis is not supported, and the F-ratio will be larger and the corresponding p value should be smaller than 0.05.

3. Result and Finding

3.1 BW Citation Count and ABW Citation Count

Tables 2 and 3 show BW citation count mean and ABW citation count mean in each quarter from 2017 to 2020. No matter H-group or L-group, it seems that either BW citation count means or ABW citation count means are different between different quarters and between different years.

Table 2: BW Citation Count Mean in Each Quarter

BW Citation Group	Year	BW Citation Count Mean			
		Q1	Q2	Q3	Q4
H-Group	2017	164.75	137.26	115.75	149.32
	2018	162.01	177.02	187.6	178.97
	2019	82.85	121.76	122.54	162.09
	2020	66.53	145.4	146.72	178.34
L-Group	2017	9.22	8.14	6.52	7.79
	2018	8.27	9.04	9.44	8.81
	2019	5.91	2.89	4.36	4.37
	2020	2.24	4.98	4.92	7.4

Source: This Research

Table 3: ABW Citation Count Mean in Each Quarter

ABW Citation Group	Year	ABW Citation Count Mean			
		Q1	Q2	Q3	Q4
H-Group	2017	5.48	4.89	4.31	4.78
	2018	4.93	5.11	5.30	5.10
	2019	2.39	3.35	3.49	4.48
	2020	4.13	4.00	3.63	2.06
L-Group	2017	3.13	2.48	1.91	2.12
	2018	2.24	2.49	2.71	2.69
	2019	0.85	1.26	1.31	2.00
	2020	1.71	1.57	3.22	0.74

Source: This Research

In order to confirm the inference obtained from Tables 2 and 3, ANOVA is applied. Table 4 shows the results of ANOVA on BW citation count between four quarters in each year from 2017 to 2020. Table 5 shows the results of ANOVA on ABW citation count between four quarters in each year from 2017 to 2020.

Table 4: Result of ANOVA on BW Citation Count between Different Quarters

Year	BW Citation Group	Quarter	BW Citation Count			
			Sum Square	Mean Square	F	p
2017	H-Group	Between Quarters	1,173,736.2	391,245.4	1.545	0.201
		Within Quarters	934,359,449.5	253,282.6		
	L-Group	Between Quarters	3,496.4	1,165.5	63.891	0.001***
		Within Quarters	68,952.6	18.2		
2018	H-Group	Between Quarters	326,038.8	108,679.6	0.196	0.899
		Within Quarters	2,156,822,924.0	555,452.7		
	L-Group	Between Quarters	720.4	240.1	10.371	0.001***
		Within Quarters	93,142.6	23.2		
2019	H-Group	Between Quarters	3,209,978.3	1,069,992.8	3.863	0.009**
		Within Quarters	1,123,824,213.0	277,008.7		
	L-Group	Between Quarters	4,739.5	1,579.8	184.657	0.001***
		Within Quarters	35,796.6	8.6		
2020	H-Group	Between Quarters	6,426,178.5	2,142,059.5	6.196	0.001***
		Within Quarters	1,310,976,893.4	345,721.8		
	L-Group	Between Quarters	13,115.0	4,371.7	384.789	0.001***
		Within Quarters	44,683.5	11.4		

Source: This Research; $p < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

Table 5: Result of ANOVA on ABW Citation Count between Different Quarters

Year	ABW Citation Group	Quarter	ABW Citation Count			
			Sum Square	Mean Square	F	p
2017	H-Group	Between Quarters	644.9	215.0	108.738	0.001***
		Within Quarters	7,352.3	2.0		
	L-Group	Between Quarters	818.5	272.8	480.164	0.001***
		Within Quarters	2,130.9	0.6		
2018	H-Group	Between Quarters	67.0	22.3	8.983	0.001***
		Within Quarters	9,816.1	2.5		
	L-Group	Between Quarters	143.9	48.0	80.565	0.001***
		Within Quarters	2,358.4	0.6		
2019	H-Group	Between Quarters	2,179.5	726.5	358.361	0.001***
		Within Quarters	8,180.3	2.0		
	L-Group	Between Quarters	727.6	242.5	834.890	0.001***
		Within Quarters	1,221.9	0.3		

