USE: Utrecht University School of Economics

Department: Banking and Finance

Author: Xiwen Zhang

Student Number: 8174369

Topic

The Impact of Japan's Nuclear Wastewater Discharge on Marine Fisheries Stock Prices in Japan and China

Supervisor: Prof. dr. Irene Monasterolo

Co-reader: Prof. dr. Kees Koedijk

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Abstract

This study investigates the impact of Japan's decision to release nuclear wastewater from the Fukushima Daiichi nuclear power plant on the stock prices of marine fisheries in Japan and China. By using event study methodology and various financial models, including the Capital Asset Pricing Model (CAPM), the Fama-French three-factor (FF-3) model, and the CH-3 model, the research analyzes the immediate, medium-term and long-term effects on the stock returns of marine fisheries companies. The empirical results show sustained negative impacts on the Japanese market, while the Chinese market displays a short-term positive impact followed by a significant long-term negative impact. In the Japanese market, the shift in parameter is significant, suggesting an increase in systematic risk. On the other hand, the Chinese market shows an increase of sensitivity to market factor, but the shift is not significant, indicating no structural change in systematic risk. This paper provides important insights to investors and policymakers for managing portfolio risks and understanding market dynamics related to climate policy shocks. The study adds to the existing literature by pointing out the different market reactions in Japan and China, highlighting the need for customized risk management strategies.

Contents

1. Introduction

1.1 Background

On March 11, 2011, a massive earthquake and tsunami struck the east coast of Japan, causing the failure of three out of six nuclear reactors at the Fukushima Daiichi nuclear power plant (FDNPP). Since then, contaminated water from FDNPP has been treated using multi-nuclide removal equipment (ALPS) and stored in tanks on site. However, the International Atomic Energy Agency expects that all tanks will be full by the summer of 2022 (IAEA, 2020). On April 13, 2021, the Japanese government approved a plan to discharge over one million tons of contaminated water from the destroyed FDNPP into the Pacific Ocean. The process is expected to last for over 30 years. The IAEA (2023) has reviewed the plan and determined that the release of the ALPS-treated water would not have a significant radiological impact on people or the environment. On August 22, 2023, the Japanese government announced that it would start releasing nuclear wastewater into the sea on August 24. This decision has garnered significant global attention, especially from neighboring countries such as China.

The discharge of nuclear wastewater into the Pacific Ocean can cause damage to the marine ecosystem, which can have far-reaching effects on the global ecosystem. In the aftermath of the FDNPP accident, the Japanese fisheries industry was severely impacted. Products from Fukushima Daiichi were being sold at a considerable discount compared to domestic products, and even products from nearby prefectures were being sold at substantially lower prices

(Wakamatsu & Miyata, 2017). When Japan officially announced the beginning of the discharge of nuclear wastewater into the ocean, the marine fisheries in contaminated waters could face a similar situation.

1.2 Research Questions

There have been many studies on the impact of nuclear accidents on various industries, especially on the public utilities and energy sector stock markets. However, there is relatively little research on the impact of nuclear wastewater discharge on the stock market. Besides, existing studies focus on the impact of Japan's plans to discharge nuclear wastewater, but there is a lack of research on the impact of Japan's official announcement of the nuclear wastewater discharge date on the stock market, specifically on the Japanese and Chinese marine fisheries stock market. To fill this gap, this paper focuses on two questions:

1. Does the announcement affect the Japanese and Chinese marine fisheries stock market?

2. Is there a structural change in the parameters of regression models after the announcement?

To answer these questions mentioned above, this thesis develops a comprehensive empirical analysis, implementing the most used and robust financial methods, using data from marine fisheries companies publicly listed in Japan and China. Firstly, the event study method (Fama et al., 1969) is used to estimate the impact based on the Capital Asset Pricing Model (CAPM) (Sharpe, 1964). Secondly, I test for the presence of a structural break in the beta after the announcement. Finally, to make the results robust, the Fama & French (1993) three-factor (FF-3) model is used in the Japanese market and the CH-3 model (Liu et al., 2019) is used in the Chinese market to verify if the results differ from those obtained using the CAPM.

1.3 Contributions and Structure

By integrating theoretical models with empirical data, this thesis provides new insights into the dynamics between environmental decisions and market responses, contributing to the existing body of knowledge. It also provides a basis for policymakers, environmental managers, and industry stakeholders to make decisions, ensuring a balance between environmental safety and economic sustainability in future environmental crises.

The research primarily focuses on the economic impacts of decisions regarding nuclear energy on marine biodiversity and the global fisheries market. It presents comprehensive empirical results on the impact of Japan's nuclear wastewater discharge on marine fisheries, offering new perspectives and insights on the subject. This research can be a crucial reference for future studies examining the links between environmental policy, public health, and economic activity.

This paper is organized as follows:

- Section 2 reviews the relevant literature on the impact of environmental events on the stock market.

- Sections 3, 4, and 5 describe the hypotheses, data, and methodology, respectively.
- Section 6 presents and discusses the results.
- Section 7 provides the conclusion.