2020	H-Group	Between Quarters	2,106.4	702.1	311.111	0.001***
		Within Quarters	8,034.3	2.3		
	L-Group	Between Quarters	3,410.5	1,136.8	953.070	0.001***
		Within Quarters	4,968.0	1.2		

Source: This Research; $p^* < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

In Table 4, with regard to BW citation H-groups, the BW citation count variances between four different quarters in 2019 and 2020 are of significance whereas the BW citation count variances between four different quarters in 2017 and 2018 are free of significance. BW citation H-groups in different quarters have significantly different BW citation count means only in 2019 and 2020. With regard to BW citation L-groups, the BW citation count variances between four different quarters in all years are of significance. BW citation L-groups in different quarters have significantly different BW citation count means from 2016 and 2020.

In Table 5, with regard to either ABW citation H-groups or ABW citation L-groups, the ABW citation count variances between four different quarters in all years are of significance. ABW citation groups in different quarters have significantly different ABW citation count means from 2016 and 2020.

Tables 6 and 7 show the results of ANOVA on BW citation count and ABW citation count between four years from 2017 to 2020. With regard to any group of BW citation groups in Table 6, the BW citation count variances between different years are all of significance. With regard to any group of ABW citation groups in Table 7, the ABW citation count variances between different years are all of significance, too. Different years have significantly different BW citation count means and ABW citation count means no matter what group is.

Table 6: Result of ANOVA on BW Citation Count between Different Years

BW Citation Group	Year	BW Citation Count			
		Sum Square	Mean Square	F	p
H-Group	Between Years	60,515.2	20,171.7	1,214.358	0.001***
	Within Years	264,646.6	16.6		
L-Group	Between Years	6,434,754.4	2,144,918.1	5.978	0.001***
	Within Years	5,537,119,411.6	358,784.4		

Source: This Research; $p^* < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

Table 7: Result of ANOVA on ABW Citation Count between Different Years

ABW citation Group	Year	ABW Citation Count			
		Sum Square	Mean Square	F	p
H-Group	Between Years	3,821.6	1,273.9	1,299.162	0.001***
	Within Years	15,779.8	1.0		
L-Group	Between Years	9,041.7	3,013.9	1,199.248	0.001***
	Within Years	38,380.7	2.5		

Source: This Research; $p^* < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

By merging four quarters into one single year, Tables 8 further shows the multiple comparisons of ANOVA on BW citation count between every two years from 2017 to 2020. With regard to BW citation H-groups, BW citation count variances between every two years are of significance. According to the significant mean differences between all BW citation H-groups, 2018 have the highest BW citation count meanwhile 2019 have the lowest BW citation count mean. With regard to BW citation L-groups, BW citation count variances between 2018 and 2017, between 2019 and 2018, between 2020 and 2018, are of significance; while the other BW citation count variances are free of significance. According to the significant mean differences between all BW citation L-groups, 2018 has the highest BW citation count meanwhile 2019 has the lowest BW citation count mean.

Table 8: Multiple Comparisons of ANOVA on BW Citation Count between Different Years

BW Citation Group	Year		BW Citation Count		
	Year (I)	Year (J)	Mean Difference (I-J)	Std. Error	p
H-Group	2018	2017	0.923	0.092	0.001***
	2019	2017	-3.589	0.091	0.001***
	2019	2018	-4.512	0.090	0.001***
	2020	2017	-3.101	0.093	0.001***
	2020	2018	-4.024	0.091	0.001***
	2020	2019	0.487	0.090	0.001***
L-Group	2018	2017	33.763	13.764	0.014*
	2019	2017	-20.809	13.620	0.127
	2019	2018	-54.572	13.441	0.001***
	2020	2017	-8.284	13.844	0.550
	2020	2018	-42.046	13.668	0.002**
	2020	2019	12.526	13.523	0.354

Source: This Research; $p^* < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

By merging four quarters into one single year, Tables 9 further shows the multiple comparisons of ANOVA on ABW citation count between every two years from 2017 to 2020. With regard to either ABW citation H-groups or ABW citation L-groups, ABW citation count variances between every two years are of significance. According to the significant mean differences of ABW citation H-groups, 2018 have the highest ABW citation count meanwhile 2019 have the lowest ABW citation count mean. According to the significant mean differences of ABW citation L-groups, 2018 also have the highest ABW citation count meanwhile 2019 also have the lowest ABW citation count mean.

Table 9: Multiple Comparisons of ANOVA on ABW Citation Count between Different Years

ABW Citation Group	Year		ABW Citation Count		
	Year (I)	Year (J)	Mean Difference (I-J)	Std. Error	p
H-Group	2018	2017	0.099	0.023	0.001***
	2019	2017	-1.075	0.022	0.001***
	2019	2018	-1.174	0.022	0.001***
	2020	2017	-0.683	0.022	0.001***
	2020	2018	-0.782	0.022	0.001***
	2020	2019	0.392	0.022	0.001***
L-Group	2018	2017	0.221	0.036	0.001***
	2019	2017	-1.479	0.036	0.001***
	2019	2018	-1.701	0.035	0.001***
	2020	2017	-1.339	0.037	0.001***
	2020	2018	-1.560	0.037	0.001***
	2020	2019	0.141	0.036	0.001***

Source: This Research; $p < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

In general, no matter H-group or L-group, the A-shares in different quarters of a year have significantly different BW citation count means and different ABW citation count means. No matter H-group or L-group, the A-shares in different years also have significantly different BW citation count means and different ABW citation count means. The A-shares in 2018 have the highest BW citation count means and ABW citation count means while the A-shares in 2019 have the lowest BW citation count means and ABW citation count means. The varying tendency does not show.

3.2 Stock Price Variance

Table 10 shows the stock price means of all groups in each quarter of ever year from 2017 to 2020.

With regard to BW citation H-groups, it seems that the stock price means are different between different quarters and between different years; the same as BW citation L-groups, ABW citation H-groups and ABW citation L-groups.

Table 10: Stock Price Means of Each BW citation groups and ABW Citation Groups

Year	Group	Stock Price Mean (RMB)			
		Q1	Q2	Q3	Q4
2017	BW Citation H-Group	19.42	17.60	18.09	17.33
	BW Citation L-Group	23.23	19.53	20.48	18.47
	ABW Citation H-Group	19.63	18.55	18.99	18.34
	ABW Citation L-Group	23.01	18.63	19.61	17.47
	Total	21.33	18.59	19.30	17.91
2018	BW Citation H-Group	17.30	13.48	12.32	11.23
	BW Citation L-Group	18.22	15.23	13.32	11.03
	ABW Citation H-Group	18.32	14.45	13.34	11.21
	ABW Citation L-Group	17.22	14.30	12.30	11.05
	Total	17.77	14.37	12.82	11.13
2019	BW Citation H-Group	14.27	13.65	15.30	17.17
	BW Citation L-Group	13.26	14.20	15.34	16.13
	ABW Citation H-Group	14.05	14.42	15.73	16.91
	ABW Citation L-Group	13.49	13.47	14.91	16.41
	Total	13.76	13.93	15.32	16.64
2020	BW Citation H-Group	18.56	22.69	23.68	23.34
	BW Citation L-Group	15.54	17.16	18.29	20.22
	ABW Citation H-Group	16.59	20.00	23.97	22.46
	ABW Citation L-Group	17.49	19.66	18.11	21.32
	Total	17.05	19.83	20.97	21.73

Source: This Research

In order to confirm whether the stock price means between BW citation H-groups and L-groups are significantly different or not, Table 11 shows the results of ANOVA on the stock price between different BW citation groups. In 2017, the stock price variances between BW citation H-groups and L-groups in Q1, Q2 and Q3 are of significance. In 2018 and 2019, the stock price variances between BW citation H-groups and L-groups in all quarters are free of significance. In 2020, the stock price variances between BW citation H-groups and L-groups in Q2 and Q3 are of significance while the stock price variances in Q1 and Q4 are free of significance. In general, there are only five quarters in total sixteen quarters from 2017 to

2020 are of significance. It is hard to conclude that BW citation count has significant impact on the stock price.