2. Literature Review

2.1 Market Impact of Nuclear Incidents

Numerous studies have been conducted to investigate the impact of nuclear accidents on the stock market. The Three Mile Island (TMI) disaster in 1979, the Chernobyl incident in 1986, and the Fukushima Daiichi accident in Japan are the most widely analyzed.

A study that looks at the immediate and long-term impacts of the TMI accident on the stock returns of public utility firms finds that the accident has an immediate negative impact on equity prices for both nuclear and non-nuclear-based firms (Hill & Schneeweis, 1983). Moreover, it is observed that the magnitude of the relative shift in the post-period beta parameter is closely related to the amount of nuclear capacity (Bowen et al., 1983). A large number of abnormally negative returns may be an indicator of a shift to a new riskier environment. Investors seem to believe that losses to utilities committed to nuclear energy would not be fully compensated for via changes in allowed returns, or that market conditions will not allow the firms to fully recover even with increased allowed returns.

Regarding the market response in the United States to the Chernobyl nuclear disaster, it is important to note that there is no direct connection between Chernobyl and any American power company. While the results show that there are negative price reactions to the accident, the impact on both nuclear and non-nuclear utilities is minimal and temporary (Kalra et al., 1993).

Following the FDNPP incident, the stock prices of utilities with nuclear power plants, particularly in Japan, experienced a sharp decline (Kawashima & Takeda, 2012). This is due to investors reassessing the risks associated with nuclear energy, as highlighted by the disaster. According to the study that analyzes hypotheses on the (cumulative) abnormal returns based on a three-factor model through joint tests by multivariate regression models and bootstrapping, the results show the same trend (Ferstl et al., 2012). The incident also led to policy changes, especially in Germany, where a transition towards renewable energies resulted in a redistribution of shareholder wealth from nuclear to renewable energy companies. (Betzer et al., 2011). These findings are observed through an analysis of the cross-section of returns, benchmark model parameters, and idiosyncratic volatility of nuclear energy firms after the incident. There are also some studies about the impact on other sectors. For example, Wakamatsu & Miyata (2017) discover that Fukushima products were significantly discounted compared to domestically displayed products; even products from adjacent prefectures were also heavily discounted.

2.2 Impacts of Nuclear Wastewater Discharge on Marine Fisheries

The controversies surrounding the release of treated nuclear wastewater differ among incidents. For instance, the TMI accident that occurred in Pennsylvania, USA resulted in a partial core meltdown. Fortunately, there was no significant release of radioactive materials into the environment (Office of Public Affairs, 2022). The accident caused internal equipment damage, rather than extensive leakage of radioactive materials into the external environment, as was the case with FDNPP. On the other hand, the Chernobyl accident resulted in a massive release of radioactive materials directly into the atmosphere, causing significant environmental and health impacts (Chernobyl Forum Expert Group 'Environment,' 2006). Due to the primary pathway for radioactive material dispersion being through the air, not water, the treatment and discharge of nuclear wastewater are not primary concerns. Hence, issues related to the treatment and discharge of radioactive wastewater did not emerge as major public concerns after the TMI and Chernobyl accidents.

The marine fisheries industry is the most directly and immediately affected industry among all the industries affected by the discharge. I will examine the implications from both supply and demand perspectives, drawing upon recent findings and analyses.

On the supply side, releasing treated nuclear wastewater into the marine environment raises concerns over the bioaccumulation of radionuclides in the food web, potentially impacting fish stocks critical for the marine fisheries industry. Ferreira et al. (2023) emphasize the environmental persistence of tritium (3H) and its potential for biomagnification through food webs, highlighting the risk it poses to marine biodiversity and fishery resources. Similarly, Lu et al. (2021) discuss the ecological impacts of radionuclide pollution on the atmosphere, hydrosphere, biosphere, and pedosphere, underscoring the long-term risks to marine ecosystems and the fisheries that depend on them.

It is important to note that marine organisms accumulate and concentrate elements and radionuclides in their bodies, particularly as you move up the food chain (Morales-Castilla et al., 2015). This can have an impact on the demand for seafood from Japan and the potentially affected countries, as public opinion is influenced by concerns over the discharge of these substances, which affects the consumption of seafood from Japan and thus trade quantities (M. Wang et al., 2022). For instance, a study conducted by Mckendree et al. (2013) found that over 30% of respondents reported a reduction in their seafood consumption following the Fukushima nuclear plant accident. Additionally, more than 50% of those surveyed believe that Asian seafood poses a health risk due to the Japanese nuclear disaster. A similar situation may occur when Japan releases nuclear wastewater.

2.3 Impact of Nuclear Wastewater Discharge on Japan and China

Both Japan and China are important fishery countries. China currently has the highest marine production, accounting for almost 15% of the world's fisheries, which is more than the total captures of the second- and third-ranked countries combined. In contrast, Japan accounts for about 3% of global captures and is ranked eighth in marine production. In 2019, Asia represented 72% of the 158 million tons of aquatic foods available for human consumption, while its population comprised 60% of the world's population. The five largest consuming countries in 2019 were China, Indonesia, India, the United States of America, and Japan, consuming 59% of all available aquatic foods for human consumption, with China alone consuming 36% of it. (FAO, 2022).