Table 11: ANOVA on Stock Price between BW citation Groups

Year	Quarter	BW Citation Group	Stock Price (RMB)			
			Sum Square	Mean Square	F	p
2017	Q1	Between Groups	7,383.1	7,383.1	15.746	0.001***
		Within Groups	950,439.1	468.9		
	Q2	Between Groups	1,748.2	1,748.2	4.388	0.036*
		Within Groups	751,326.0	398.4		
	Q3	Between Groups	2,451.3	2,451.3	5.754	0.017*
		Within Groups	731,009.5	426.0		
	Q4	Between Groups	591.8	591.8	1.106	0.293
		Within Groups	984,905.1	535.3		
2018	Q1	Between Groups	399.5	399.5	0.750	0.386
		Within Groups	1,018,033.3	532.4		
	Q2	Between Groups	1,486.9	1,486.9	3.102	0.078
		Within Groups	937,513.1	479.3		
	Q3	Between Groups	502.1	502.1	1.170	0.280
		Within Groups	865,369.8	429.3		
	Q4	Between Groups	20.3	20.3	0.171	0.680
		Within Groups	241,129.5	119.3		
2019	Q1	Between Groups	525.3	525.3	2.596	0.107
		Within Groups	419,119.7	202.4		
	Q2	Between Groups	155.2	155.2	0.223	0.637
		Within Groups	1,433,345.8	695.5		
	Q3	Between Groups	0.6	0.6	0.001	0.980
		Within Groups	2,209,049.9	1,071.3		
	Q4	Between Groups	553.2	553.2	0.445	0.505
		Within Groups	2,543,846.1	1,242.7		
2020	Q1	Between Groups	4,442.9	4,442.9	3.226	0.073
		Within Groups	2,669,102.3	1,377.2		
	Q2	Between Groups	14,747.2	14,747.2	6.872	0.009**
		Within Groups	4,141,513.2	2,145.9		
	Q3	Between Groups	14,015.0	14,015.0	5.703	0.017*
		Within Groups	4,738,210.8	2,457.6		
	Q4	Between Groups	4,676.3	4,676.3	1.351	0.245
		Within Groups	6,677,269.3	3,461.5		

Source: This Research; $p^* < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

With regard to ABW citation count, Table 12 shows the results of ANOVA on the stock price between different ABW citation groups. In 2017, the stock price variance between ABW citation H-groups and L-groups in Q1 is of significance while the stock price variances in the other quarters are free of significance. In 2018 and 2019, the stock price variances between ABW citation H-groups and L-groups in all quarters are free of significance. In 2020, the stock price variance between ABW citation H-groups and L-groups in Q3 is of significance while the stock price variances in the other quarters are free of significance. In general, there are only two quarters in total sixteen quarters from 2017 to 2020 are of significance. It is also hard to conclude that ABW citation count has significant impact on the stock price.

Table 12: ANOVA on Stock Price between ABW Citation Groups

Year	Quarter	ABW Citation Group	Stock Price (RMB)			
			Sum Square	Mean Square	F	p
2017	Q1	Between Groups	5,804.7	5,804.7	12.359	0.001***
		Within Groups	952,017.5	469.7		
	Q2	Between Groups	3.3	3.3	0.008	0.927
		Within Groups	753,070.9	399.3		
	Q3	Between Groups	167.1	167.1	0.391	0.532
		Within Groups	733,293.8	427.3		
	Q4	Between Groups	348.9	348.9	0.652	0.420
		Within Groups	985,148.1	535.4		
2018	Q1	Between Groups	577.4	577.4	1.085	0.298
		Within Groups	1,017,855.4	532.4		
	Q2	Between Groups	11.0	11.0	0.023	0.880
		Within Groups	938,989.0	480.1		
	Q3	Between Groups	542.1	542.1	1.263	0.261
		Within Groups	865,329.9	429.2		
	Q4	Between Groups	13.6	13.6	0.114	0.736
		Within Groups	241,136.2	119.3		
2019	Q1	Between Groups	162.8	162.8	0.804	0.370
		Within Groups	419,482.1	202.6		
	Q2	Between Groups	466.2	466.2	0.670	0.413
		Within Groups	1,433,034.9	695.3		
	Q3	Between Groups	342.9	342.9	0.320	0.572
		Within Groups	2,208,707.6	1,071.1		
	Q4	Between Groups	125.0	125.0	0.101	0.751
		Within Groups				

		Within Groups	2,544,274.3	1,242.9		
2020	Q1	Between Groups	385.6	385.6	0.280	0.597
		Within Groups	2,673,159.6	1,379.3		
	Q2	Between Groups	55.4	55.4	0.026	0.873
		Within Groups	4,156,205.0	2,153.5		
	Q3	Between Groups	16,525.9	16,525.9	6.728	0.010**
		Within Groups	4,735,699.9	2,456.3		
	Q4	Between Groups	581.5	581.5	0.168	0.682
		Within Groups	6,681,364.1	3,463.6		

Source: This Research; $p^* < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

However, by observing the stock prices in each quarter, the distribution is not normal. Via the Kolmogorov-Smirnov test, the distribution of the stock price is seriously skewed. Therefore, the stock prices of all effective samples are further transformed by natural logarithm for advanced analysis. Table 13 shows the results of ANOVA on the natural logarithm transformed stock price (hereinafter, the LN stock price) between different BW citation groups. In 2017, the LN stock price variances between BW citation H-groups and L-groups in Q1, Q2 and Q3 are of significance. In 2018, the LN stock price variances between BW citation H-groups and L-groups in Q1 and Q2 are of significance. In 2019, the LN stock price variance between BW citation H-groups and L-groups in Q4 is of significance. In 2020, the stock price variances between BW citation H-groups and L-groups in all quarters are of significance. In general, there are ten quarters of total sixteen quarters from 2017 to 2020 in which the LN stock price variances are of significance. It concludes that BW citation count has significant impact on the LN stock price.

Table 13: ANOVA on LN Stock Price between BW citation Groups

Year	Quarter	BW Citation Group	LN Stock Price (RMB)			
			Sum Square	Mean Square	F	p
2017	Q1	Between Groups	8.0	8.0	18.627	0.001***
		Within Groups	871.9	0.4		
	Q2	Between Groups	4.4	4.4	10.693	0.001***
		Within Groups	779.4	0.4		
	Q3	Between Groups	5.1	5.1	12.610	0.001***
		Within Groups	699.2	0.4		
	Q4	Between Groups	1.6	1.6	3.657	0.056
		Within Groups	816.4	0.4		
2018	Q1	Between Groups	2.4	2.4	4.854	0.028*

		Within Groups	925.6	0.5		
	Q2	Between Groups	2.5	2.5	5.166	0.023*
		Within Groups	965.0	0.5		
	Q3	Between Groups	0.6	0.6	1.223	0.269
		Within Groups	915.3	0.5		
	Q4	Between Groups	0.0	0.0	0.108	0.743
		Within Groups	867.9	0.4		
2019	Q1	Between Groups	0.4	0.4	0.911	0.340
		Within Groups	846.2	0.4		
	Q2	Between Groups	0.1	0.1	0.191	0.662
		Within Groups	970.8	0.5		
	Q3	Between Groups	0.8	0.8	1.392	0.238
		Within Groups	1,187.3	0.6		
	Q4	Between Groups	2.5	2.5	4.021	0.045*
		Within Groups	1,250.2	0.6		
2020	Q1	Between Groups	2.9	2.9	4.302	0.038*
		Within Groups	1,299.5	0.7		
	Q2	Between Groups	9.4	9.4	11.765	0.001***
		Within Groups	1,548.7	0.8		
	Q3	Between Groups	6.6	6.6	8.671	0.003**
		Within Groups	1,471.4	0.8		
	Q4	Between Groups	12.3	12.3	15.470	0.001***
		Within Groups	1,527.5	0.8		

Source: This Research; $p < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

Table 14 shows the results of ANOVA on the LN stock price between different ABW citation groups. In 2017, the LN stock price variance between ABW citation H-groups and L-groups in Q1 is of significance. In 2018 and 2019, the LN stock price variances between ABW citation H-groups and L-groups in all quarters are free of significance. In 2020, the stock price variances between ABW citation H-groups and L-groups in Q3 and Q4 are of significance. In general, there are three quarters of total sixteen quarters from 2017 to 2020 in which the LN stock price variances are of significance. It concludes that ABW citation count has no significant impact on the LN stock price.