Japan and China are interconnected by the Pacific Ocean. They border the East China Sea, but Japan is also a fishing state of the Yellow Sea. The two countries share the fish stocks of the Yellow Sea and the East China Sea (Guifang Xue, 2005). The Ocean currents, such as the Kuroshio Current, have the potential to carry nuclear-contaminated water towards the coastal areas of China directly affecting its marine environments and marine life.

Diplomatic relations between China and Japan are complex, with historical issues and territorial disputes making it difficult to maintain friendly relations. Environmental and safety issues such as nuclear wastewater discharge can quickly become politicized, potentially being perceived as irresponsible actions towards neighboring countries' marine environmental safety.

China has raised concerns over Japan's decision to discharge nuclear wastewater into the ocean, expressing dissatisfaction with the move. Following Japan's announcement of the discharge date, theGeneral Administration of Customs of the People’s Republic of China (2023) has decided to comprehensively suspend the import of aquatic products (including edible aquatic animals) originating from Japan from August 24, 2023 (inclusive). This suspension undoubtedly hurts Japanese marine fisheries.

2.4 The Market Model, the FF-3 Model, and the CH-3 Model

An event's impact on potentially affected firms can be estimated by analyzing the change in their market price around the time of the event. One important consideration of this method is to evaluate how much the security price performance during the event differs from what is considered normal. This involves comparing the actual security returns to the expected returns based on the model that determines equilibrium expected returns (Brown & Warner, 1980). In other words, a security's price behavior is deemed 'abnormal' only when compared against a specific benchmark. Therefore, defining a model to generate 'normal' returns is essential before one can identify and measure abnormal returns.

The most widely used method of generating returns is the single index market model, which proposes a direct relationship between the returns of a specific security and a market portfolio. Various factors can influence the price of a security over time, some of which are market-wide influences and, therefore, affect prices of all securities. One approach commonly used to eliminate market-wide influences is the CAPM which derives from a set of theoretical assumptions. This is also the reason why the CAPM is used in this paper.

Reducing the variance of the abnormal return is another major purpose of specifying the appropriate model for expected return. Using multifactor models for event studies has limited benefits. Empirical evidence shows that additional factors have only a small marginal explanatory power, resulting in little reduction in the variance of the abnormal return. However, the reduction in variance is most significant when sample firms share a common characteristic, such as belonging to the same industry or market capitalization group. (Mackinlay, 1997). Therefore, this paper also utilizes the FF-3 model to analyze the impact on the Japanese marine fisheries stock market to get robust results.

China's political and economic environments are different from those in developed economies like Japan and the US. For instance, China's IPO regulatory framework has undergone reform in recent years, but prior to these changes, the country used a merit-based system for the past two decades, in contrast to the registration-and-disclosure system that exists in most countries. This system involves conducting substantial examinations and value judgments on proposed IPOs to ensure quality control. It also involves the adoption of disclosure-based rules similar to those used in many developed economies (Chen & Zhao, 2024). The IPO process in China is highly regulated, with candidate firms required to meet strict pre-specified profitability and revenue thresholds. Those that meet these standards typically face a further waiting period. The total number of firms allowed to issue an IPO in a given period, known as the IPO "quota," is tightly controlled by government policy, often resulting in a backlog of firms awaiting review, particularly after an IPO "suspension" period. This tightly regulated IPO market has led to alternative public listing strategies, such as reverse mergers (Lee et al., 2019). This strategy involves a private firm acquiring control rights in a publicly traded company (often called a shell) and subsequently merging its assets into the shell in exchange for newly issued shares. Empirical findings show that a significant majority of reverse mergers in China involve shells from the smallest 30% of stocks, indicating the strategic targeting of these firms due to their potential shell value (Liu et al., 2019).

For the reasons mentioned above, it is questionable whether the factors that determine returns in other markets would be equally important for China's domestic market. Although several studies have examined the cross-sectional stock returns in China using the Fama & French (1993) framework, their results are mixed and provide inconclusive empirical evidence.

Hu et al. (2019) conduct a study using historical A-share returns for Chinese stocks listed on the Shanghai Stock Exchange and Shenzhen Stock Exchange between 1990 to 2016. Their research focuses on investigating the size and value factors in the cross-section of returns for the Chinese stock market. They find a significant size effect, but no robust value effect. Similarly, F. Wang & Xu (2004) and Hilliard & Zhang (2015) also discover no value effect in the Chinese stock market. However, other studies have found significant value effects. Cheung et al. (2015) observe a large and significant premium for value, as measured by book equity over market equity, in the China A-shares market using the constituents of the MSCI China A Index as the universe of stocks in their analyses covering the period from December 31, 2001, to December 31, 2013. Additionally, Cakici et al. (2017) obtain Chinese stock data from Datastream for the period covering January 1994 to March 2011 and find the same results. These differences in findings are often attributed to the choices of sample periods and research methods (Cheung et al., 2015; Hu et al., 2019).