Table 14: ANOVA on LN Stock Price between ABW Citation Groups

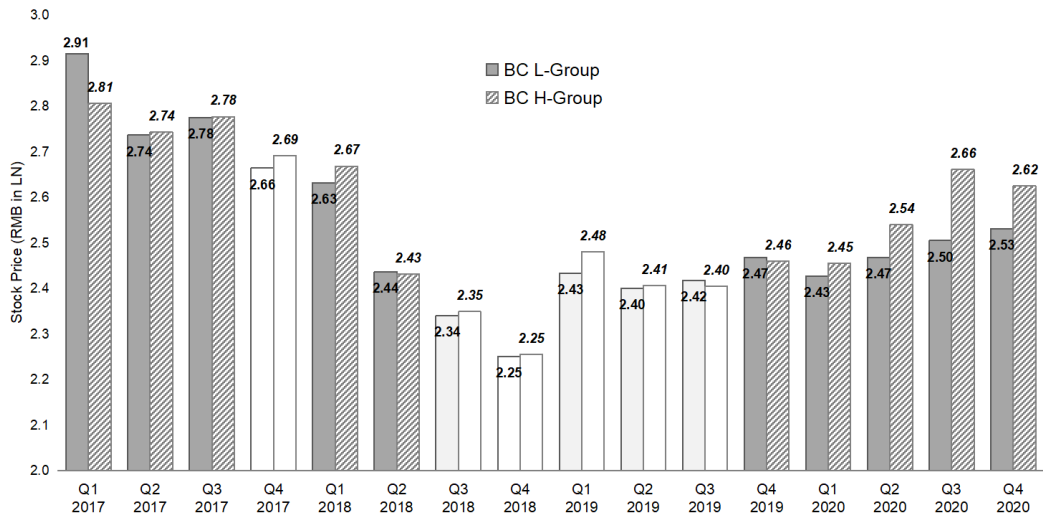
Year	Quarter	ABW Citation Group	LN Stock Price (RMB)			
			Sum Square	Mean Square	F	p
2017	Q1	Between Groups	5.9	5.9	13.766	0.001***

		Within Groups	873.9	0.4		
	Q2	Between Groups	0.0	0.0	0.046	0.830
		Within Groups	783.8	0.4		
	Q3	Between Groups	0.0	0.0	0.002	0.963
		Within Groups	704.4	0.4		
	Q4	Between Groups	0.4	0.4	0.790	0.374
		Within Groups	817.6	0.4		
2018	Q1	Between Groups	0.6	0.6	1.296	0.255
		Within Groups	927.3	0.5		
	Q2	Between Groups	0.0	0.0	0.023	0.879
		Within Groups	967.5	0.5		
	Q3	Between Groups	0.0	0.0	0.087	0.768
		Within Groups	915.8	0.5		
	Q4	Between Groups	0.0	0.0	0.022	0.882
		Within Groups	867.9	0.4		
2019	Q1	Between Groups	1.2	1.2	2.857	0.091
		Within Groups	845.4	0.4		
	Q2	Between Groups	0.0	0.0	0.034	0.854
		Within Groups	970.8	0.5		
	Q3	Between Groups	0.1	0.1	0.158	0.691
		Within Groups	1,188.0	0.6		
	Q4	Between Groups	0.0	0.0	0.047	0.829
		Within Groups	1,252.6	0.6		
2020	Q1	Between Groups	0.4	0.4	0.562	0.453
		Within Groups	1,302.0	0.7		
	Q2	Between Groups	2.5	2.5	3.063	0.080
		Within Groups	1,555.7	0.8		
	Q3	Between Groups	11.8	11.8	15.487	0.001***
		Within Groups	1,466.2	0.8		
	Q4	Between Groups	4.0	4.0	4.966	0.026*
		Within Groups	1,535.8	0.8		

Source: This Research; $p < 0.05$, $p^{**} \leq 0.01$, $p^{***} \leq 0.001$

Since BW citation count has significant impact on the LN stock price, Figure 2 further shows the comparison bar chart of LN stock price means of BW citation H-groups and L-groups from 2017 to 2020, wherein, the blank bars indicate that the mean differences between BW citation H-groups and L-groups are free of significance in those quarters.