Since existing studies still dispute the applicability of the FF-3 model in China, Liu et al. (2019) construct size and value factors in China. They suggest adopting a modified version of the FF-3 model, called the CH-3 model. The size factor in the CH-3 model excludes the smallest 30% of firms, which are often valued as potential shells in reverse mergers, bypassing strict IPO constraints. It is based on the earnings-price ratio, which encompasses the book-to-market ratio in capturing all Chinese value effects. The CH-3 model performs better than a model created by simply replicating the Fama & French (1993) procedure in China. While the FF-3 model leaves a 17% annual alpha on the earnings-price factor, the CH-3 model explains most of the reported Chinese anomalies, including profitability and volatility anomalies. Therefore, I prefer using the CH-3 model for the Chinese market as it significantly outperforms the FF-3 model.

3. Research Questions and Hypotheses

The purpose of this study is to investigate the impact of Japan's Nuclear Wastewater Discharge on the stock returns of marine fisheries in Japan and China. Although Japan had planned to discharge nuclear wastewater since 2021, it was not until August 21, 2023, that Japan officially announced the timing of the wastewater discharge, at which point everything was finally settled. The days following the announcement should provide evidence and the magnitude of an impact on marine fisheries stock returns. To test whether there is an impact on the Japanese and Chinese marine fisheries stock market, I consider the null hypothesis for each country as follows:

H_0^1: Japan's Nuclear Wastewater Discharge has no effect on marine fisheries stock prices.

The above hypothesis assumes that the parameters of the asset pricing process used to determine equity values, such as the market model, FF-3 model, and CH-3 model, are stable. However, it is questionable whether the population parameter remains unchanged over both the estimation and residual periods, and this can be tested. If it is allowed that parameters may change between the estimation and residual periods, the interpretation of the relative price shifts becomes more complex. They are not simply one-time losses but possibly the result of structural changes in the economy that may require alterations in the regulatory process. Therefore, any change in the beta parameter would be of interest to regulators. To test beta shifts, I propose the following null hypothesis for each model used in this paper:

H_0^2: There is no structural change in the systematic risk between the pre-and post-event periods.

4. Data

To conduct an empirical analysis, I created two portfolios of marine fisheries companies - one consisting of 8 publicly listed companies in China (see Table1) and the other of similar companies in Japan. The weight of each company in the portfolio is determined by its market capitalization. Daily stock returns data from January 1, 2022, to March 1, 2024, are obtained from financial databases to capture market reactions before and after the announcement of discharge.

Table 1 Companies selected in the portfolios

COMPANY(JAPAN)	CODE_JP	COMPANY(CN)	CODE_CN
Maruha Nichiro Corporation	1333.T	Zoneco Group Co., Ltd.	002069.SZ
Kyokuyo Co., Ltd	1301.T	Shandong Homey Aquatic Development Co.,Ltd.	600467.SS
Toyo Suisan Kaisha, Ltd.	2875.T	Joyvio Food Co., Ltd	300268.SZ
Daisui Co.,Ltd.	7538.T	CNFC Overseas Fisheries Co.,Ltd	000798.SZ
Nissui Corporation	1332.T	Shandong Oriental Ocean Sci-Tech Co., Ltd.	002086.SZ
Marubeni Corporation	8002.T	Zhanjiang Guolian Aquatic Products Co., Ltd.	300094.SZ
Tohto Suisan Co., Ltd.	8038.T	Shanghai Kaichuang Marine International Co., Ltd	600097.SS
Nichimo Co., Ltd.	8091.T	Shandong Zhonglu Oceanic Fisheries Company Limited	200992.SZ

To accurately reflect the specific risks and investment environment of each country, I use the market (MKT) factor found on Kenneth R. French’s official website for Japan. As for China, I use China's 3-month government bond yields as the risk-free rate and the CSI 300 Index as the market index. The CSI 300 Index is a capitalization-weighted stock market index designed to replicate the performance of the top 300 stocks traded on the Shanghai and Shenzhen stock exchanges. The index serves as a benchmark for the performance of the Chinese equity markets, covering approximately 70% of the market capitalization of the two exchanges combined. The CSI 300 Index is widely recognized both domestically and internationally as a key indicator of the health and trends within China's A-share market.

To expand the market model, for the Japanese market, I use the FF-3 model, and the SMB and HML factors for Japan can also be found on Kenneth R. French's official website. For the Chinese market, I use the Ch-3 model. The trading and financial statement data of China’s domestic stock market, the A-share market is obtained from the China Stock Market & Accounting Research (CSMAR) database, the most reliable source of information for the

Chinese security market, to calculate the size and value factors in the CH-3 model. The market factor is described above.

5. Methodology

In this study, I examine how the stock prices of marine fisheries are affected by the discharge event. I use an event study methodology and define the day of the event as t_0, the initial date of the event window as t_1, and the final date of the event window as t_2. The length of the event window is calculated as $L_1 = t_2 - t_1 + 1$, which only includes trading days. To measure the short-term, medium-term and long-term effects, I choose three different event windows: $(t_1, t_2) = (0, 2)$, $(0, 30)$, and $(0, 120)$. To get estimated parameters, the estimation window is set as 250 transaction days before the event.

5.1 Relative Price Shifts Based on the Market Model

The following market model within the CAPM framework is estimated for each portfolio in the estimation window:

$$R_{i,t} = \alpha_i + \beta_i * R_{m,t} + \varepsilon_{i,t} \quad (1)$$

where $R_{i,t}$ is the (log-)return at time t of the portfolio i (throughout the paper, we denote the discrete return of an asset net of the risk-free rate simply as return), $R_{m,t}$ is the market (log-)return, and $\varepsilon_{i,t}$ is an i.i.d. error term with $E(\varepsilon_{i,t})=0$ and $cov(\varepsilon_{i,t},R_{i,t})=0$.

Using the estimated parameters $\widehat{\alpha_i}$ and $\widehat{\beta_i}$ obtained from model (1), I calculate abnormal return (AR) for portfolio i in period t as follows:

$$AR_{i,t} = R_{i,t} - \left(\widehat{\alpha_i} + \widehat{\beta_i} * R_{m,t}\right) \tag{2}$$

The cumulative abnormal return (CAR) is then obtained by summing the abnormal returns over the event window, as follows:

$$CAR_i(t_1, t_2) = \sum_{t=t_1}^{t_2} AR_i \tag{3}$$

If the event does not affect stock prices, the CAR should not be significantly different from zero. In other words, the null hypothesis H_0^1 can not be rejected statistically if the event has no influence on stock prices.

To compare whether the event affects the marine fisheries in the two countries differently, I normalize CAR for each portfolio to get the standardized cumulative abnormal return (SCAR), as follows:

$$SCAR_i(t_1, t_2) = \frac{CAR_i(t_1, t_2)}{\sigma_i(t_1, t_2)} \tag{4}$$

Where $\sigma_i(t_1, t_2)$ is the standard deviation of these abnormal returns over the event window from t_1 to t_2, which is calculated as follows:

$$\sigma_i(t_1, t_2) = \sqrt{\frac{\sum_{t=t_1}^{t_2}\left(AR_{i,t} - \overline{AR_i}\right)^2}{t_2 - t_1 + 1}} \tag{5}$$

where $\overline{AR_i}$ is the average of abnormal returns of portfolio i.

Despite the market model being recognized as a primary benchmark in financial research due to its simplicity and ease of interpretation, it is not without its statistical shortcomings. These include assumptions of no autocorrelation, homoskedasticity, normal distribution, and the presumption of no relationship between the market index serving as the regressor and its stochastic elements. To mitigate these limitations in my study, I employ Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors. This approach helps accommodate the potential for autocorrelation and heteroskedasticity and, to a certain degree, deviations from a normal distribution.

5.2 Tests of the Market Model Parameter

I test for the presence of significant differences in systematic risk (beta) to understand if the market is pricing marine stocks differently in Japan and China in terms of the systematic risk profile after the discharge event.

To test the second hypothesis H_0^2, I estimate beta before and after the event individually using model (1). Then I conduct a Chow test (Chow, 1960) to investigate whether there is a structural change in the parameter (beta) of the regression model between the pre-event period $(-250, -1)$ and the post-event periods (0, 120). If the null hypothesis H_0^2 is rejected, it implies that the systematic risk of the portfolio has significantly changed after the event.

5.3 Expanding of the FF-3 Model in Japan

In this section, I extend the CAPM in eq. (1) to the FF-3 model for the Japanese market. For a single asset, let:

$$R_{i,t} = \alpha_i + \beta_i * R_{m,t} + \gamma_i * SMB_t + \rho_i * HML_t + \varepsilon_{i,t} \quad (6)$$

where SMB (Small Minus Big) represents the size factor, defined as the differential between the average returns of small-cap stock portfolios and large-cap stock portfolios, and HML (High Minus Low) signifies the value factor, calculated as the discrepancy in mean returns between portfolios of "value" stocks, characterized by high book-to-market ratios, and "growth" stocks, identified by low book-to-market ratios, $\varepsilon_{i,t}$ is assumed to be an i.i.d. error term.

Using the estimated parameters $\hat{\alpha}_i$, $\hat{\beta}_i$, $\hat{\gamma}_i$, and $\hat{\rho}_i$ got from model (6), I calculate AR for portfolio i in period t as follows:

$$AR_{i,t} = R_{i,t} - \left(\widehat{\alpha_i} + \widehat{\beta_i} * R_{m,t} + \hat{\gamma}_i * SMB_t + \hat{\rho}_i * HML_t\right) \quad (7)$$

CARs and SCARs during the event windows are calculated by equations (3) and (4) to test H_0^1 in the FF-3 model framework.

Further, I repeat the test for parameter (beta) shifts described in section 5.2 to test H_0^2 for Japanese market in the FF-3 model framework. In this regard, a rejection of the null hypothesis H_0^2, implies that the systematic risk of the portfolio has significantly changed after the event.

5.4 Expanding of the CH-3 Model in China

The CH-3 model integrates two key adaptations for the Chinese market. It initially discards the smallest 30% of stocks to avoid their shell-value contamination. The model then harnesses the remaining stocks to derive factors, while constructing a value factor rooted in earnings-to-price ratios.

I follow the steps below to calculate the factors of the CH-3 model:

1. Exclude the smallest 30% of stocks to avoid biases from nominal value discrepancies.

2. Divide the remaining 70% of stocks into two size groups based on the median market value: Small (S) and Big (B).

3. Further categorize the stocks into three earnings-to-price ratio (E/P) groups: Value (V, top 30%), Neutral (M, middle 40%), and Growth (G, bottom 30%).