Figure 2: Comparison of Stock Price Means between BW citation H-groups and L-groups



Source: This Research

With regard to ten quarters in which the mean differences are of significance in Fig. 2, there are seven quarters in which BW citation H-groups have higher LN stock price means than BW citation L-groups, while only three quarters in which BW citation H-groups have lower LN stock price means than BW citation L-groups. Finally, it concludes that the A-shares in higher BW citation count groups have higher stock price means than the A-shares in lower BW citation count groups mostly. In most situations, the BW citation count could be applied for classifying China A-share's stock price. More particularly, in 2020, the LN stock price mean differences between BW citation H-groups and L-groups show an enlarging trend though it is under Covid-19 pandemic. Covid-19 somehow changed the listed companies performance by changing human living style and the industry development.

4. Conclusion and Recommendation

Based on the company integrated patent database of China A-shares and the stock price data in sixteen quarters from 2017 to 2020, the impact of patent backward citation on the stock price before and under COVID-19 pandemic was thoroughly analyzed via ANOVA. The BW citation count is defined as the number of total patent backward citations of the A-share. The ABW citation count is defined as the average number of backward citations per invention grant of the A-share. Thousands of A-shares in each quarter were divided into two citation groups according to the percentile rank of their BW citation counts and ABW citation counts, wherein, H-group stands for the group in which

the A-shares having BW citation counts above percentile rank 50 while L-group stands for the group in which the A-shares having BW citation counts below percentile rank 50. The following conclusions were arrived:

(1) China A-shares of BW citation L-groups in different quarters had significantly different BW citation count means every year from 2017 to 2020, whereas China A-shares of BW citation H-groups in different quarters had significantly different BW citation count means only in 2019 and 2020. China A-shares of ABW citation H-groups in different quarters every year from 2017 to 2020 had significantly different ABW citation count means, the same as the A-shares of ABW citation L-groups.

(2) China A-shares of BW citation H-groups in different years from 2017 to 2020 had significantly different BW citation count means, the same as the A-shares of BW citation L-groups. China A-shares of ABW citation H-groups in different years from 2017 to 2020 had significantly different ABW citation count means, the same as the A-shares of ABW citation L-groups.

(3) From 2017 to 2020, the A-shares of BW citation H-group had the highest BW citation count mean in 2018 among all BW citation H-groups, the same as the A-shares of BW citation L-group in 2018. The A-shares of BW citation H-group had the lowest BW citation count mean in 2019 among all BW citation H-groups, the same as the A-shares of BW citation L-group in 2019 among all BW citation L-groups.

(4) From 2017 to 2020, the A-shares of ABW citation H-group had the highest ABW citation count mean in 2018 among all ABW citation H-groups, the same as the A-shares of ABW citation L-group in 2018. The A-shares of ABW citation H-group had the lowest ABW citation count mean in 2019 among all ABW citation H-groups, the same as the A-shares of ABW citation L-group in 2019 among all ABW citation L-groups.

(5) Via ANOVA, the stock price variances between different BW citation H-groups and L-groups were free of significance in most quarters from 2017 to 2020, the same as the stock price variances between different ABW citation H-groups and L-groups. Neither BW citation count or ABW citation count had impact on the stock price.

(6) By the natural logarithm transformation on the stock price, the LN stock price was reformed. The LN stock price variances between different BW citation H-groups and L-groups showed significance in most quarters from 2017 to 2020, whereas the LN stock price variances between different ABW citation H-groups and L-groups were still free of significance. In addition, the A-shares in BW citation H-groups had higher LN stock price means than the A-shares in BW citation L-groups mostly.

(7) In most situations, the A-shares in higher BW citation count groups had higher LN stock price means than the A-shares in lower BW citation count groups. The patent

backward citation count could be applied as an indicator for classifying China A-share's stock price, whereas the average backward citation count could not. More particularly, it worked well under COVID-19 pandemic in 2020.

The finding would improve the understanding of China patents and the innovation behaviour of China A-shares over the recent years. It would also contribute the state of the art in the listed company evaluation.

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