4. Create value-weighted portfolios for the six size-E/P combinations: S&V, S&M, S&G, B&V, B&M, and B&G.

5. Weight each stock within the portfolios by its market capitalization, including non-tradable shares.

6. Compute the Size (SMB) and Value (VMG) factors from these portfolios as follows:

$$SMB = \frac{1}{3}(S\&V + S\&M + S\&G) - \frac{1}{3}(B\&V + B\&M + B\&G) \tag{8}$$

$$VMG = \frac{1}{2}(S\&V + B\&V) - \frac{1}{2}(S\&G + B\&G) \tag{9}$$

7. The market factor (MKT) is calculated by subtracting the risk-free rate from the return of the market index. In this paper, the risk-free rate is the yield of the 3-month Chinese government bond. The market index is the CSI 300 index.

After getting MKT, SMB, and VMG factors described above, the CH-3 model can be set as follows:

$$R_{i,t} = \alpha_i + \beta_i * R_{m,t} + \gamma_i * SMB_t + \rho_i * VMG_t + \varepsilon_{i,t} \tag{10}$$

Using the estimated parameters $\hat{\alpha}_i$, $\hat{\beta}_i$, $\hat{\gamma}_i$, and $\hat{\rho}_i$ got from model (10), AR for portfolio i in period t can be calculated as follows:

$$AR_{i,t} = R_{i,t} - \left(\hat{\alpha}_i + \hat{\beta}_i * R_{m,t} + \hat{\gamma}_i * SMB_t + \hat{\rho}_i * VMG_t\right) \tag{11}$$

Now I can use equation (3) to obtain CARs and equation (4) to obtain SCARs for testing H_0^1 in the short-term, medium-term, and long-term event windows in the CH-3 model framework.

Finally, the process of testing for parameter (beta) shifts, as described in section 5.2, is repeated for the Chinese market within the CH-3 model framework. If the null hypothesis H_0^2 is rejected, it implies that the systematic risk of the portfolio has significantly changed after the event.

6.Empirical Results

6.1 Market Model's Results

In this section, I analyze the CARs and SCARs using the CAPM model to test H_0^1 and present the regression results for the marine fisheries stock prices in Japan and China before and after the announcement of the nuclear wastewater discharge to test H_0^2.

6.1.1 Empirical Results on Stock Price Responses Based on the Market Model

Table 2

CARs and SCARs using the CAPM mode (unit: %). *** and ** indicate statistical significance at the 1% and 5% levels, respectively.

Mkt	(0,2)		(0,30)		(0,120)	
	CAR	SCAR	CAR	SCAR	CAR	SCAR
Japan	-1.2156	-1.2319	-25.8773	-22.4032***	-73.1037	-58.7632***
China	26.0042	4.0167***	-17.1510	-3.9722***	-80.3173	-25.2107***

In the CAPM analysis, I calculate the CARs and SCARs for the Japanese and Chinese markets across 3 different event windows. Table 2 displays the CARs and SCARs results for both markets.

In the short-term event window (0, 2), the CAR for Japan is slightly negative at -1.21%, with a SCAR of -1.23%, indicating a minor immediate negative impact on stock prices. In contrast, China's CAR is significantly positive at 26%, with a SCAR of 4.02%, suggesting a substantial immediate positive reaction in the Chinese market, consistent with the reports of Chinese news media after the announcement.

Moving to the medium-term event window (0, 30), Japan's CAR becomes more negative at -25.88%, with a significantly negative SCAR of -22.40%, highlighting a more pronounced adverse impact over a month. Moreover, China's CAR turns negative at -17.15%, with a SCAR of -3.97%, indicating a reversal from the short-term positive reaction to a medium-term negative impact.

In the long-term event window (0, 120), Japan's CAR further deteriorates to -73.10%, with a SCAR of -58.76%, reflecting a sustained negative impact over four months. Similarly, China's CAR continues to decline to -80.32%, with a SCAR of -25.21%, indicating a significant and prolonged negative effect in the Chinese market.

In summary, in the short term, the Chinese market demonstrated a notably positive reaction, while the Japanese market displayed a slight negative response. However, over time, both markets exhibited a negative trend, with the Japanese market experiencing a particularly pronounced and sustained adverse impact. This suggests that the nuclear wastewater discharge event significantly and negatively affected both markets in the medium and long term, albeit with varying degrees and durations of impact.

6.1.2 Empirical Results Regarding the Stability of the Market Model

The preceding section demonstrates that, on average, stock prices of marine fisheries decreased after the announcement of the discharge of nuclear wastewater in the medium and long term. The negative market reactions imply a sustained decline when the parameters used to determine stock prices are steady.

However, if the parameters have changed during the post-event period, negative market reactions suggest a decline due to structural changes in systematic risk. To investigate this further, I compare the parameters of the market factor between the periods before and after the event.

Table 3
Results for the market model estimations. HAC robust standard errors in parenthesis. $***$ denotes significance at 1% level; $**$ denotes significance at 5% level; $*$ denotes significance at 10% level.

Mkt	Pre-event		Post-event		
	$\hat{\alpha}_i$	$\hat{\beta}_i$	$\hat{\alpha}_i$	$\hat{\beta}_i$	F-test
Japan	0.1926	0.7148***	0.0354	0.9281***	4.07
	0.0852*	0.1080	0.0944	0.0900	
China	0.0482	0.4805***	-0.1443	0.7033**	0.40
	0.1019	0.1063	0.3286	0.2961	

Table 3 presents a comparison of risk-related variables between the pre- and post-event periods. The results indicate that the estimated intercepts are not significant for Japan and China before and after the event. In a CAPM market model framework, this finding means that we don't need to consider other factors to explain the linear relationship between a portfolio's expected return and the return of the market portfolio.

The analysis then turns to the estimated betas, which serve as a measure of systematic risk. Systematic risk reflects the structural relationship between each portfolio's returns and market returns. The key interest lies in identifying any structural changes in systematic risk between the pre-event and post-event periods.

In the period before the event, the estimated beta for Japan is 0.7148, indicating a strong positive relationship between Japanese portfolio returns and market returns. Following the event, the estimated beta increases to 0.9281, remaining significant at the 5% level. This increase in the beta coefficient suggests that the event makes the Japanese portfolio more closely tied to the overall market movements. With a F-value of 4.07, the Chow test result suggests that I can reject H_0^2 at the 5% significance level. This indicates evidence of a significant increase of the systematic risk after the event.

For China, the estimated beta increases from 0.4805 in the pre-event period to 0.7033 in the post-event period. However, the F-test value of 0.40 indicates that this change in beta is not statistically significant, implying no significant change in the systematic risk of Chinese portfolios between the pre-event and post-event periods.

The analysis reveals a notable distinction in the impact of the event on the systematic risk of the Japanese and Chinese markets. For Japan, there is an increase in systematic risk post-event, as indicated by the higher beta. The increase is significant confirmed by the Chow test. This suggests that after the event, the Japanese portfolio becomes more sensible to overall market movements, indicating higher systematic risk post-event. In contrast, the Chinese market does not show a statistically significant change in systematic risk between the pre-event and post-event periods, indicating that the event does not significantly alter the relationship between Chinese portfolio returns and overall market returns. This difference highlights different market dynamics and investor reactions in Japan and China in response to the announcement of the Japan's nuclear wastewater discharge.

6.2 The FF-3 Model and the CH-3 Model Analysis

In this section, I analyze the CARs and SCARs using the FF-3 model in the Japanese market and the CH-3 in the Chinese market. Then, I present the regression results for the marine fisheries stock prices in Japan and China before and after the event to test if there is any structural change in the systematic risk.

6.2.1 Empirical Results on Stock Price Responses Based on the FF-3 Model and the CH-3 Model

Table 4

CARs and SCARs using the Fama-3 model in Japan and the CH-3 model in China (unit: %). *** and ** indicate statistical significance at the 1% and 5% levels, respectively.

Mkt	(0,2)		(0,30)		(0,120)	
	CAR	SCAR	CAR	SCAR	CAR	SCAR
Japan	0.6773	0.4797	-28.1555	-15.4693***	-58.1869	-31.3424***
China	24.5381	3.6986***	-26.4108	-6.1849***	-121.3757	-35.4671***

Table 4 displays the CAR and SCAR results for short-term, medium-term and long-term event windows using the Fama-French three-factor model for the Japanese portfolio and the

CH-3 model for the Chinese portfolio.

In the short-term event window (0, 2) for the Japanese portfolio, the CAR and SCAR show a slight positive reaction. However, in the medium-term event window (0, 30), the CAR becomes significantly negative at -28.16%, with a SCAR of -15.47%, suggesting a strong adverse impact. Moving to the long-term event window (0, 120), the CAR drops further to -58.19%, with a SCAR of -31.34%, reflecting a prolonged negative effect.

As for the Chinese portfolio, during the short-term event window, the CAR is notably positive at 24.54%, with a SCAR of 3.70%. However, in the medium-term event window, the CAR turns negative at -26.41, indicating a medium-term adverse impact. Finally, in the long-term event window, the CAR and SCAR deteriorate further, showing a significant prolonged negative effect.

The results of the CAPM and the FF-3/CH-3 models for both the Japanese and Chinese markets reveal several key differences. In the short-term event window, both models indicate a significant positive reaction in the Chinese market. However, the FF-3 model shows a slight positive reaction in Japan compared to the negative impact observed in the CAPM model. In the medium-term and long-term event windows, both markets show significant negative CAR and SCAR under all models, indicating a sustained negative impact of the nuclear wastewater discharge event. In the Japanese market, the FF-3 model demonstrates a much smaller negative impact compared to the CAPM model. However, in the Chinese market, the negative impact is more pronounced under the CH-3 model than the CAPM model, especially in the long-term window. Additionally, under the CAPM model, the negative effect in the Japanese market is larger than that in the Chinese market during all the event windows. Conversely, the results for the Chinese market under the CH-3 model show that the negative effect exceeds that in the Japanese market under the FF-3 model in long-term event window. This comparison suggests that while short-term impacts may vary slightly between models, the medium to long-term adverse effects are consistently observed.

6.2.2 Empirical Results Regarding the Stability of the FF-3 Model and the CH-3 Model

Table 5
Results for the FF-3 model and the CH-3 model. HAC robust standard errors in parenthesis. $***$ denotes significance at 1% level; $**$ denotes significance at 5% level; $*$ denotes significance at 10% level.

Mkt	Event-pre				Event-post				
	$\hat{\alpha}_i$	$\hat{\beta}_i$	$\hat{\gamma}_{i,SMB}$	$\hat{\rho}_{i,HML}$ $\hat{\rho}_{i,VMG}$	$\hat{\alpha}_i$	$\hat{\beta}_i$	$\hat{\gamma}_{i,SMB}$	$\hat{\rho}_{i,HML}$ $\hat{\rho}_{i,VMG}$	F-test
Japan	0.1706*	0.6729***	-0.6733***	0.1426	0.0047	0.8331***	-0.2725	0.3038**	2.28
	0.0851	0.1111	0.2539	0.11724	0.1708	0.0959	0.1941	0.1265	
China	0.2872*	0.5899***	0.4740**	-0.4846**	0.6166*	0.8064***	1.3972***	-0.6272**	0.65
	0.1450	0.1743	0.2285	0.1889	0.3289	0.2318	0.2233	0.2494	

Table 5 indicates that the estimated intercepts of the FF-3 model for Japanese market and the CH-3 model for Chinese market are not significant at least at 5% significance level before and after the event. This finding means that we don't need to consider other factors except the factors included in the models.

In the pre-event period, the Japanese portfolio exhibits significant relationships with the market (MKT) and size (SMB) factors, indicating a strong dependency on overall market movements and size effects. However, the value (HML) factor is not significant. Post-event analysis reveals several notable changes:

1. The market factor's influence becomes more pronounced, suggesting an increased sensitivity to market returns.

2. The significance of the SMB factor diminishes, indicating a reduced impact of size-related effects.

3. A new significant relationship with the HML factor emerges, indicating that the value factor becomes relevant in the post-event period.

The F-test value of 2.28 indicates that the change in the market beta is statistically significant, suggesting that the systematic risk in the Japanese market significantly increases post-event.

For the Chinese market, the pre-event period demonstrated significant relationships with the market (MKT), size (SMB), and value (VMG) factors, indicating comprehensive sensitivity to these influences. Post-event analysis shows consistent significance and increased magnitudes for these factors:

1. The influence remains significant and increased, reflecting a stronger relationship with market returns.

2. The significance and magnitude of the SMB factor also increase, indicating a heightened impact of size effects.

3. The VMG factor remains significant with an increased magnitude, suggesting sustained and amplified sensitivity to value versus growth dynamics.

The F-test value of 0.65 indicates that the change in the market beta is not statistically significant, implying that the systematic risk in the Chinese market does not significantly change post-event.

In the Japanese market, both the CAPM and FF-3 models show a significant increase in the market beta (MKT) post-event, indicating increased market sensitivity and systematic risk. The FF-3 model additionally reveals changes in other risk factors. The size factor (SMB) is significant initially but not post-event. The value factor is only significant during the post-event period. This highlights the FF-3 model's ability to provide a more thorough understanding of the market dynamics beyond what the CAPM model captures.

For the Chinese market, both the CAPM and CH-3 models indicate an increase in the market beta post-event, but this change is not statistically significant, suggesting stable systematic risk. The CH-3 model demonstrates that the market's sensitivity to size (SMB) and value (VMG) factors keep significant during the pre- and post-event period. The CH-3 model provides a more comprehensive explanation of the portfolio’s returns.

7. Conclusion

In my paper, I have conducted a first thorough analysis of the impact of Japan’s nuclear wastewater discharge announcement on the stock prices of marine fisheries in Japan and China. The purpose of this analysis is to determine whether the event affected the marine stock markets of both countries and to assess any change in systematic risk.

For the Japanese market, the CAR and SCAR analysis revealed a negative impact on stock prices over the medium and long term, indicating that the event leads to a sustained decline in market value. The analysis of the market factor parameter shifts using both the CAPM and FF-3 models shows a significant increase in the market beta post-event, indicating a substantial rise in market sensitivity and systematic risk.

The CAR and SCAR analysis for China shows an initial positive reaction in stock prices, followed by a long-term decline. This suggests that there is a complex response where initial optimism gave way to sustained negative sentiment in the Chinese market. The analysis for market factor parameter shifts using the CAPM and CH-3 models indicates an increase in the market beta post-event, but this change is not statistically significant. This outcome suggests that the systematic risk in the Chinese market remains stable post-event. The findings for the Chinese market using the CH-3 model differ from those for the Japanese market using the CH-3 model. In the case of the Chinese market, the significance of the size and value factors remains consistent, emphasizing the importance of these factors in comprehending market behavior.

The study shows that multifactor models are good at capturing complex market responses. This is important for investors and policymakers. It suggests that we need customized investment strategies and risk management approaches for each market when dealing with climate events. Understanding these unique market dynamics can help make better decisions. This way, we can reduce risks and take advantage of market opportunities after climate events.

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